The Self-Tracker's Journey: situated engagement and non-engagement with personal informatics systems over time

Candidate: Daniel Bryan Peter Harrison (University College London).

Supervisors: Dr Paul Marshall (University of Bristol, University College London), Prof Nadia Bianchi-Berthouze (University College London) and Dr Jon Bird (University of Bristol).

Examiners: Dr Parisa Eslambolchilar (Cardiff University) and Dr Catherine Holloway (University College London).

A dissertation submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy, University College London**.

Declaration

I, Daniel Bryan Peter Harrison confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

Almost one quarter of adults fail to meet physical activity guidelines: activity tracking systems promise a solution, by supporting people to be more active by quantifying their steps and utilising behaviour change techniques. Results on the effectiveness of these technologies sometimes show benefits, but little is known about how people use them over a longer time and what impact they might have on one's physical activity even after they have been abandoned.

Relying on rich, explorative, qualitative research, this thesis examines use and non-use, of activity trackers over time and the influence they have on users' attitudes and behaviours. Firstly, a longitudinal mixed-method study, lasting over one year, was conducted with new tracker users to understand use and behavioural impacts over time. Secondly, a comparative interview study with existing and previous users in two, culturally and physically different, urban settings allowed us to uncover further contextual factors. A combined bottom-up thematic analysis of the data from all 98 participants revealed the steps of "the self-tracker's journey", from initial motivations and use, to engagement over time, and the affective and behavioural outcomes of use.

Therefore, this thesis makes three contributions to knowledge, to design, and to research practice, respectively. Firstly, our knowledge contribution shows (a) how positive outcomes from use can come beyond the period of use, providing a better understanding of phases of tracking. It also shows (b) how there can be negative outcomes, especially when people become over reliant or obsessed with their tracker. Secondly, our findings have implications for how tracking systems should be designed to better support tracking over time, while avoiding negative consequences. Thirdly, this thesis contributes to research practice by highlighting the importance of considering context of use, use over time, and impacts beyond use of these technologies and engagement with data per se.

Acknowledgements

A PhD is a considerable undertaking and I would have never made it this far without the help, support and encouragement I have received from a great many people. I don’t have space to thank everyone by name, but I am incredibly grateful to everybody who has made a difference over the last seven years. However, there are some people in particular I would like to thank.

Breaking with tradition, I would first of all like to thank the 98 people who kindly participated in my two studies. Academia can be a thankless environment and we should remember to properly appreciate those who help us conduct our work. Without the time sacrifices these people made from their busy lives none of this work would have been possible, so again, thank you.

Of course, my PhD would have also not have been possible without the guidance and support provided by my supervisory team, so I would like to give a massive thank you to my ever-patient, kind and thoughtful PhD supervisors, Paul Marshall, Nadia Berthouze and Jon Bird, each of whom have given me countless hours of advice and encouragement, have read my drafts (no matter how rough) and have stayed on my side throughout. Paul, it has been a pleasure working with you for so long, thank you for all the advice, help, drinks and encouragement along the way. Nadia, I have always appreciated your perspective to help frame my work and keep me on track. Jon, without your help with the *feelybean* and supervising my MSc project I might have never ended up taking this path, so thank you. I’m sure you’re all almost as pleased as I am to get this PhD finished, but I hope you all appreciate how grateful I am and that after my lengthy PhD journey you will all keep in touch and be excited to work with me on future projects!

I would also like to thank everyone in UCLIC for providing me with the support, resources and opportunities to undertake this work. When I started my MSc in 2011 I never thought I would still be here so many years later, but I am very happy to have been part of the group for so long, and worked alongside so many amazing people who have had a positive impact on me and my thesis. I hope we can all keep in touch in conferences across the world. I would also like to thank the students who put their faith in me to supervise their own MSc projects. I hope you were all happy with how these went!

I would also like to thank Gregory Abowd and the Ubicomp Lab in the Georgia Institute of Technology, who kindly hosted my three-month stay in Atlanta during 2014, and the Ubihealth network who funded this trip. Without this opportunity I would not have been able to collect data for my comparison study, which is an integral part of my thesis and contribution.

I also owe great thanks to the EPSRC, who funded my PhD research through a DTG. I have also been lucky enough to win two small grants through EPSRC-funded Networks, including The Balance Network and GetaMoveOn (GAMO). This funding enabled me to undertake an independent research project and write a white-paper think-piece related to my literature, which was used to engage other academics and third-sectors in a symposium in 2017.

Alongside my PhD I have been lucky enough to work with some amazing and inspiring people in Microsoft Research Cambridge and in Northumbria University. I would like to thank all of my colleagues at Microsoft Research, particularly Abi Sellen and Richard Banks, who supervised my time there over 2 years, between two internships and a research contract, offering me a lot of advice and support along the way. I would also like to thank John Vines, who offered me a job in Northumbria University when I moved up to Newcastle in 2018 and cheered me on through the final stages of writing. Working alongside my PhD has not only given me a means to pay the bills, but has also been a great source of inspiration, experience and learning, making me a much stronger researcher along the way. I've really enjoyed these opportunities and have made some amazing friends.

My family has also been a constant source of inspiration. My mum, Lin, and nan, Glad have always supported and encouraged me in following my dreams, for which I am forever in their debt. I hope that my company and smiles over the years have been enough to repay at least some of what I owe you both. I hope you will enjoy reading this thesis and see where all of the hours have gone.

Finally, I want to thank my wonderful wife Marta. You've been the best source of support and inspiration, and loved and cared for me from day 1. You've kept me going through everything, even when you've been struggling to find your own way. It has been fantastic to work through this journey together, and I couldn't have done it without you. I've loved our adventures along the way, and I'm so very excited for all of our future adventures together, especially now that I'm done with my PhD and we can get on with living our lives and welcoming our little addition into the family!

Impact Statement

The expertise, knowledge, analysis, discovery and insights presented in this thesis have had significant impact inside and outside of academia through my strong record of publishing, presenting and otherwise disseminating my research, as well as my supervision and research-led teaching of other students and collaborations in industry.

Within academia, my PhD work has had significant impact with 4 directly-related and 4 indirectly-related peer-reviewed publications in top HCI venues including ACM CHI and Ubicomp, which have demonstrably had impact in academia by already amassing almost 200 citations. My Ubicomp 2015 paper *"Activity Tracking: Barriers, Workarounds and Customisation"* has alone received over 90 citations and 900 downloads in the ACM Digital Library and further outputs from my PhD are set to be published once I have completed my thesis. I have also won further funding related to my research through two EPSRC Network+ grants, which have allowed me to continue my research and impact on the community. I was recently selected as a fellow of the EPSRC GetAMoveOn network+, which has provided me with further opportunities to have impact and disseminate my work amongst the broader community. Ultimately, this work has informed the research and development of digital health and wellness technologies to encourage healthy activities over time.

Beyond my publishing and bidding activities I have created impact in academia by engaging with internationally recognised academics in HCI and beyond, including those in computer science, health psychology and design. I have been invited to present my work at international forums, many of which, including the UCL Behaviour Change conference and the GAMO symposium have also engaged those from industry, alongside academics. More recently I have applied these learnings to work undertaken at Northumbria University, on projects looking at improving students' mental wellbeing, and fatigue in healthcare. My work has also had impact on other graduate students, through my related project-supervision of 5 MSc students, who undertook independent research under my supervision, on topics related to promoting physical activity, designing tracking devices and understanding habit formation.

This work has also had impact outside of academia. Alongside my doctoral research, I have applied knowledge and skills gained during my PhD to digital health and wellbeing projects in leading HCI research groups including at Microsoft Research in Cambridge, where I worked on solutions to support self-management of health, and research on a system for cancer treatment.

Finally, I have also disseminated my research through publication of public-facing research photographs. I was twice chosen as a finalist in the EPSRC research photography competition, which resulted in photographs and a description of my research being covered in multiple UK news outlets (e.g. *The Guardian*, *The Independent*, *The Mail*). Further to this I was also part of a quantified-self photo series, which received worldwide press coverage including articles in *Bloomberg* and *The British Photography Journal.*

Preface

I am the primary author of this thesis, and all the work presented is my own. However, my PhD would have not been possible without the support, feedback and guidance I have received from my supervisors. Fittingly, I have written this thesis in the second person plural to reflect and recognise the feedback and guidance I have received from my supervisors throughout this journey.

This PhD commenced in October 2012, and empirical research was completed in early 2015. The writing of this thesis has been a long labour of love, mostly written part-time alongside paid work in different companies and institutes, resulting in a significant time gap between completing the empirical research and eventual submission in 2019. During my PhD I was fortunate enough to take up various research opportunities, including a 3-month stay in Gregory Abowd's Ubicomp Lab in The Georgia Institute of Technology, Atlanta. I chose to visit this group, not only because of the incredible team of researchers located there, but also because of the contrast Atlanta offered with London, when considering people's use of tracking technologies. I also spent time away from my PhD during two Internships at Microsoft Research Cambridge, where I then went on to work part-time.

I have written this thesis following the thread of the "self-trackers journey", a broadly defined journey similar to that of many of my participants. This journey progresses from participants very first interactions with tracking, to changing their behaviour and their attitudes (nor not), and all of their engagements with the trackers and their behaviours in-between. This idea was inspired by the in-depth, longitudinal approach that I took in my first study – capturing the richness of the data I gathered throughout this was challenging when presenting the studies by themes, so following an exemplar journey from beginning to end seemed to be an appropriate way to engage the reader in the journey that our participants progressed through.

To immerse myself into the self-tracking community and ensure that I was familiar with the technologies my participants were using, I took it upon myself to start a self-tracking journey of my own. Beginning with my use of a Fitbit Zip in November 2012, I have since tracked the number of steps I have taken (along with other personal attributes such as my weight and other exercise) almost every single day. At the height of my empirical studies I was wearing and actively using up to 6-trackers at once, including: Fitbit Zip, Fitbit Flex, Fitbit One, Nike Fuelband SE, Misfit Shine, Garmin Vivofit, BASIS B1 and Apple Watch, amongst others. Beyond these systems for tracking physical activity, I have also used other personal informatics and quantified-self systems, including those for tracking diet, sleep, and other forms of physical activity such as cycling and running. My experience of using these technologies is relevant on two counts. Firstly, they aided my interviewing and understanding of how my participants used these technologies in their everyday lives, by referring to specific unique functionalities and features. Secondly, using these technologies had an influence on my own life and allowed me to better understand and empathise with my participants. However, my use of these technologies was not undertaken as a specific auto-ethnography or self-study and I do not specifically include my own experiences anywhere in this thesis, beyond how this might have influenced my interviewing and analysis of the collected data.

I have presented my work at various events and over the seven years since the start of my PhD, and my work has resulted in multiple peer-reviewed publications, four of which (co-authored with my PhD supervisors) were directly related to my PhD research and have contributed to various parts of this thesis. Accordingly, other researchers have built upon my published work, as is demonstrated by the citations this work has received. For example, at time of writing my 2015 Ubicomp paper has received more than 90 citations, many of which directly build upon the novel contributions presented in this work. As such, some of the novel findings from my PhD which are presented in this thesis no longer appear as state-of-the-art. However, this thesis does still present a novel contribution to knowledge, and one which I intend to further disseminate in peer-reviewed publications. Independently of my PhD-related publications, I have also published other work that is related to my PhD topic and broader research interests, but does not contribute to this thesis, which is written completely independently of these publications. These additional publications have instead resulted from research and collaborations separate to my PhD work, including my supervision of MSc students, and work undertaken during internships and other research positions. The following page outlines these contributing publications, along with a list of invited talks where I have presented my PhD findings to industry and other researchers, along with other related publications demonstrating my further impact in the field.

Associated Publications and awards

Contributing publications

- **Harrison, D.**, Berthouze, N., Marshall, P. (2017). A review of physical-activity tracking technologies and how to assess their effectiveness. White paper published by EPSRC Get a Move On (GAMO) Network+.
- **Harrison, D.**, Marshall, P., Bianchi-Berthouze, N. and Bird, J. (2015) Activity Tracking: Barriers, Workarounds and Customisation. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing*. [25% acceptance rate].
- **Harrison, D.**, Marshall, P., Berthouze, N., and Bird, J. (2014). Tracking physical activity: problems related to running longitudinal studies with commercial devices. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication*, 699-702.
- **Harrison, D.**, Bird, J., Marshall, P., and Berthouze, N. (2013). Looking for bright spots: a bottom-up approach to encouraging urban exercise. *British HCI Workshop on Habits in HCI*.

Related publications

- Fleck, R., Cecchinato, M. E., Cox, A. L., **Harrison, D.**, Marshall, P., Na, J. H., & Skatova, A. (2020). Life-swap: how discussions around personal data can motivate desire for change. *Personal and Ubiquitous Computing*, 1-13.
- Cecchinato, M.E., Rooksby, J., Hiniker, A., Munson, S., Lukoff, K., Ciolfi, L., Thieme, A. and **Harrison, D.** (2019). Designing for Digital Wellbeing: A Research & Practice Agenda. In *Proceedings of the 2019 CHI Conference Extended Abstracts on Human Factors in Computing Systems.*
- Pateman, M., **Harrison, D.**, Marshall, P. and Cecchinato, M.E (2018). The Role of Aesthetics and Design: Wearables in Situ. In *Proceedings of the 2018 CHI Conference Extended Abstracts on Human Factors in Computing Systems.*
- Renfree, I., **Harrison, D.**, Marshall, P., Stawarz, K., & Cox, A. (2016). Don't kick the habit: The role of dependency in habit formation apps. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 2932-2939). [43% acceptance rate]
- **Harrison, D.,** & Cecchinato, M.E. (2015). Give me five minutes!: feeling time slip by. In *Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers* (pp. 45-48). ACM.
- Fleck, R. and **Harrison, D.** (2015). Shared PI: Sharing Personal Data to Support Reflection and Behaviour Change. *CHI '15 workshop on Beyond Personal Informatics: Designing for Experiences with Data*.
- **Harrison, D.**, & Rogers, Y. (2013). UCLIC. *interactions*, *20*(6), 84-87.

Awards

- EPSRC, via Get a Move on Network (GAMO). (2017). Small grant to write a think-piece that scopes how future technologies to enhance levels of physical activities should be investigated in a holistic and long-term manner.
- EPSRC, via Get a Move on Network (GAMO). (2019). GAMO fellow.

Invited talks

- *The current state of self-tracking technologies and interventions for encouraging increased activity and how to assess them: a critical review.*
  Get a Move On (GAMO) First Annual Symposium. May 2017.
- *Responses to activity tracker use.*
  Microsoft Research Cambridge Summer School. July 2015.
- *The importance of sustained engagement with activity trackers*.
  Invited talk. UCL eHealth tech sharing seminar. April 2015.
- *In the wild activity tracking: academic research with commercial systems.*
  Invited talk. UCL Behaviour Change Conference. February 2015.
- *Long-term situated use of personal informatics technologies.*
  Invited talk. Georgia Tech Ubicomp group seminar. October 2014

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Chapter 1. Introduction

In the 10 years since the mainstream introduction of modern-day activity trackers with the original Fitbit Tracker in 2009, activity tracking systems have become hugely popular. Activity trackers accounted for 85% of the 23 million wearables shipped in the third quarter of 2016 (idc.com, 2016), a market which is expected to grow to more than 245 million per annum by the end of 2019 – with a market value of $25 billion (ccsinsight.com, 2015). Activity tracking functionalities are also increasingly integrated into other technologies we carry around with us each day, including the growing smartwatch market, which is estimated to have overtaken sales of dedicated activity-tracking wearables in 2017 (wareable.com, 2018). These trackers lay within a growing suite of personal informatics technologies, which allow users to actively or passively track, and reflect on, various aspects of their lives. Other common self-tracking technologies include connected scales, diet tracking applications and sleep trackers, as well as those that are directed towards healthcare, such as blood glucose monitors.

Personal informatics systems may be used for a variety of reasons, one typical motivation being for behavioural change (Li, 2010), which is useful to consider within the context of physical activity. The World Health Organisation consider fact that people are becoming less active to be a *major* global health challenge (WHO, 2010). They state that inactivity is responsible for approximately 3.2 million deaths each year and is also a risk factor for many chronic diseases (WHO, 2013). One cause of decreased activity is that people are less active in their day-to-day routines – with more sedentary jobs and leisure activities, and less use of active transport, people do considerably less physical activity outside of planned exercise than they once did. In 1999, Levine et al. coined the term "NEAT", or "Non-Exercise Activity Thermogenesis", to represent all those activities done when not sleeping, eating, or engaging in planned sports-like exercise. These include behaviours such as walking, taking the stairs instead of the lift, or cycling instead of driving. By encouraging a greater level of movement in these day-to-day activities, one can more easily integrate increased levels of physical activity into peoples' routines, compared to undertaking planned exercise. As such, this is a sensible area to focus on, as these habits may be easier to sustain over time.

Activity tracking technologies typically work by passively measuring levels of physical activity taken by the user throughout the day, usually in the form of steps taken, and often utilise behaviour change techniques, such as goal setting and gamification, to help users change their behaviour. Broadly speaking, these technologies are similar to pedometers, albeit with additional functionality. Interventions based on pedometers have been shown to be, at least in some cases, successful in increasing levels of physical activity (Bravata et al, 2007). Rooksby et al. (2014) found that many activity tracker users believe these systems will empower and motivate them to manage their health and wellness, and we ultimately argue this can help them change behaviour to do more NEAT activity. However, despite their recent popularity, our understanding of how people use and engage with activity trackers over time and in their everyday lives, along with the ability for them to help users change their behaviours is still not well understood.

In the ten years since their mainstream introduction, personal informatics systems have been the focus of academic research across a variety of disciplines, including human-computer interaction (HCI) and health psychology. Existing cross-disciplinary work has focused on how people initially adopt and integrate these self-tracking technologies into their lives and have proposed models of use (e.g. Li et al., 2013, Rooksby et al., 2014, Epstein et al., 2015). Other studies, such as randomised control trials (RCT), have concentrated on measuring the efficacy of these systems in changing behaviour (e.g. Finkelstein et al., 2016; Jakicic et al., 2016; Harries et al., 2016). However, both approaches have limitations. Qualitative studies are generally not conducted over a long time-period or do not consider the context of use, and thus may present an inaccurate picture of how these technologies are used over time. RCTs generally focus on efficacy, without understanding how people use these technologies over time in their day-to-day lives or unexpected outcomes from use. Moreover, the unintended outcomes and potential side effects of introducing behaviour change technologies into people's lives may come with negative consequences. For example, research suggests that people enjoy activities less when they are quantified (Etkin, 2016), behaviour change technologies may create dependencies on the technology to sustain a new behaviour (Renfree et al., 2016), and people may only make changes to their activity because they are being tracked (Attig and Franke, 2018). The importance of considering these potential negative effects was called for in a 2018 blogpost by the ACM Future Computing Academy (Hecht et al., 2018).

1.1 Research Aims and contributions

Motivated by the real-world problem of physical inactivity and the limitations in current research which will be discussed in more depth in Chapter 2, this thesis investigates the following **research question**:

RQ: How do healthy adults use and experience activity trackers over time and in different situations?

To answer this question, the following **research objectives** have been set, which findings from our studies address:

RO1: Update the current understanding of how healthy adults initially engage with activity trackers (Chapter 4)

RO2: Explore how healthy adults use, and not use, trackers over time and the factors that impact this (Chapter 5)

RO3: Categorise how healthy adults change their behaviour or attitudes, as a result of using these tracking technologies (Chapter 6)

Overall, this thesis makes **three types of contributions:** to knowledge, to design, and to research practice. Each of these is divided into further contributions and the implications for future work that derive from them.

Our first contribution is to knowledge and extends the current understanding of people's engagement over time with personal informatics systems in two ways. Through our classification of phases of tracking over time and factors that influence engagement which build on previous work (Li et al., 2010; Epstein et al., 2015) and our consideration of contextual factors (Suchman, 1987), we are able to explain of how (a) **the use of tracking technologies over time is not necessarily aligned with outcomes**. Furthermore, by providing a more complete understanding of users' behavioural and affective responses to personal informatics use, we find how some responses to tracking are negative, and discuss (b) **the unintended and potentially harmful outcomes from use of self-tracking systems,** which we characterise as *harmful informatics.*

Our second contribution speaks to the design of activity tracking systems. As such we provide three implications for design to better support real-world use. Here, we encourage designers of these technologies to (a) **embrace the temporal use and changing ecologies of tracking systems**, to (b) **support users in having meaningful interactions with their data** and finally, we suggest that designers should (c) **consider the salience of data and physicality of tracking solutions**.

Finally, our third contribution focuses on research practice and presents three methodological implications for those who evaluate personal informatics systems, recommending that these systems are (a) **studied over time**, to move beyond novelty effects and look at behavioural changes that happen after the period of initial use. We also suggest a broader focus to (b) **consider changes beyond the tracked activity**, as use of personal informatics systems may encourage people to change other behaviours**.** Finally, motivated by the importance of situated use, we suggest (c) **a greater focus on the impact of context** when evaluating behaviour change technologies, as this can have a significant impact on how people engage with these technologies over time.

1.2 Research Scope and Approach

We took a longitudinal and comparative approach, by carrying out two in-depth qualitative studies: firstly, we conducted a longitudinal mixed-method study, lasting over one year, with a diverse sample of 50 new tracker users located in London to understand use and behavioural impacts over time; secondly, we undertook a comparative interview study with 48-existing and previous users of activity trackers in two, culturally and physically different, urban settings to allowed us to uncover further contextual factors.

Rather than looking at a broad range of self-tracking technologies, we have specifically concentrated on healthy adult's adoption and use of activity tracking technologies, particularly those that quantify activity with steps. We have purposefully focused on healthy adults, as opposed to targeting populations such as children or older adults, because this population are most typical of those who purchase and use these devices. Furthermore, diverse populations with particular needs are likely to engage with these technologies in different ways, diluting the focus of our work.

The tracking systems we studied include wearable devices both provided by the research team, and owned by participants, as well as digital apps that can be used on mobile phones. We focus on this wide range of systems because they reflect the messiness of systems used in the real world. Finally, we have scoped this research around NEAT activity because it comprises a series of physical activities that can be more easily integrated into a daily life and have a lower adoption barrier compared to planned physical exercise.

1.3 Thesis structure and "the self-trackers' journey"

Rather than presenting the findings from our research as a typical collection of chapters focusing on independent studies, we instead use the framing of a hypothetical "Self-Trackers Journey". As such, we present findings from the thesis in three chapters, that loosely overlap with temporal stages of use: initial engagement with activity trackers, phases of tracking over time and in different situations, and finally, responses to use of tracking systems. This abstracted self-tracking journey comes from the thematic analysis of data collected in both studies. Presenting our findings in this way helps to forefront the importance of use over time. However, although presented chronologically, it is important to realise that the self-trackers journey is complex and does not follow a linear pathway.

For example, we have presented "responses to tracking" at the end of the self-trackers journey, but in reality, these responses may occur at any time, and are likely to evolve and change over time.

Because the self-tracker's journey has multiple pathways, changing goals and obstacles along the way, we guide the reader through the journey with a number of diagrams, similar to Figure 1.1. These are intended to help the reader locate themselves within the broader narrative of the thesis and easily see how different parts of the journey tie together. The titles and subtitles are intended to be as intuitive as possible, allowing the presentation of results to be easily navigated.

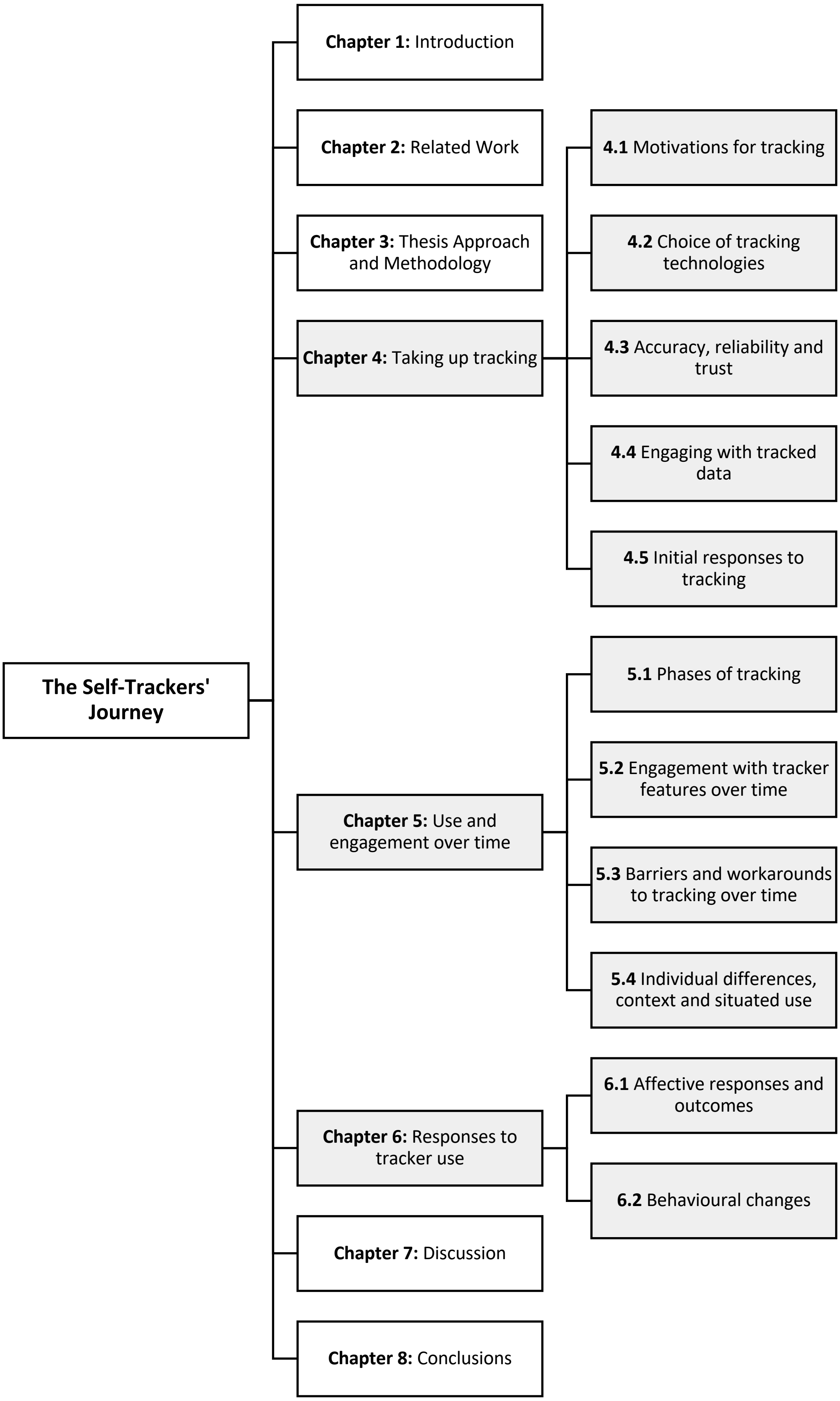

Figure 1.1 – Overall outline of the Self-Trackers' Journey

Chapter 2. Related Work

This chapter presents a critical overview of existing relevant work. We begin by presenting an overview of the real-world motivations for studying this area, before engaging with the existing behaviour change and self-tracking literature, identifying areas where research could produce a better understanding of how people adopt and use (or not use) tracking systems in the wild. We then examine the different approaches taken when studying self-tracking systems, to understand and motivate our own research in this area.

Chapter 3. Thesis Approach and Methodology

Moving on from our examination of the existing work into self-tracking systems, chapter 3 outlines and discusses the approach we took and the methods we used in relation to the research aims of this thesis. We present the particular details of the methods we used for our two studies, including details of the participant nomenclature we use throughout the remainder of the thesis.

Chapter 4. Taking Up Tracking

In this chapter, we present results from our participants' initial use of their tracking technologies, including their motivations for using the technology, how they appropriated and interacted with them after first use, and any behavioural or psychological responses that happened because of this initial use. In short, this chapter characterises the beginning of "the self-trackers journey", leaving Chapter 5 to describe how our participants' use and engagement with these tracking technologies changed over time, and Chapter 6, to describe the longer-term outcomes of their use of these tracking technologies.

Chapter 5. Use and Engagement Over Time

Continuing from the work set out in Chapter 4, this chapter further characterises the ways people use their activity tracking technologies and changes over time. In particular, we offer a rich description of the different phases of tracking identified in our research: *continued engagement, lapsing, stopping*, and *returning* to tracking. These phases extend and further characterise previous models in the literature. We then focus on the different factors which influenced our participants use of their tracking technologies: presenting insights into how people's use of the various features and functionalities embodied in activity tracking technologies change over time and affect their overall use of the tracker; the barriers, or challenges trackers face when using these technologies and the ways that some users have created workarounds to lessen the effects of these; then, we provide an overview of the effects that context had on our participants physical activity, use and engagement with their trackers, and behavioural outcomes.

Chapter 6. Responses to Tracker Use

The final findings chapter discusses our participants' behavioural and psychological responses to tracking over time, detailing the processes participants went through and the factors that affected these outcomes. We present both behavioural outcomes and psychological outcomes, as our participants changed their behaviours and attitudes towards the tracked behaviour. Furthermore, we also detail how they made changes to behaviours beyond those they were tracking, and how using their activity tracking systems affected different behaviours.

Chapter 7. Discussion

This chapter discusses our findings and contributions in the context of the existing literature and direction taken by commercial trackers. We discuss our research questions in the context of the literature and our findings, presenting our contributions to knowledge. Additionally, we present implications for design of future personal informatics systems, and methodological implications for researchers evaluating these systems, again grounded in the results from our work.

Chapter 8. Conclusions

Finally, we conclude the thesis with a short summary of our work and contributions.

Chapter 2. Related Work

Personal informatics systems generally track, or quantify, an attribute about a person (such as the number of steps they take, or the food they eat) and present this data back to the user in an easy to understand format. Activity trackers, which generally passively record the number of steps one has taken in a day, are perhaps the most popular personal informatics system and have attracted a large amount of attention in the media and have been the focus of academic research across a variety of disciplines. Activity tracking systems usually include various behaviour hange techniques to encourage users to be more active, though it is important to mention that these technologies are used for a variety of reasons beyond behaviour change, as we present in this chapter. At the outset of this research commercially-available activity tracking systems were more limited than the devices that are available today, some of which now offer heart rate, heart rate variability and measures of blood oxygen, amongst others. Instead, the research presented in this work is mostly based on users of more limited systems that mostly relied on counting steps. However, many of the findings are equally applicable to other types of personal informatics system measuring other attributes, as we discuss in Chapter 7. A large body of work now focuses on how people adopt these trackers and integrate them into their lives, considering not only changes to the tracked behaviour, but also how the trackers become part of one's daily routine. However, more work needs to look at: "**How, healthy adults use and experience activity trackers over time and in different situations?"**, the overall research question and contribution of this thesis.

In this chapter we present a critical overview of current work within personal informatics and behaviour change, so that we can better understand the gaps in our current understanding of the use of activity tracking systems over time. We present an overview of: the real-world problem of physical inactivity and activity around the world, including governmental activity recommendations; a review of past and present self-tracking and personal informatics technologies, and how these are understood to be used in the real world, with a particular focus on physical-activity tracking related technologies; personal informatics models of use; and finally, a review of the behaviour change and habit formation literature, specifically where useful for understanding people's use of activity tracking technologies.

2.1 Physical activity and inactivity

We start by providing an overview of physical activity, inactivity and associated guidelines for activity levels. Worldwide there is a strong focus around encouraging people to be more active which is both unsurprising and well-grounded. Quantifying and increasing awareness of activity-levels is a potential way of encouraging people to be more active, though as we later explain behaviour change is not the only reason people use these technologies. Physical inactivity is a "leading risk factor for death", with the World Health Organisation claiming that "globally, 1 in 4 adults is not active enough" (WHO, 2017, no page number given). Here, we overview the problem of physical inactivity, covering the myriad factors contributing to global physical activity trends, along with the recommended levels of physical activity for different populations. This section further explores the problems with physical inactivity and recommendations for physical activity.

2.1.1 Inactivity and its causes

Understanding the factors that prevent people from being active is key to appreciating how activity tracking systems will be used in the real-world and aid people in being more active. According to the World Health Organisation (2013), physical inactivity, which is strongly linked to obesity and is a risk factor for many chronic diseases, is responsible for approximately 6% (3.2 million) of all deaths each year. The Organization for Economic Co-operation and Development (OECD, 2013), who report population statistics for 34 mostly-western countries, found that more than half (52.8%) of the adult population were overweight or obese, and obesity levels between 2000 and 2011 increased in *all 34 countries* included in the report. The number of overweight and obese adults is believed to be as high as 68.8% in the US (Flegal, et al., 2012) and 61% in the UK (NHS Information Centre, 2009).

The World Health Organisation (2013) suggest that, beyond our increased use of technology, the global decrease in physical activity is partly caused by: inactive work and leisure activities; sedentary occupations; and, increased use of non-active transportation. Although these results were derived from all the WHO member states, situational and contextual factors impact the challenges and barriers people face to being more active, resulting in specific contextual challenges and potentially leading to inequalities (Althoff et al., 2017). Other more personal factors can also act as barriers to being active, such as psychological barriers, weather, the built environment and access to different transport solutions, and access to safe and suitable places for exercise (Humpel, Owen and Leslie, 2002). However, these factors are often less considered in HCI work.

To combat the problems of inactivity, the WHO recommend encouraging moderate intensity activities such as walking and cycling, as these offer significant health benefits and people can *"quite easily"* (WHO, 2017. no page number given) meet recommended activity levels throughout the day. This claimed ease is debateable given the difficulty in changing any behaviour, and in particular physical activity behaviours and habits are considered difficult to change (Prochaska, Johnson and Lee, 1998).

2.1.2 NEAT activities

Physical activity takes many forms, and positive health benefits are not only the result of vigorous sports activities, or training sessions completed in the gym, but also smaller non-planned activities that form part of one's everyday activity, such as cleaning the house or walking around the shops. These less-vigorous activities present an easier opportunity for people to get more activity into their lives, and activity tracking solutions offer a way to track and encourage these activities. In 1999, Levine et al. coined the term "Non-Exercise Activity Thermogenesis", or NEAT, to refer to all activities that are not sleeping, eating, or doing sports-like activities, and explained the virtues of these. Since then, studies (e.g. Levine, 2004) have shown the positive health impacts of increasing NEAT through small changes in day-to-day activities such as using the stairs. A recent study showed that even a change as minor as "chair-based fidgeting" (Figure 2.1) can have significant positive effects on energy expenditure (Koepp, Moore and Levine, 2016).

Figure 2.1 – Chair-based fidgeting solutions: FootFidget[1] and CoreChair[2]. (images from Koepp, et al., 2016.)

Targeting an increase in NEAT activities may be particularly useful as they can be easily integrated into the lives of otherwise sedentary individuals through small changes made throughout the day. For example, one way for people to routinely incorporate more NEAT activity into their lives might be through increased use of active transport solutions, such as walking and cycling (Van Kempen, et al., 2010). Research has shown large improvements to both physical and psychological wellbeing after taking up more active transport solutions (Martin, Goryakin and Suhrcke, 2014), and these may

[1] www.footfidget.com
[2] www.corechair.com

represent an easier way to integrate physical activity into one's daily routine, compared to planned exercise.

2.1.3 Active Transport

Active transport solutions such as walking and cycling, are also a good way for people to integrate more low-to-moderate physical activity into their daily routine, but figures vary considerably between different locations. For example, in London where most of the research in this thesis took place, 20% of journeys are made by foot, and fewer than 2% are completed on a bicycle (Transport for London, 2010). Elsewhere, in metropolitan Atlanta where we also conducted research, it is estimated that just 1.4% of commuting-journeys were completed by foot and just 0.2% are made by bicycle (Atlanta Regional Commission, 2016).

Various external and environmental factors often prevent people using active transport solutions, even when they might want to. Frequently cited barriers to utilitarian walking and cycling include: personal safety concerns; a lack of time, or knowledge, of suitable routes; unsuitable weather conditions; and, a lack of motivation to conduct physical activity (Parkin, Ryley and Jones, 2007). The EPSRC-funded *"Understanding walking and cycling project"* (Pooley et al., 2011) discovered that poor weather conditions were the largest barrier preventing people in the UK from choosing to walk as a transport method, and safety concerns were the biggest barrier preventing people from choosing to cycle. Another contributing factor is the physical makeup of places – London is a much more densely populated city than Atlanta, meaning that many journeys can be shorter. Further to this, Pooley et al. (2011) state that the public have a *"perception that walking and cycling are not normal"* (p.2), highlighting an interesting and relevant social norm. This supports previous findings by Horton (2007), who found that some non-cyclists seem to believe that cyclists are a dangerous group of "other" people, indulging in an activity that is "not normal". Given these barriers to active transport, interventions focused on tracked physical activity alone may not be enough to encourage people to use more active transport.

2.1.4 Physical activity guidelines

Many guidelines for physical activity levels exist, but perhaps the most well-known is for healthy adults to take 10,000 steps a day, a figure that originated from a 1960's Japanese marketing campaign (Figure 2.2) encouraging sales of pedometers (Hatano, 1993). Despite the dubious source, research agrees this level is appropriate for many health adults (Tudor-Locke et al., 2011a), it is widely acknowledged by healthcare professionals and it is frequently implemented as the default behavioural goal for most activity trackers. However, it may not be appropriate for all: some children and adolescents should perhaps aim for more steps (Tudor-Locke et al., 2011b); a lesser goal of 5,000-7,000 steps may be better for older adults (Tudor-Locke et al., 2011c); and, recommending a fixed number of daily steps may not be the right approach for those with chronic pain, as overdoing activity on bad days has negative consequences on their ability to remain active (Singh et al., 2014; Ayobi et al., 2017).

Figure 2.2 – Japanese "manpo-kei" pedometer marketing poster

Given the strong focus that most activity trackers have on steps, one might think that steps alone are sufficient to meet activity guidelines. However, this is not the case: most guidelines recommend a combination of strength training and aerobic activity. For example, the National Health Service (NHS) in the UK recommends healthy adults take either: 150 minutes of moderate aerobic activity and strength training on 2 days; 75 minutes of vigorous physical activity and strength training on 2 days; or, a mix of vigorous and moderate aerobic activity with strength training on 2 days, each week (NHS.uk, 2011). These, and other, lifestyle guidelines are often communicated through educational mass-media campaigns (e.g. Figure 2.3), but there is a gap between an individual's awareness of recommended activity levels, their desire and intention to do more activity, and their success in doing so (Craig and Mindell, 2009). For example, in the UK, where it is believed that less than 40% of adults meet recommended activity levels (Department of Health, 2010), commercial research funded by Fitbit in 2013 identified that 60% of the adult population were aware of the associated health risks of physical inactivity, but only 10% felt that this had a strong positive impact on their behaviour (Fitbit, 2014). The Health for England 2007 survey (Craig and Mindell, 2009) presented more rigorous and independent research, approximating that 66% of the British adult population were aware of recommended levels for physical activity, but that around 70% of the population took less exercise than recommended, although 69% did have a desire to take more exercise.

Figure 2.3 – Sitting Is the New Marrying Henry VIII – Photograph of a poster from a 2014 campaign to encourage people to move for 1 hour each day

As described later in this chapter, behaviour change is complex and awareness alone does not appear to be effective in encouraging exercise. Instead, a combination of education through media campaigns and other behaviour change techniques, such as social support, has been found to be more effective (Sallis, Bauman and Pratt, 1998; Kahn et al., 2002). Successful behaviour change interventions should be targeted with a range of techniques (Michie, Stralen and West, 2011). Although it is not their only use, activity tracking system do provide an opportunity to engage users with measures of activity levels (there is a gap between what people think they do and what they actually do (Vandelanotte et al., 2011)), and embody different behaviour change techniques. As of May 2017 Fitbit's home page[3] states *"Fitbit motivates you to reach your health and fitness goals"*, and similarly the Withings Activite product page[4] says *"activity tracking helps you move more, feel better, and sleep better"*. However, there is still relatively little research looking at the role these systems can play in the behaviour change process, and more importantly, how they are used in the wild and over longer time periods.

2.2 Self-tracking and personal informatics

The activity tracking technologies we focus on in this thesis are just one example of the many different self-tracking ubiquitous computing systems that now exist and allow users to either actively, or passively, measure, track and record aspects of their lives. These technologies are referred to as "Quantified Self", or "personal informatics" systems, both of which are relatively

[3] www.fitbit.com
[4] www.withings.com/uk/en/products/activite-steel

recent expressions. "Personal informatics" was coined by Ian Li et al. in 2010 as systems that *"help people collect and reflect on personal information"* (Li et al., 2010, p.557). The term "Quantified Self" was first used and popularised by two *Wired* editors in 2007 with the advent of the Quantified Self Labs[5]. The two terms are often used interchangeably. Work in this area has grown significantly both commercially and in academia, to the point that in 2017, Kersten-van Dijk et al. referred to personal informatics as *"a new scientific field"* (p.2). Despite the recent interest, personal informatics arguably has much older roots in "lifelogging" (Sellen and Whittaker, 2010) – an activity that humans have engaged in for hundreds of years, but which modern technology has now made more accessible.

Our understanding of self-tracking can be grounded in what has come before, with a long history of self-trackers throughout history. For example, Benjamin Franklin famously logged "13 virtues" (including temperance, silence, order, etc.) about himself each day (Franklin, 1791) and in 1945, Bush imagined "the Memex", for total capture of all the files and materials one encounters in life (Bush, 1945; Sellen et al., 2010). More recently, starting in 2005 (and finishing in 2015) Nicholas Felton manually tracked many aspects of his life, and created annual infographics on the website www.feltron.com. Additionally, athletes and their coaches have tracked and carefully controlled aspects of their lives related to their performance for far longer than general consumers, showing how insights into one's life can result in enhanced performance when carefully considered (e.g. Ng and Ryba, 2018).

General interest in personal informatics technologies has exploded over the past decade and a broad range of commercial products and applications now exist, in the form of pervasive connected scales, activity trackers, cycle computers, GPS tracking devices, mobile phone applications and more. People use these technologies to quantify various aspects of their lives, including but not limited to: physical activity; physiological data such as weight, blood pressure and heart rate; mood; and, their time spent using technology (Cecchinato et al., 2019). People's motivations for self-tracking are broad, but often relate to behaviour change or self-improvement, to be the best, most-successful versions of themselves (Choe et al., 2014). This data may be background-recorded by devices and applications, manually logged using computer systems or paper records, or a combination of the two. However, despite the broad range of self-tracking systems available, we still do not have a complete understanding of how different people, in different situations, use these devices over a longer term, and to what extent they work in supporting behaviour change. Of particular interest in this thesis are devices for tracking physical activity, movement and health. Quantifying these parts of a person's life

[5] www.quantifiedself.com

gives the opportunity to leverage behaviour change techniques already discussed in this chapter for example by setting goals, using rewards, increasing knowledge of activity, or by levering social norms and influences.

2.2.1 Active vs. passive tracking

Personal tracking changed significantly with the advent of technologies that allow *passive*, rather than *active* logging – i.e. systems such as activity trackers that background-record data without manual engagement from the user. Pedometers, first envisaged by Leonardo da Vinci more than half a millennium ago (Da Vinci, published: 1938), were one of the first technologies for automatically recording human activity. However, differently to modern activity trackers, while pedometers allow users to *passively* track the number of steps they take, they must then *actively* check the recorded data and manually transcribe or log this (e.g. Ayobi et al., 2017). Use of a pedometer could be considered semi-automated tracking, whereas more modern activity tracking systems would be considered *passive* tracking (Choe et al., 2017a). Examples of systems that rely upon the user *actively* self-tracking behaviours include manually logging food or keeping a record of dreams. Despite their simpler technology, lack of connected features and reliance on semi-passive tracking, pedometers have been shown to be successful in encouraging behaviour change when used as part of an intervention to increase levels of physical activity (e.g. Bravata et al., 2007).

There is considerable effort, both commercially and in academia, towards allowing metrics to be tracked passively. Examples include beakers that measures contents and calories[6], to research exploring automatic tracking of food consumption with wearables (Thomaz et al., 2015). One of the motivations for this work is to remove the effort of tracking from the user - as we discuss in section 2.3.2, one reason users stop tracking is because of the sometimes-considerable efforts needed. For example, using the MyFitnessPal app[7] to keep an accurate record of all the food that one eats requires the user to carefully log not only the types of foods, but also their weights and ingredients. This is, of course, time consuming and may even cause some users to change their eating habits – eating a more limited diet so to save time when inputting their meals into the app (Cordeiro et al., 2015). Designers of interventions should consider what effect the actual process of tracking has on the targeted behaviour, as Duncan et al. (2016) have started investigating in their work on physical activity, sitting and sleep behaviours.

[6] www.myvessyl.com
[7] www.myfitnesspal.com

2.2.2 Tracking physical activity

Technologies for tracking ambulatory activity generally fall into two groups: those designed primarily to track sports activities (usually utilising GPS); and those that use accelerometers and other sensors to record NEAT (Levine, 2006) activities throughout the day. This thesis primarily focuses on NEAT activities and technologies that automatically track them, although these may be used in combination with other tracking technologies. The application of modern technology to this area is relatively recent, with notable academic work in this area, precursory to the current commercial-systems, includes the HCI work published by Consolvo et al. (2006, 2008a, 2008b) on *"Houston"* and "*The Ubifit Garden"* – both systems utilising a step-tracker connected to a mobile phone application, a display showing the number of steps counted. These systems, and other similar works in HCI (e.g. Lin et al., 2006) not only logged the number of steps the users took, but were also designed with other functionalities to encourage people to change their behaviour and be more active.

Interest in activity tracking has exploded since these first HCI works, with particular growth since the first consumer tracking technologies were released in the late 2000's. Making sense of the broad range of multi-disciplinary academic research undertaken, Ayobi et al. (2016) conducted a review of the academic work within HCI, and identified three streams of existing research: *psychologically*, *phenomenologically*, and *humanistically* informed. The *psychologically* grounded research is mostly related to behaviour change and psychological approaches. The *phenomenologically* grounded stream *"seeks to understand how wearable self-tracking technologies are used and experienced in practice"* (p.2776) and finally, the *humanistically* informed stream takes a broader perspective, drawing upon *"concepts and perspectives that are grounded in research fields such as digital humanities, media studies, and sociology"* (p.2777). Our approach for this literature review includes research from all three strands, further taking forward our holistic approach to making sense of how people use and engage with activity tracking systems over time. We have drawn from several review papers of the behaviour change literature that already exist (e.g. Michie et al., 2011a; Michie et al., 2011b) and Sullivan and Lachman's (2016) paper, which provides an in-depth overview of the behaviour change techniques explored in the literature, related to physical activity and tracking. Therefore, we mostly draw from the phenomenological and humanistic streams, as these are less understood and reviewed in the current literature.

2.2.2.1 Systems for tracking physical activity

The most common way to tracking NEAT physical activity is by measuring steps. The first step counting device was envisaged by Da Vinci over 500 years ago (see Figure 2.4, Da Vinci, published: 1938). Modern pedometers traditionally use a small mechanical switch to detect steps: the movement created by each step causes the switch to move, completing the circuit and thus counting a step. However, these devices are not always accurate, especially when users walk at lower speeds, and positioning is critical (Crouter, Karabulut and Bassett, 2003; Schneider et al., 2003). More modern activity trackers instead use accelerometers to detect and record movement, along with software algorithms to determine steps from the recorded data (Zhao, 2010; Scarlett, 2007). The main practical advantage of using an accelerometer is that the accelerometer works across 3-axes, so there are fewer restrictions in the design of the device and where on the body it can be worn. Accelerometers also allow the intensity of movements to be recorded and may also be used to classify quantify other activities such as running, cycling, or even eating (Thomaz et al., 2015). Accelerometer-based trackers can be reliable and accurate at counting steps when walking, but they may create false-positives, being "fooled" into also counting other movements as steps. Additionally, these technologies are less accurate at quantifying other activities, such as cycling or weight training.

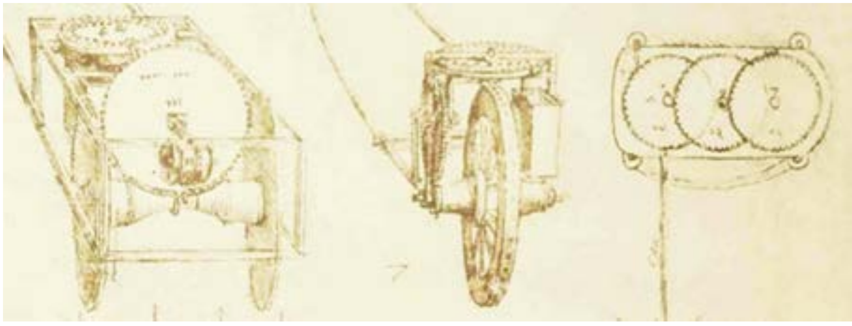

Figure 2.4 – Da Vinci's "pedometer"

A huge number of accelerometer-based solutions for measuring steps exist, not only activity trackers but also other wearable devices such as smartwatches (Cecchinato et al. 2015; 2017), smartphone applications (and in-built functionalities) and even handheld games consoles such as the *Nintendo 3DS*[8] that offers in-game rewards for real-life steps. Although we focus on tracking ambulatory activity, where appropriate we also refer to other personal informatics systems (e.g. food, sleep, weight, blood pressure, etc.) as many users build ecologies of tracking devices for measuring different metrics (Rooksby et al., 2014).

[8] www.nintendo.com/3ds

Figure 2.5 – Activity trackers in different form factors. (from left to right) Fitbit Zip clip[9], Jawbone UP3 wristband[10], Withings Steel HR watch[11]

Dedicated activity trackers are available in different form factors, including clip-based devices, wristbands and watches (Figure 2.5), each with different concerns as to how they are integrated into one's everyday life. For example, smartwatches that also track physical activity can present issues with engagement, if the user is bombarded with other non-related notifications (Cecchinato et al., 2017). Traditionally these devices have only used accelerometers to record activity, but more recently they have offered additional tracking metrics through embedded sensors such as heart-rate monitors and ECG (e.g. Apple Watch Series 5 and onwards).

2.2.2.2 Apps vs. wearables to track physical activity

Along with wearable devices for tracking activity, there are also many free and paid-for smartphone applications which offer step-tracking functionality. More recent smartphones, such as the Apple iPhone 5S and newer, include a specially designed "co-processor" to track steps without a large overhead on the battery, potentially encouraging new people to track who otherwise might have not. Using the iPhone as an example, these devices record steps without involvement from the user, maintaining a record of the previous 7-days steps, so that a user can immediately see their activity data from the previous week when they first download a step tracking app. A benefit of using smartphone apps is the greatly reduced barrier to adoption, as they may be used without an additional purchase, at least for those who already own a smartphone. Recent commercial research has suggested that 68% of Americans own a smartphone (Smith, 2015), although this number may be lower amongst older adults and those with lower socioeconomic status. Furthermore, tracking functionality is often only included in more recent and costly higher-end devices, potentially leading to inequalities in access.

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[9] www.fitbit.com/zip
[10] www.jawbone.com/fitness-tracker/up3
[11] www.withings.com/products/steel-hr

2.2.2.3 Measures of activity

Although most apps and devices quantify users' activity by recording the number of steps taken, steps are not always the most holistic measure of overall physical activity: they do not account for non-step based activities such as cycling, or any of the recommended strength training, or weight-bearing, activities (see section 2.1.4). Measures such as Nike's fuel[12], Mio's PAI[13], energy expenditure (EE) or metabolic equivalents (METs) attempt to offer holistic measures of effort, but current devices may not be accurate enough when tracking these other activities to provide accuracy in these more holistic measures, despite what manufacturers might claim (e.g. Rosenberger et al., 2016). Research has found that most users consider step tracking alone to be the most important function of activity trackers (Alley et al., 2016).

2.2.2.4 Accuracy of activity tracking systems

The accuracy of activity tracking technologies is often brought into question by users, reviewers and researchers alike. As already mentioned, false positives arising from movements other than steps can happen, a factor which may negatively influence a person's trust: end-users may be distrustful of devices they perceive to be inaccurate (Yang et al., 2015). Numerous studies have analysed accuracy of devices and apps for tracking physical activity and found generally positive results: a systematic review of 22 studies conducted by Evenson et al. (2015) showed reasonably high validity when tracking steps. However, other evidence suggests that some devices are less accurate for certain populations including the elderly and slow walkers (Feito et al., 2012; Lauritzen et al., 2013), and they are generally inaccurate at tracking non step-based activities.

Consistency of step tracking, rather than absolute accuracy, is also an important factor for end users, as they may be more interested in comparing the number of steps they take over time. However, there is inherent difficulty in testing this between different users and devices.

2.3 Real world use and adoption of activity trackers

There is a growing body of research focusing on the ways in which people use and integrate activity trackers into their lives. This research shows that people sometimes adopt trackers in unexpected ways, not only using them for the purposes of self-improvement, as one might expect, but also for

[12] www.secure-nikeplus.nike.com/plus/what_is_fuel/
[13] www.mioglobal.com/pai.aspx

other reasons such as for documentation, or purely because of an interest in the technology (Rooksby et al., 2014).

Another characteristic that frequently arises with relation to use of these novel technologies is that of "abandonment". This is frequently cited in mainstream media, backed up with commercial research suggesting high levels of abandonment along with short term use (e.g. Arthur, 2014). More recently, research focusing on the phenomenological and humanistic factors (Ayobi et al., 2016) has begun to provide us with a better understanding of the reasons why people track, and the factors that might prevent them tracking over a longer term. This thesis focuses on the phenomenological and humanistic considerations relevant for understanding why and how people use and integrate tracking technologies into their lives, and the utility they bring.

2.3.1 Motivations for taking up tracking

People's reasons for taking up tracking stem from a variety of different motivations. Although behaviour-change and self-improvement are often the most cited reasons, not all use is driven by these desires. One obvious distinction comes by considering intrinsic and extrinsic motivations, which may be useful when considering behaviour change and engagement with the technology. Those who are driven by intrinsic motivations are perhaps more likely to have self-improvement goals in mind and hope to reach them using the tracker. Extrinsic motivations may be useful to leverage, along with social factors such as competitions and rewards, which can influence the behaviour of self-trackers (Rooksby et al., 2014; Fleck and Harrison, 2015). Leveraging people's extrinsic motivations to track and change behaviour is worth further consideration as tracking technologies are embedded into a greater number of devices, removing barriers to entry (i.e. purchasing a tracker) for many new self-trackers who may start tracking without an intrinsic motivation to change, providing new opportunities for these technologies to impact people's lives.

Focusing on understanding the ways that people use self-tracking technologies in the wild, Lupton (2014a) identified five "modes" of self-tracking (private, pushed, communal, imposed and exploited), where only one (private) describes an intrinsically-motivated user taking up tracking of their own volition. The other modes all include some sort of outside encouragement: with *pushed* tracking this imagines an external actor encouraging the user to track, this could either be a friend or an authority figure; *communal* tracking relates to tracking where motivation comes from participation in a group; *imposed* self-tracking is where a user is forced to track for another's benefit, such as when monitoring a workforce; and, *exploited* tracking relates to where individuals' data are *"repurposed for the (often commercial) benefit of others"* (p.10).

Lupton's models of tracking perhaps do not represent what most think of when considering self-tracking in the space of wellness technologies, where a user has taken up tracking because of their own interests and self-agency (even if the tracker has been gifted), rather than being externally driven. Instead, Rooksby et al. (2014) described five styles of personal tracking identified from their sample of 22 participants, most of whom had taken up tracking as per Lupton's "private" mode, i.e. they had chosen to track themselves. Rooksby's styles include: *directive tracking*, where participants were driven by a goal; *documentary tracking*, where participants wanted a record of their data; *diagnostic tracking*, where participants were looking for links, or relationships, between multiple tracked aspects; *collecting rewards*, where participants were inspired by some sort of gamification or competition; and, *fetishized tracking*, where use is because of their interest in *"gadgets and technology"* (p.1169). Rooksby et al. suggest that directive and documentary tracking were the most common in their sample, which is what one might intuitively expect.

Although not all tracking is related to self-improvement, this is still a large driver of people using personal informatics systems. Furthermore, just because one does not start tracking with an intention to change their behaviour, this might still be an outcome, or their intention may change (Epstein et al., 2015; Rooksby et al., 2014); there has been limited research on how users' style of tracking might change over time. Given the growth of tracking systems embedded into other technologies such as smartphones and smartwatches, there is an opportunity to leverage behaviour change techniques to encourage people who are otherwise not motivated to change.

2.3.2 Barriers to tracking

Despite the popularity of tracking systems, they are often only used for a short term. Recent research looking at novelty effects in use of activity trackers (Shin et al., 2019) define long-term use as anything over 6 months, but compared to uptake of other novel technologies this is relatively short (Rogers, 2003). Some reports have suggested that approximately one third of devices are abandoned within 6-12 months of purchase (Endeavour Partners, 2014), whilst others have found that 74% of health-related smartphone apps are used fewer than ten times (Consumer Health Information Corporation, 2011). However, this does not help us understand the reasons why people stop tracking - there is often an assumption that short-term usage represents failure and long-term use is necessary for sustained behaviour change, but this belief is generally not verified with users of the system (Arthur, 2014). Given this apparent use pattern, research has considered the reasons people stop using their trackers. As we outline in the following sections, stopping use of a tracker is not always the same as abandoning tracking, and indeed stopping tracking does not necessarily represent failure. However, users still face challenges when tracking, and research has begun to document the myriad barriers that users must overcome and suggest design recommendations to lessen these obstacles. As expressed by Consolvo et al. ten years ago (2009), *"if done poorly, the technology is likely to be abandoned"* (p.414).

For the most part, research focusing on abandonment considers users of physical - usually wearable - devices, rather than software applications. Whereas tracking with a physical device requires the user to adopt and carry an additional piece of hardware, smartphone apps only require the user to carry their smartphone. However, this does not mean that using a smartphone app is necessarily a better option: using an app might make the tracked behaviour less salient compared to wearing a device, by hiding the data away resulting in lower engagement (Choe et al., 2017a). Additionally, using a smartphone to track steps might sometimes pose issues, particularly for those who wear outfits without pockets. Wearable devices with a greater number of functions, such as smartwatches, may alleviate some of these barriers by encouraging further interactions, but are not without their own challenges (e.g. Cecchinato et al., 2015; 2017b).

Adopting a new piece of technology, especially one that needs to be carried all the time such as an activity tracker or a smartwatch, can come with many challenges. Through various studies (e.g. Yang et al., 2015; Clawson et al., 2015; Lazar et al., 2015; Epstein et al., 2016a; Gulotta et al., 2016) researchers have identified a large range of barriers to engagement with tracking systems, including: reliability and the technology not working; battery life and charging the battery; comfort, physical form and aesthetics; quality of data and appropriateness of the tracked data; and, removal of features, such as social support. Some users find the costs associated with tracking too high and stop. This may be particularly true for tracking that has a high manual, or active, element, and therefore more of a cost (Epstein et al., 2016a), which should be considered when designing and evaluating tracking tools.

2.3.3 Temporality of use

Rather than tracking consistently over a longer-time period, various studies (e.g. Epstein et al. 2015; Epstein et al. 2016a; Berg, 2017; Meyer et al., 2017) have instead found that people track temporally: having periods when they are highly-engaged with tracking, broken up by periods where they are less engaged, or not tracking at all. Different models and language have been used to describe these different levels of engagement, from likening levels of engagement to Flow (Lomborg, Thylstrup and Schwartz, 2018), to integrating temporal use into overall models of use (Epstein et al., 2015).

Stopping tracking is often referred to as abandonment, but as work in the field has progressed, we have gained a better understanding of how users adopt these technologies over time and the more temporal nature of tracking. Whilst a user may stop tracking, because of a barrier to engagement or otherwise, this does not always constitute "abandonment" of the technology – users may return to tracking with the same, or a different tracker. Indeed, the literature provides multiple reasons why one might track over a short term: some users may stop tracking because they have learnt enough, or satisfied their curiosity, and then "happily abandon" their tracker (Clawson et al., 2015). This may happen after even a short period of use, as users may find that the data offered is not useful over a longer-term (Rooksby et al., 2014; Epstein et al., 2016a). Other research has found that users may stop tracking after a change in "life circumstance", such as when they change their preferred physical activity, or experience a significant life event (Epstein et al., 2015; Epstein et al., 2016a).

Use of personal informatics systems is often temporal and many factors can influence engagement over time. These factors are not just related to the barriers to tracking described in the previous section, but also contextual and other factors. For example, the situation of use has a large influence on how people interact with their devices (Patel and O'Kane, 2015), which may potentially influence people's use over time. However, little work has looked at, and compared, the broader context of use around personal informatics technologies, considering factors such as the physical environment and social norms. The temporal nature of use and engagement with self-tracking technologies is further discussed and characterised in models of personal informatics use, in section 2.4.

2.3.4 Sensemaking, wisdom and reflecting on tracked data

Making sense of personal health information involves interpretation of, and the creation of insights or wisdom from data (e.g. Faisal, Blandford and Potts, 2013). Correctly making sense of tracked data can be a challenging task for users and may impact the actionable changes they make as a result. For example, users may create incorrect interpretations of, and narratives around, the tracked data, which may then lead to them making unsustainable or negative behavioural changes. The challenges with making sense of tracked data can be particularly apparent when considering multivariate analysis, where users can experience difficulties considering multiple independent tracked data points, the potential relationships between these and the temporal aspects of this data. For example, comparing body mass and physical activity data may lead to incorrect interpretations if other factors (such as diet) are not also considered, and data recorded in the past can be more difficult to interpret (Tang and Kay, 2017). The communication or visualisation of this data also plays an important role in this process and may impact how users engage with, and interpret, their tracked data.

To make sense of data people often construct their own narratives around it, based on their existing preconceptions and belief models, or to support their preferred thinking structures. These may be based on fundamental misunderstandings in technology of physiology (e.g. Kay, Morris and Kientz, 2013), or from incorrect health belief models, which are famously not grounded in science but instead people's previous experience and community "folk stories" (Greenhalgh, Helman and Chowdhury, 1998). As such, users may incorrectly interpret tracked data, which could potentially result in them making negative behavioural changes. Another challenge when making sense of tracked data surrounds the lack of contextual data recorded alongside the tracked data, which, as highlighted by Choe et al. (2014) can be a particular challenge when reflecting on data at a later date, or when other people attempt to make sense of the tracked data.

Many self-trackers attempt to better understand themselves by creating a more holistic data picture of themselves, by tracking a larger number of personal metrics, over time (Li, Forlizzi and Dey, 2010). One might imagine that this would assist users in moving beyond the limitations of incorrect interpretations based on a narrow focus on a single tracked behaviour, resulting in a better understanding and well-grounded actionable insights. However, the challenges with making sense of data can be further exacerbated when considering multiple variables. Here one must carefully consider the relationships between different measures, how these may have causal relationships, and how they each change over time. Recent academic work with personal-informatics tool users has considered how one could positively leverage social sensemaking to share, contextualise and better understand one's own data (Puussaar, Clear and Wright, 2017), and other work has looked into bringing together these multi-faceted data sources and presenting them in a way that makes sense to users, through combined visualisations, or through machine-learning generated "insights" (e.g. Bentley et al. 2013; Jones and Kelly, 2018).

Reflecting and engaging with tracked data is an important part of making sense of it (Choe et al., 2017b). Fleck and Fitzpatrick (2010) present five levels of reflection, moving from a descriptive stage where no reflection is happening, through to "reflective", "dialogic", "transformative" and finally "critical" reflection. Of particular interest in this model to us, and others working in behaviour change (e.g. Slovak, Frauenberger and Fitzpatrick, 2017), are the transformative levels and above, where users may act upon insights gained from reflecting on the data, making changes to their lives. A deeper level of reflection on the part of users relates to a greater level of sense-making, transforming collected data into information, knowledge and wisdom, therefore encouraging users to think about tracked data as a broader influence on their behaviour.

2.4 Personal Informatics Models

Models are used to help understand and describe the use of a tool and within personal informatics two models have been widely discussed: Li et al.'s (2010) stage-based model of Personal Informatics Systems and Epstein et al.'s 2015 update of this, the Lived Informatics Model.

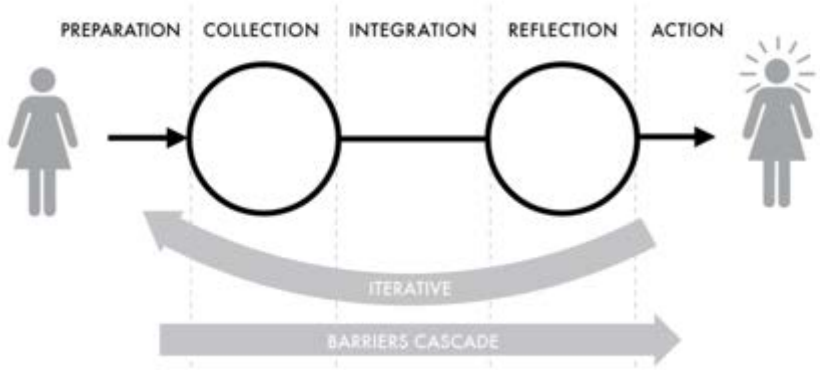

Figure 2.6 – A Stage-based model of Personal Informatics Systems (Li et al., 2010)

Li's model (Figure 2.6) was based on a study of early adopters of personal informatics tools and breaks down the stages of engagement and transformation that characterise these systems. When this model was published in 2010, there was still relatively little literature on the topic and thus it is heavily influenced by the transtheoretical model of behaviour change (see section 2.5.2 and Prochaska et al., 1998) to describes the stages gone through when tracking.

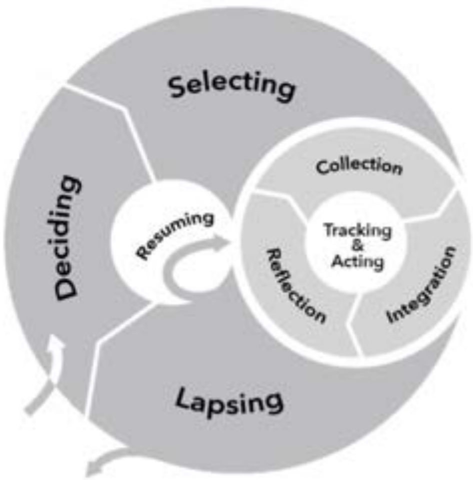

Figure 2.7 – The Lived Informatics Model of Personal Informatics (Epstein et al., 2015)

Over time our understanding of users' use and engagement with personal informatics systems has grown, particularly as we have moved beyond early adopters and expert users, who might experience fewer barriers than naive users (Rapp and Cena, 2014) and thus not represent the late majority of users who are now taking up use of these technologies (Rogers, 2003). Additionally, Li's model does not incorporate the nuances of everyday life and how these influence tracking behaviours.

Rooksby et al.'s (2014) understanding of the situated use of personal informatics systems helped inform Epstein's (2015) take on the stage-based model, the "lived informatics model". This model provides a more comprehensive understanding of how people track over time, using different systems and tracking different metrics. It also includes *lapsing* and *resuming,* two key temporal concepts outlined in the previous section. After lapsing users may resume tracking, or stop tracking and leave the model. Additionally, the model shows *collection*, *reflection* and *integration* behaviours happening cyclically during tracking, rather than in a linear fashion, showing how these processes do not happen in distinct stages, but during a process of use, reflection and action. However, the model does not present a nuanced view of the factors that impact the stages of engagement over time and it does little to consider the behavioural or other outcomes of tracking.

2.5 Behaviour change and habit formation

As we have shown in the prior sections, people take up use of different personal informatics technologies for a variety of reasons. However, one of the key motivations for use for many is self-improvement, or behaviour change. A considerable amount of research in HCI has focused on behaviour change related to health and wellbeing, particularly with personal informatics technologies to encourage healthy behaviours, such as with activity tracking. To comprehend people's use of these technologies for behavioural change it is useful to understand the psychological mechanisms that play a part in the behaviour change and habit formation processes. In the following sections we provide an overview of this research, particularly focusing on areas where this literature can help our understanding of how people can use and adopt ubiquitous computing technologies for encouraging behaviour change. The different ways in which the mind works provides insights into the mechanisms that can be used to change behaviour, through conscious changes and unconscious nudges. Further to the attempts made to change people's physical activity through education and public policy, a huge body of behaviour change research exists, and through theories and frameworks this work provides us with an understanding of the behaviour change process. Finally, taxonomies of behaviour change techniques (BCTs) provide us with a common grammar with which to discuss methods for encouraging change.

2.5.1 Dual process models of human behaviour

Personal informatics systems may target behaviour change at either a conscious or subconscious level, whereby a user either makes a conscious effort to change, or the technology subconsciously encourages them to do so. The concept of these two distinct thought processes, although not recent, has gained traction and attention within the behaviour change literature in the past two decades. Kahneman popularised the notion of two mind systems in his book *Thinking, Fast and Slow* (2011), where he defines the "System-1" way of thinking as fast, automatic and subconscious, and "System-2" as reflective, considered, slow and conscious. The majority of behaviour change interventions traditionally focus on the System-2 mind, relying on a person's conscious decision to change, for example with interventions such as joining a training programme, which requires a conscious effort. An intervention targeting subconscious (System-1) thoughts might instead use an external stimulus, such as the "twinkly lights" intervention (Rogers et al. 2010) which lead people to a stairway to encourage them to use the stairs instead of a lift.

In recent years, there has been an increased interest in behaviour change interventions that focus on System-1 (e.g. Marteau, 2018). These include small changes to the environment that "nudge" (Thaler and Sunstein, 2008) people into making particular decisions. However, despite this focus on nudging, it is important to realise that nudges (or "choice architecture" – see section 2.5.3) are not the only factors that work on the automatic system. Existing behaviours, or habits, are also an automatic behaviour and changing and overcoming these habitual behaviours can present a significant challenge. Additionally, priming effects, such as those seen in advertising can also have a large effect on peoples' automatic decision-making processes. As such, external, environmental and ambient factors such as the context of use, should also be considered when evaluating and designing behaviour change technologies.

2.5.2 Behaviour change theories, frameworks and taxonomies

Many different behaviour change theories exist, designed to characterise human behaviour or inform interventions. They can be useful tools when evaluating interventions as they can help us better understand people's intentions and behaviours. Many of these models have a strong focus on conscious system 2 processes. Models useful when considering physical activity interventions include, but are not limited to *The Transtheoretical Model of Behaviour Change* (TTM) (Prochaska, Johnson and Lee, 1998), *The Theory of Reasoned Action* (Ajzen and Fishbein, 1980), *The Theory of Planned Behaviour* (Ajzen, 1991), *Social Cognitive Theory* (Bandura, 2001) and *The Health Belief Model* (Janz and Becker, 1984). Buchan et al. (2012) conducted a review of current and emergent theoretical behaviour change practices in physical activity interventions and identified two main types: 1. Stage-based models, and 2. Social cognitive models. These models can be useful when analysing people's behaviour after using technologies to encourage behaviour change.

One of the most popular stage-based models used when designing and evaluating interventions for health and physical activity is *The Transtheoretical Model of Behaviour Change* (Prochaska, Johnson and Lee, 1998). This theory has a particular focus on the stages of change (Table 2.1), which are put forward as the series of processes one goes through when making a change to behaviour. These stages of change are frequently used when assessing an individual's willingness to change behaviour, or progress in a behaviour change intervention. Armitage (2009) suggested that other stage-based models, such as Gollwitzer (1993), are better alternatives because their stages are more appropriate for use in behaviour change interventions. However, other stage-based models are considerably less commonly used than the transtheoretical model when assessing human behaviour.

Stage	**Definition**
Precontemplation	Those who are not considering, or thinking about, changing their behaviour within the next six months.
Contemplation	Those who are intending to change their behaviour within the next six months, are aware of the benefits of changing, but also the costs.
Preparation	Those who are intending on changing their behaviour within the next month.
Action	Those who have made changes to their behaviour within the last six months and are possibly tempted to relapse.
Maintenance	Those who have made changes and are working to prevent relapse. This stage may last between 6 months and 5 years.
Termination	Those who have made a change to their behaviour and no temptation to relapse.

Table 2.1 – Stages of the Transtheoretical Model of Behaviour Change (Prochaska, Johnson and Lee, 1998)

The other broad approach identified by Buchan et al. (2012) includes social cognitive models, such as *The Theory of Planned Behaviour* (Ajzen, 1991) and *Social Cognitive Theory* (Bandura, 2001). The theory of planned behaviour focuses entirely upon the system 2 mind, assuming that an individual's cognitive beliefs, self-efficacy and intention determine their behaviour. Whereas these other theories instead focus more on the influence that context of use has on understanding human behaviour. Ultimately, an approach considering both stage-based and social models makes sense when evaluating human behaviour in situ, as they both influence behaviour.

Although well respected, and responsible for our greater understanding of human behaviour, behaviour change theories have been subject to some criticism (e.g. Buchan et al., 2012). Behaviour change is more complex than these models account for, being moderated by myriad external factors such as situation, context and personal circumstances, which can have a huge influence on a person's behaviour and likelihood to change. Additionally, these models tend to focus on System-2 thinking, relying upon peoples' conscious decision to change and largely ignoring System-1 constructs, such as social norms and nudges, as well as the effect of existing habits.

2.5.2.1 Behaviour change Frameworks

Behaviour change frameworks are generally based on systematic reviews of behaviour change theories, interventions and models. They are therefore more comprehensive and can more easily be applied to new interventions. Two popular frameworks useful when considering technologies for encouraging physical activity are *MINDSPACE* (Dolan et al., 2010) and the Behaviour Change Wheel (Michie, van Stralen, and West, 2011).

The MINDSPACE (see Table 2.2) framework was published as a report for the British Cabinet Office by the *Institute of Government.* It is designed to better educate government policymakers about behaviour change, and aid in the creation of public policy. The framework builds upon work on dual process models of human behaviour, defining them as the "cognitive" and "automatic or context" models (Dolan et al., 2010). The authors propose that most existing interventions and policies target the cognitive, system 2, whereas those that focus on the automatic, system 1, mind may be more useful for public policy. However, they admit that it is not clear how well system 1 strategies "last" and that there is *"relatively little practical evidence about how the effects might habituate over time"* (Dolan et al., 2012. p.274).

Cue	Behaviour
Messenger	We are heavily influenced by who communicates information to us.
Incentives	Our responses to incentives are shaped by predictable mental shortcuts such as strongly avoiding losses.
Norms	We are strongly influenced by what others do.
Defaults	We "go with the flow" of pre-set options.
Salience	Out attention is drawn to what is novel and seems relevant to us.
Priming	Our acts are often influenced by sub-conscious cues.
Affect	Our emotional associations can powerfully shape our actions.
Commitments	We seek to be consistent with our public promises and reciprocate acts.
Ego	We act in ways that make us feel better about ourselves.

Table 2.2 – The MINDSPACE Framework Cues (Dolan et al., 2010)

Although the authors deliberately focus on cues that may be easily leveraged in public policy behaviour change interventions that work largely on the system 1 mind, the influences and techniques represent a review of the behaviour change literature at large and thus, has further reaching uses and implications.

Michie, Stralen and West (2011) criticise MINDSPACE's strong focus on the automatic system, stating that behaviour change frameworks should be comprehensive and *"apply to every intervention that has been or could be developed"* (p.3) and propose the COM-B system as an alternative. COM-B, a framework for understanding human behaviour, is based on an evaluation of 19 existing behaviour change frameworks and theories. The name comes from its four components: Capability, Opportunity, Motivation and Behaviour (Figure 2.8), and recognises the interactions between: psychological and physical capability; opportunities in the physical and social environment; and, reflective and automatic motivation. Thus, it moves beyond many of the limitations we have pointed out in traditional behaviour change theories.

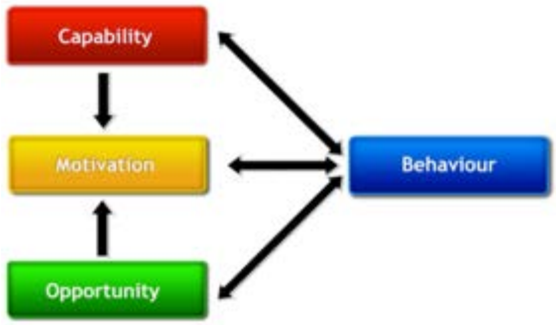

Figure 2.8 – The COM-B System (Michie, Stralen and West, 2011)

Further to the TTM, the COM-B system forefronts the issues of opportunity and capability, both aspects that we have already highlighted as important factors for physical activity behaviour change. However, the system does not include a person's emotion or *perceived* opportunities, which can also have an effect on a person's behaviour, due to aspects such as social norms, lack of resources, or even more salient options.

Building on the foundations set by the COM-B system, Michie et al., also created the behaviour change wheel (Figure 2.9), an infographic which includes nine intervention "functions", seven policies, extending the three requirements from the COM-B system.

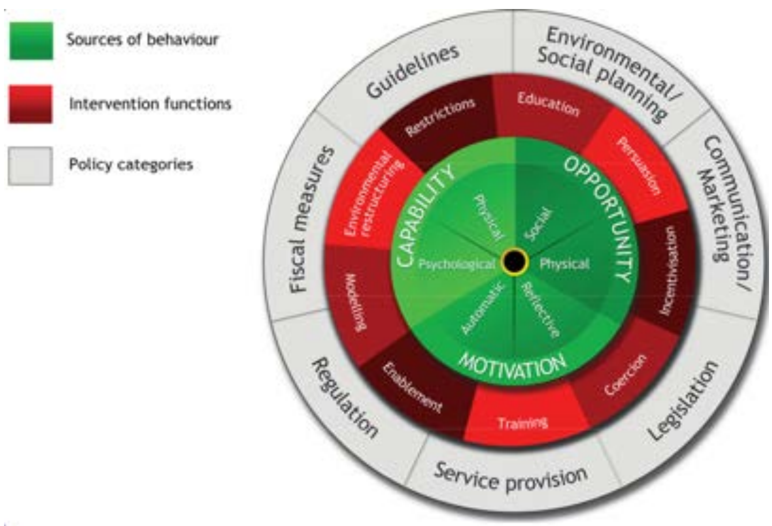

Figure 2.9 – The Behaviour Change Wheel (Michie, Stralen and West, 2011)

The behaviour change wheel forefronts the issues of situated use and behaviour change techniques, which are critical to our understanding when designing or evaluating behaviour change interventions. The seven policy categories around the outside ring (Figure 2.9 and Table 2.3) characterise external factors which may moderate effectiveness and design of an intervention, and the nine "intervention functions" in the middle ring describe, at a high-level, the behaviour change techniques which may be embodied in interventions.

Intervention	**Definition**
Education	Increasing knowledge or understanding.
Persuasion	Using communication to induce positive or negative feelings or stimulate action.
Incentivisation	Creating expectation of reward.
Coercion	Creating expectation of punishment or cost.
Training	Imparting skills.
Restriction	Using rules to reduce the opportunity to engage in the target behaviour (or to increase the target behaviour by reducing the opportunity to engage in competing behaviours).
Environmental Restructuring	Changing the physical or social context.
Modelling	Providing an example for people to aspire to or imitate.
Enablement	Increasing means or reducing barriers to increase capability, beyond education or training, or opportunity, beyond environmental restructuring.

Table 2.3 – Definitions of interventions (Michie, Stralen and West, 2011)

2.5.2.2 Taxonomies of behaviour change techniques

One limitation of the behaviour change wheel is that it does not provide a common language or definition for specific behaviour change techniques (BCTs), which could potentially cause issues when analysing interventions and comparing different systems or interventions. To combat this issue, Abraham and Michie (2008) created a taxonomy of 26 different BCTs: a starting point towards a comprehensive taxonomy of techniques to serve as a common definition and language for comparing and documenting interventions. Based on a large-scale multidisciplinary review, the updated and extended *Behaviour Change Technique (BCT) Taxonomy V1* was then published in 2013 (Michie et al, 2013). This new taxonomy, which will need to be further developed over time, identified *93* behaviour change techniques in 16 groups.

The BCT Taxonomy V1 is useful when comparing the BCT's embodied in different commercially available activity tracking systems and we have used this in the thesis to help us analyse data to aid our understanding of how our participants used and interacted with different behaviour change techniques in the real world. Commercial activity tracking systems use different behaviour change techniques (BCTs) to encourage users to take more exercise, including techniques such as goal-setting (Consolvo et al., 2006; Gasser et al., 2006), social influence (Consolvo et al., 2006; Lane et al., 2011), abstract displays of recorded data (Consolvo et al., 2008a; Consolvo et al., 2008b) and gamification (Lin et al., 2006; MacVean and Robertson, 2012), all of which have been evaluated in academic studies.

2.5.3 Nudging and Choice Architecture

There is a growing body of "choice architecture" (Thaler and Sunstein, 2008) research, showing the benefits and successes of behaviour change interventions that focus on nudging users to change through a variety of mechanisms. These interventions and nudges focus on System-1 thinking (see section 2.5.1), often achieved by changing situational factors in the environment to encourage better choices and may be embodied within activity tracking technologies, to change behaviour without a persons' conscious thought.

These techniques have been used to great effect in various ways, such as increasing pension saving by leveraging social norms (Halpern, 2016), making small environmental changes such as changing the size of a wine glass to decrease alcohol consumption (Pechey et al., 2016), or changing tableware to help with portion control (Hollands et al., 2015). However, these techniques can also be used to a negative effect: positioning of chocolates and sweets near checkouts in shops and supermarkets increases customers' likelihood of purchasing them, but replacing them with fruit can reverse peoples' buying patterns (Just and Wansink, 2009).

Much of this research suggests that changing context and environment, rather than following a path of self-encouraged behaviour change, is more successful, and some researchers (e.g. Marteau, 2018) have even suggested that sustained behaviour change at a society level is not possible without making environmental changes to encourage these changes in behaviour. However, changes required to nudge people to be more active are unclear, complex, and highly individual, particularly considering the wide range of influences on people's health and wellness. Ultimately, interventions that focus on both the System-1 and 2 minds may be most successful in creating new, healthy, habits.

2.5.4 Habits and Habit Formation

An important consideration when encouraging behavioural change is the sustainability of a new behaviour, ensuring that changes become habitual and are not only a short-term effect. As we further discuss later in section 3.1.1, much of the behaviour change work in HCI is conducted over a short-period and thus any changes observed may only be the result of novelty effects. Habits can be thought of as System-1 processes, being automatic and unconscious and requiring little thought (Kahneman, 2003). Pre-existing habits are an important part of our unconscious decision making and can often result in people following an existing pattern of behaviour despite having a desire to change. For example, when faced with a lunch choice one might choose a usual, unhealthy option, rather than a healthier alternative. Understanding and leveraging the formation of habits is key to promoting sustained changes in behaviour.

There is a close relationship between behaviour change and habit formation: a large body of behaviour change work focuses on either changing existing habits or producing new ones and behaviour change interventions should support the creation of new habits. This can be challenging, especially with complex and poorly defined behaviours such as "do more physical activity". This is partially because of the high amount of effort involved in the behaviour (most existing interventions for physical activity have high relapse rates (Buchan et al. 2012)), and partially because of the lack of an easily imagined and measured goal. A more suitable goal might be "walk to work every day". Another problem relates to a person's reliance on a behaviour change technology for "scaffolding" their new behaviours (Renfree et al., 2016). This means removal of the technology could result in participants reverting to their previous behaviours.

Habit formation is a complex process of which repetition is an important part, but and it is unclear how much repetition is required. A popular study by Lally et al. (2010) found that, on average, a new activity became habitual after 66 days. In their study of 96 participants forming new eating, drinking or activity habits, the time taken for new activities to become habitual varied between 18 and 254 days, demonstrating that complex habits take longer to form than simple ones. Much of the research in habit formation focuses on simple, measurable tasks where the context and cue are stable, which is often not the case when considering physical activity: complex habits such as being more active can take longer to become habitual, and may never become automatic (Verplanken, 2006). Similarly, in smoking cessation studies have found that after an entire year without smoking there is still a 43% chance of relapse, and after 5 years without a cigarette there is still a 7% chance of relapse (US Department of Health and Human Services, 1990). Furthermore, myriad situational "System-1" factors such as the weather, traffic and working or social demands also add additional complexity. A useful approach when considering behaviour change and habit formation is to create an individualised, achievable and simple goal: i.e. a goal of "run 5 miles each day" is more likely to be achieved than “be more active” (Locke and Latham, 2002). As such, a simple step-goal as embodied in many commercial activity trackers may represent an easier way to habitually become more active.

2.6 Summary

Throughout this review of the literature we have set the scene for our work on the self-tracker’s journey. Along the way we have identified missing pieces in our current understanding of how and why people engage with activity tracking systems in the real world over time, and the behavioural outcomes which may result.

We first motivated the importance of physical activity, presenting the problems and causes of inactivity and physical activity guidelines from various health bodies. We then described the activity tracking offerings and noted an incongruity between activity guidelines and the focus of the tracking systems: guidelines always include some amount of resistance-training, whereas activity tracking systems instead focus only on encouraging steps (usually 10,000). Following this, we focused on personal informatics technologies and their use in the real world. Traditionally, short-term use and abandonment of self-tracking technologies has been characterised as a failure, but more recently researchers have begun to take a more nuanced approach in understanding people’s temporal use of these tracking systems over time. Considerations such as why people start tracking, their goals and changes, their engagement over time and the barriers to continued use they face, all have an impact on the temporality of use, but research has done little to bring these facets together when considering temporal use, again something that we will better understand in this thesis.

Finally, we reviewed the behaviour change and habit literature. Personal informatics technologies are used for a variety of reasons, but behavioural change is a key motivation for many. Accordingly, we reviewed the relevant behaviour change literature, focusing on dual process models of human behaviour and the relationship of two cognitive systems to behaviour change interventions. Recent work suggests that factors working on subconscious System-1 processes, such as the environment, nudges and existing habits, have a greater influence on our behaviour than our conscious (System-2) intentions. Personal informatics systems may work on both decision-making systems, but most embedded BCTs focus on System-2. Considering the impact of System-1, we can expect that the context of use of these systems will have a significant influence on their use and any behavioural outcomes. However, little work has taken personal circumstances into account when evaluating personal tracking technologies, or considered their use in different contexts. These are things we will focus on in our own studies.

Concluding, the work presented in this chapter provides a good understanding of how people use and engage with activity trackers, but throughout the chapter we have identified existing limitations and gaps which we will address in our own work. Ultimately, a more in-depth understanding of human behaviours around activity tracking, particularly in context and over time is required: what we have characterised as "the self-tracker's journey". In the next chapter we relate our research questions and objectives to the limitations presented in this chapter, along with presentation of the approach that we have taken.

Chapter 3. Thesis Approach and Method

This chapter sets out our approach and methods used to study "The Self-Tracker's Journey", how people use activity tracking systems in the real-world and over time. We took a broad approach, collecting qualitative data over time and in different situations to create a rich picture of how healthy adults use tracking systems and fit them into their everyday lives. Part of the work presented in this chapter informed Harrison et al. (2013, 2014).

Motivated by the real-world problem of physical inactivity and the limitations identified in the previous chapter this thesis investigates the following research question:

RQ: How, and to what extent, do healthy adults use and experience activity trackers over time and in different situations?

To answer this question, the following **research objectives** have been set, which we address through each findings chapter:

RO1: Update the current understanding of how healthy adults initially engage with activity trackers (Chapter 4)

RO2: Explore how healthy adults use, and not use, trackers over time and the factors that impact this (Chapter 5)

RO3: Categorise how healthy adults change their behaviour or attitudes, as a result of using these tracking technologies (Chapter 6)

Our work is situated within the HCI literature and therefore takes an approach appropriate to this field, eschewing purely quantitative methods and Randomised Control Trials (RCTs) to measure efficacy which are familiar within fields such as health psychology, and instead focusing on the users' experience of using activity tracking systems over time in the real word. Taking a broader qualitative approach allows us to create a rich picture not only of our participants' use and engagement with their tracking systems over time, but also to understand how these technologies fit within users' within everyday lives and the multitude of different effects and outcomes this can bring. When beginning data collection for this PhD in 2013 existing research on personal informatics and activity tracking systems was considerably more limited than the current state of the art presented in the literature review section, and questions about the most appropriate methods for studying these systems were still being asked and longer-term qualitative studies had not been carried out.

This chapter first outlines potential ways of studying these technologies, motivating the need for our situated and in the wild, longitudinal, contextual, and holistic approach. We then present specific details about the two large user-studies we ran: specific methods, the materials used, and participants involved, and data analysis in the mixed method user studies.

3.1 Approach

Many different approaches have, and could, be used to explore how self-tracking systems are used in the real world. Given the nuances we have presented in the literature review about users' motivations, barriers, and temporalities of tracking, one can see that the task of studying self-tracking systems in general, but in particular those related to behaviour change, is not trivial.

Many studies of behaviour change technologies simply focus on evaluating the effectiveness of these technologies in encouraging the desired changes in behaviour. However, studying efficacy or effectiveness of the targeted behaviour alone may result in an incomplete picture of people may find these systems useful, particularly with new technologies where the real-world use is little understood. Instead, taking a more explorative, "in the wild" approach to uncover anticipated uses in the real world may be more suitable (Rogers and Marshall, 2017). Indeed, Schwanda et al. (2011) advocate taking a broader approach when evaluating behaviour change systems: taking this approach in their study of the Wii Fit, they found that use of the technology led to further changes in behaviour, leading them to characterise the Wii Fit as a "gateway fitness tool" (p.345).

Klasnja et al. (2011) discuss the difficulties with evaluating technologies for health behaviour change, arguing that large scale studies with control groups *are* necessary for demonstrating behaviour change in mature technologies, but are not practical for novel systems. They also emphasise the importance of understanding *why* a behaviour change technology works and that randomised control trials may not be the most valuable method to use. A more recent paper (Hekler et al., 2016) recommends applying the principles of agile programming to research, and suggests that findings should be published and discussed in the community as the research progresses, something which can be tricky to apply in the academic setting and in the fast-paced nature of HCI and personal informatics.

Explorative research is invaluable when first investigating adoption and use of new technologies and helps to uncover new issues, but early adopters often use technologies very differently to the late majority (Rogers, 2003). Conducting research on more mature technologies that have been adopted by a late majority, as could be considered towards the end of our data collection period, can reduce the burden of evaluating new technologies and lead to more transferable results. However, personal informatics systems are constantly changing and progressing, adding an additional layer of complexity and the need to keep research up to date with these advancements and changes in interactions. Short-term studies of behaviour change technologies can be problematic, particularly when considering novelty effects. It is also important to understand behaviours beyond the intervention: especially as physical activity behaviours may be so resistant to change. However, longitudinal studies are costly, take time, and publishing may result in less timely findings (Coleman, 2016).

This section provides considerations and an overview of the research approaches that have been taken within personal informatics studies and motivates the approach that we have taken during our work. We first dive into the issues associated with shorter-term studies of behaviour change systems, before we take a closer look at the approaches taken by our colleagues when evaluating personal informatics and activity tracking technologies: studies with devices, often prototypes, supplied by the researchers themselves; studies with existing users; studies of use over time; and finally looking at the so far limited work that has taken context of use into account.

3.1.1 Novelty and reactivity effects

It is important to consider initial effects, such as novelty effects, when evaluating any new technology, but especially when technologies are related to behaviour change as any changes observed could potentially be attributed to novelty and may not last over a longer time-period. The length of these effects varies, based on the system used and the demands the change might have on one's behaviour. For example, the novelty of playing a new computer game might last longer than using a behaviour change system, because of the required change in behaviour and the efforts involved.

Many existing behaviour change studies in HCI have been conducted over relatively short time periods and may not reach past these initial effects: in 2012 Brynjarsdottir et al. reviewed 36 HCI papers related to sustainability and behaviour change and found *"little evidence for long-term behavioural change"* and that *"the typical duration of a field study is 3-4 weeks, which is likely not long enough to go beyond novelty effects"* (pp. 949). Relevant to understanding novelty effects in personal informatics systems, and in particular activity tracking systems, are the "reactivity" effects that have been observed when people first use a pedometer (e.g. Clemes and Parker, 2009). One study (Clemes and Deans, 2012) suggests that these reactivity effects lasted just one week, supporting the idea that these initial effects are shorter than with other behaviour change technologies. The researchers in this study covertly monitored their participants steps to record a baseline of activity (telling them that the device was measuring their posture), and then revealed the recorded data to participants after two weeks. The number of steps participants took in the first week after the baseline was significantly higher than the baseline, after which the increase lessened. However, the novelty effect when using an activity tracker is likely to be longer because of the various BCTs and other features embodied in these tracking technologies, compared to simple pedometers.

3.1.2 Studies with researcher-supplied trackers

Perhaps the most obvious way to study use of tracking technologies in the real world over time, is to provide participants with a technology and observe them using it. Many of the initial studies of activity trackers, in what Ayobi et al. (2016) identified as the psychologically-informed stream, supplied participants with devices - often prototypes - and studied how these were used in the real world but over relatively short-term periods. When starting this thesis, commercial devices such as the Fitbit were rarely used in academic research, and to our knowledge no studies had provided participants with commercial activity trackers for the purpose of study. However, numerous studies have since provided participants with trackers and studied their use, and as discussed in the literature (Sullivan and Lachman, 2016) commercially-available activity tracking systems have also been used as part of interventions in academic studies, replacing costlier and less user-friendly "research" alternatives such as the Actigraph devices[14] (e.g. Cadmus-Bertram et al., 2015).

Many of the commercially available activity trackers provide means to allow researchers to collect aggregated data which can be used for assessment of the use of these technologies, as well as in interventions. However, the activity recognition algorithms used in commercial systems are a "black box": they are not documented, and researchers are not able to access the raw sensor data. Additionally, because these devices are subject to software and firmware updates that are out of the control of researchers, the accuracy and methods of tracking may change over time, making comparisons impractical.

Using consumer-focused systems does offer various benefits over developing one's own hardware or software systems for tracking, by reducing costs and resulting in systems which may more easily be adopted and used in the real world. However, there are problems with this approach: these systems are out of the control of the research team, updates may change features; and, services may even be

[14] https://actigraphcorp.com/

withdrawn entirely. These occurrences are perhaps typical of real-world use, but by providing participants with a technology the researchers are also unwittingly becoming part of the intervention if they have supplied the device, similar to how other behavioural change interventions tend to be more successful when a person is involved, compared to a wholly-digital system, even when the human has only a small role (e.g. Tate, Jackvony and Wing, 2006) and participants may have otherwise not taken up tracking. Furthermore, systems provided by researchers may not necessarily be used in the same way as those purchased by consumers: participants may act differently when they know they are being observed as part of a study.

3.1.3 Research with existing users

Another typical approach when looking at use and adoption of a novel technology is to recruit and study existing-users of said technologies. Because these technologies were only widely available in the UK the year before work on this thesis started in 2012, the initial users of these systems could be considered early adopters (Rogers, 2003) and therefore may not represent typical use of these systems as they become more mainstream.

Qualitative studies exploring the real-world use and adoption of consumer activity trackers began to appear soon after their commercial availability (e.g. Rooksby et al., 2014), often recruiting participants who had purchased trackers. This period marks the start of the phenomenologically-grounded research stream (Ayobi et al., 2016). Much of this explorative work focuses on the ways in which people engage with activity trackers in the wild, often using qualitative methods such as interviews to gain insights into their practices. Findings may be more akin to real-world use compared to those using researcher-supplied devices, but conducting single-point-in-time, or “snapshot”, interviews with participants is limiting as it relies upon self-reporting interactions, potentially some time after they happened (e.g. Epstein et al., 2015). This can potentially result in poor recall which may introduce a bias (Schmier and Halpern, 2004), and the nuanced ways in which people interact with systems over time may be lost. This is common with any self-reported data. Because of this, researchers are less able to build a detailed picture of how the ways in which people interact with these devices change over time. Additionally, as much of this research is conducted with early adopters, who may be expert users, these results may not be generalizable to a broader population.

A criticism of the explorative work in personal informatics relates to the lack of quantification and clear presentation of how common different styles and responses to tracking might be, which can useful when designing interventions (Kersten-Van Dijk et al., 2017). However, as argued in the previous section this is not necessarily the role of early, explorative work, which can instead focus on creating a *rich picture* of the use and lived experience of these systems.

3.1.4 Longitudinal and repeated measures studies

Instead of focusing on a single moment in time, longitudinal studies look at use and engagement over time. These repeated-measures studies may be conducted through multiple interviews, surveys, or automatically collected data. Longitudinal studies can help researchers better understand behavioural effects over time, and can provide insights for a better understanding of the temporal aspects of engagement with the systems. Because of the risk of relapse and lack of adherence to interventions encouraging physical activity, Marcus et al. (2000) recommend that studies in this area should have at least 24 months of follow-up: which is considerably longer than current studies in HCI.

Traditionally longer, controlled, studies such as Randomised Control Trials (RCTs) have be considered the best way to evaluate the efficacy of behaviour change interventions. These studies may provide a greater understanding of the efficacy of a behaviour change intervention as they move beyond novelty effects and utilize control groups. Several trials have been completed using activity tracking systems (e.g. Cadmus-Bertram et al., 2015, Poirier et al., 2016) but, RCTs are expensive and time consuming, and might not be best suited to the fast-paced nature of work in personal informatics. This is especially true considering the long publication timings, meaning that findings may be "out of date" by the time they are published.

Considering the relatively young age of this field, and the fact that we do not yet have a complete understanding of how people use and integrate activity trackers into their lives, we argue that it is important to take a rich, qualitative, and explorative, approach. Use of mixed methods is important, and including qualitative aspects allows researchers to not only understand whether a tool *is* successful, but *why* it is successful. Although we have argued that long-term evaluations and RCTs might not currently be the best approach for researching personal informatics, longitudinal work is important, and it is important for us to understand the lived experience of tracking over time. Furthermore, with regard to behaviour change, to assess if any changes made are lasting, or are only the result of a novelty effect (Brynjarsdottir et al., 2012). Moreover, much of the existing work relies on retrospective self-reported data, primarily using surveys and interviews with users, without making use of logged data to create a more complete understanding. Overall, it is crucial to take a humanistic and more holistic approach, focusing on the lived experience of these technologies and considering all the various factors involved including the broader context of use, including use and adoption.

3.1.5 Studies in different situations and contexts

As we showed in section 2.1 of the literature review, situational factors such as the built environment and societal attitudes towards different activities can have a strong bearing on the physical activity that people do. Similarly, one could imagine that, because tracking physical activity is so closely related to physical activity itself, the context of use of activity tracking technologies would similarly have a large effect on how people use them, and outcomes from use. However, the majority of published work into activity tracker use has taken place in North America and Europe, and very little work has directly compared use of these systems in different settings. To the best of our knowledge, only one other study has compared the use of activity trackers across locations – Bentley et al. (2013) tested their health mashups prototype with users in two cities (Chicago and Atlanta), but results from these different study locations were not directly compared. Whereas Bentley et al.'s focus was on evaluation of the prototype, we are instead interested in creating a better understanding of the influence that context may have on how users interact with their trackers.

3.2 Study Methods

To explore our overall research question, **"How, and to what extent, do healthy adults use and experience activity trackers over time and in different situations?"**, and motivated by limitations in the methods and approaches highlighted in the previous sections, we conducted two large-scale mixed-method studies focusing on how people use and engage with activity trackers over time and in different contexts. Our first study was a longitudinal mixed-method study of 50 new activity tracker users in London, with a post-study follow-up interview. Subsequently, in our second study we broadened our understanding by considering people using different tracking technologies in different situations, including 48 previous and existing activity tracker users located in London, UK and Atlanta, US.

Our two studies were conducted independently and as such we had initially intended to also analyse and present the results independently. However, when individually analysing the two datasets it was apparent that there were similar themes throughout both studies and that by combining both data sets for analysis that we could conduct a richer, more in-depth, thorough, holistic, and overall better analysis and presentation of the results by considering them together. As a result, the findings from these studies are presented together, as thematic chapters documenting the hypothetical "self-trackers journey" from chapters 4 through 6. The details of the two studies, their research aims, the participants involved, and the overall analysis are described in the sections below.

3.2.1 Study 1. Longitudinal study and follow-up

We undertook our first study to explore and better understand how people use self-tracking technologies in the real world, investigating: the temporalities of tracking; the ways in which people integrate tracking technologies into their lives; how self-trackers interact with, and act upon, the data they collect; and, the challenges they face along the way.

The study was divided into two parts: the main part of the study, which lasted for the first 28-weeks of their self-tracking journey; and, a follow-up interview which took place 52-73 weeks after participants first received their tracker. Data points included regular interviews, diaries, logged step-data and a standardised survey allowing us to gain rich insights onto the many factors that determine users' engagement and attitude towards activity tracking, which helped guide our second study and built the basis of the *self-tracker's journey* as presented throughout this thesis.

Our work took a primarily qualitative approach, starting in May 2013 and running until November 2014. For 28-weeks we logged participant data (their steps and calories burnt), asked them to complete a daily-diary entry, and interviewed them regularly: for the first 16-weeks they were interviewed every 4-weeks (depending on their availability), and were then interviewed again after a further 12-weeks (28-weeks from the start of the study). Finally, after this main part (first 28-weeks) of the study, we then invited participants to take part in a further follow-up interview, between 52-73 weeks after they first received their tracker, to better understand their continued use and move beyond behavioural study effects (30 participants took part in the follow-up) (visualised in Figure 3.1).

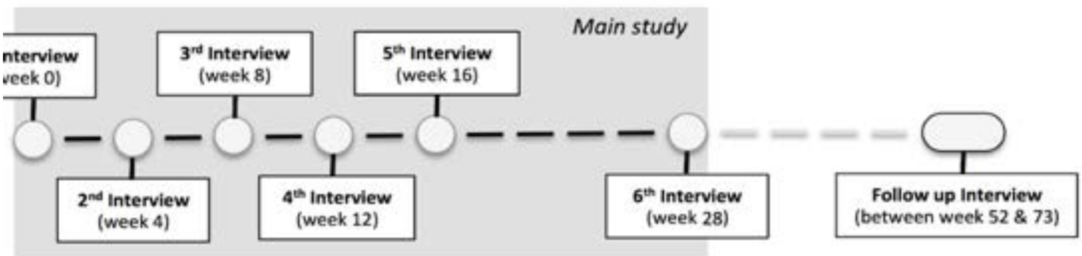

Figure 3.1 – Longitudinal study progress chart

In total we conducted approximately 180 interviews with our 50 participants, who completed a daily diary for the first 28-weeks (which was mostly used as an aide-memoir in interviews) and completed a standardised survey at four key points of the study. Where possible, we also kept a record of the steps measured by participants' activity trackers. From this rich dataset we were able to not only build up a narrative about each participant's use of the activity tracker and other personal informatics tools over time, but also understand their behavioural responses, how these changed, and other factors (external and related to the tracker) which may have affected their engagement and physical activity.

3.2.1.1 Participants

In total, 50 participants (17 men, 33 women) took part in the study. The majority were younger adults, with age distribution ranging as follows: 18-25 years old (n=14), 26-35 years old (n=26), 36-45 years old (n=8), 46-55 years old (n=1), and over 66 (n=1). Most (n=37) were employed full-time, with occupations including software engineer, journalist, and lecturer, our sample also included postgraduate students, two full-time parents and one retiree. Participants also had differing initial levels of physical activity before starting the study. This ranged from those who were training for marathons or half-marathons (some of which were completed during the study) to those who would rarely walk further than the closest bus stop. Forty-seven participants lived in London and the remaining three commuted to London from elsewhere to work or study.

3.2.1.1.1 Recruitment

Participants were recruited through an online survey (see Appendix A), which was publicised through social media, word-of-mouth and on printed flyers distributed around central London (see Figure 3.2). Recruitment started in April 2013 and ran until we had recruited and onboarded a sufficient number of suitable participants. Potential participants were given study information and a list of requirements before they could sign up:

1. **Use a mobile device capable of mobile synchronisation with the Fitbit, to allow full use of the Fitbit system.** At time of recruitment this included the Samsung Galaxy S3 and Note 2, and the Apple iPhone 4S and 5.
2. **Work, study or live in central London, and intend to continue doing so for at least the next 28 weeks.** This requirement was important for three reasons: Firstly, people living in densely populated urban areas such as London have greater access to a variety of transport options. Moreover, shorter journeys in urban environments such as London mean that self-propelled options are more practical than for those living in rural environments (Transport for London, 2012). Secondly, having participants in the same geographical location removes other potential confounding factors, such as environmental changes in weather or external events that may influence activity. Finally, this made meeting with participants for regular interviews feasible, allowed us to ensure that tracked data was synchronised and provided us with an opportunity to more easily use their diary as an aide-memoir in the interviews.

3. **Not already use an activity tracking device or system such as the *Nike Fuelband* or *Jawbone UP*.** So that all participants would begin the study with a similar level of previous knowledge and expectations, having not used these technologies before.
4. **Be aged 18 or over and have no health reasons preventing their participation in a study about physical activity.** Additionally, participants were also advised that they should consult their doctor before increasing their levels of physical activity, in line with our institutional ethical approval, which was granted for this study.

Figure 3.2 – Study Recruitment Flyer

Participation in the study was incentivised in two ways: firstly, participants were informed that they could keep the Fitbit if they completed the study; and secondly, those who completed the study were added into a prize draw to win one of five Amazon UK gift vouchers with a total value of £200 (1x £100 and 4x £25). Participants were told that they were free to leave the study at any time, but if they chose to do so they would be required to return the device given to them.

Of the 89 potential participants who signed up for this study, 50 were chosen to take part. Participants were interested in taking part in the research for multiple reasons, ranging "wanting to help out with research" to interests that were more directly related to the technology such as having general curiosity about it, to wanting to change their behaviour (see section 4.1 for a more complete analysis of all of our participants' motivations for tracking) No particular subset of applicants was chosen, but to allow participants to more easily use the social functionality offered by the Fitbit system and thus understand its effects and benefits, we made an effort to recruit some participants who knew each other. This occurred naturally because of the snowball-sampling method used, and resulted in approximately half (n=27) of our participants knowing someone else taking part in the study. This social use resembles how many consumers use the device in the wild, comparing their steps with those of peers using similar devices (Maitland and Chalmers, 2011, Rooksby et al., 2014).

3.2.1.2 Materials

Participants were provided with a "study pack" during their first interview, which consisted of a printed study workbook/ diary and Fitbit Zip activity tracker. The printed A5 study workbook (Figure 3.3 and Appendix A) included a 28-week, week-per-spread diary for participants to annotate throughout their time in the study. In addition to these diary-spread pages, the workbook also included a second copy of the information sheet, some short instructions about the study, and contact details so that the participants could get in touch with us. Participants were encouraged to fill these pages out on a daily basis and bring them along to interviews with us.

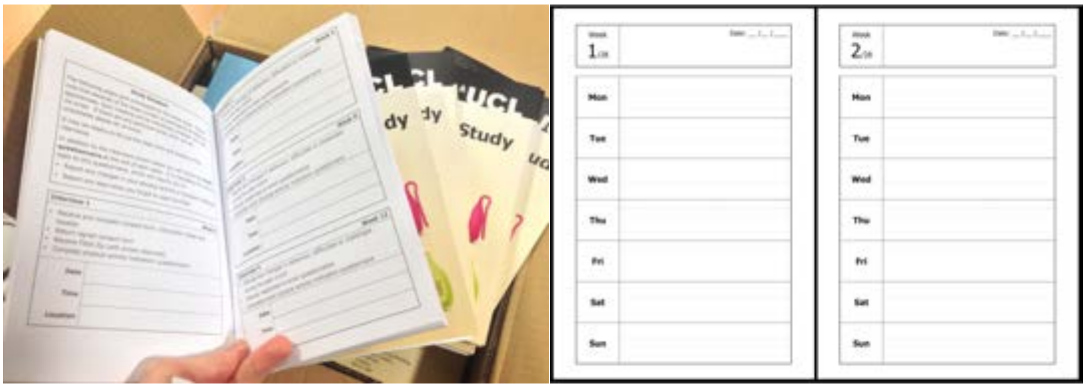

Figure 3.3 – Study Workbook

Participants were also given a Fitbit Zip activity tracker (Figure 3.4) which uses a 3-axis accelerometer to detect movement and record the number of steps taken and has a form factor that allows it to be clipped to clothing. The device includes: a screen displaying: step-count; "Fitbit Smiley", a smiley face display of recent activity; distance walked; calories burnt; and the time.

Figure 3.4 – Fitbit Zip and example screen displays

The device also includes wireless connectivity to allow data to synchronise with the Fitbit servers, when used with a computer and the included Bluetooth 4 USB dongle, or with a compatible smartphone. A website and smartphone application (Figure 3.5) are also available, which offer social functionality including a leader board, messaging, daily and "lifetime" badges, and a historical view of steps taken. Participants had access to this functionality after the baseline period (see section 3.2.1.3.1).

Figure 3.5 – Example Fitbit website (left) and iOS application (right) screens

Together, the device, its website, and the application offer a variety of BCTs to encourage increased steps. After reviewing the functionality against Michie et al.'s (2013) Behaviour Change Taxonomy V1, the following seven BCTs were found to be embodied in the system: goal setting (behaviour); goal setting (outcome); monitoring of behaviour by others; feedback on behaviour; self-monitoring of behaviour; social support; prompts/ cues; and rewards in the form of virtual badges.

The Fitbit Zip was chosen for the following reasons:

1. It is reasonably low cost (£49.99 retail in May 2013 when they were purchased), allowing us to purchase multiple devices to have a sample size larger than most previous studies.
2. It is able to store 30 days of step data without synchronisation, simplifying the process of recording a baseline.
3. It is advertised as having a long battery life (4-6 months), so the battery was unlikely to run out during the baseline period.
4. It has wireless connectivity, making synchronisation straightforward.
5. The form factor is unobtrusive and is "one-size-fits all", preventing the need for purchasing different sizing options.
6. The screen could be obscured easily, allowing us to hide step data from the participants whilst conducting baseline measurements (see section 3.2.1.3.1).
7. Step data can be retrieved from the Fitbit servers, using their API, allowing an objective record to be retrieved of participants' data throughout the project.

8. At the time of selection (January, 2013), the Fitbit Zip was well-reviewed with an average score of 4.5/ 5 stars from 276 reviews on amazon.com.

3.2.1.3 Procedure

The study was divided into two parts: the main part of the study (first 28-weeks), which involved completion of a daily diary, multiple interviews (6 per participant), regular completion of a standardised survey and logging of participant's step data; and, the follow-up interview, which took place 52-73 weeks after participants first received their tracker and was designed to allow us to better understand the longer-term effects the study and tracking (see Figure 3.1).

3.2.1.3.1 Main study procedure

What we have characterised as the main part of the longitudinal study encompasses the first 28-weeks of each participant's contact with us and includes: completion of a daily diary, for participants to record related interactions and act as an aide memoir; multiple interviews (6 per participant) to gain insight on use, non-use and changes in their behaviour over time; completion of a standardised motivation to exercise survey at key points during the study; and finally, logging of participant's step data, wherever this was possible. Our first participants started the study in May 2013, and to lessen the effects of the change in seasonal weather conditions participant's study start-dates were staggered throughout Summer and Autumn 2013.

Baseline record. Our original study design also included a baseline measurement of steps for some participants, intended to allow us to better understand the effects of activity tracker use on physical activity by collecting quantitative data to compare number of steps taken before and after their use of the tracker. This approach was motivated by research into reactivity effects of pedometer use (see section 3.1.1), our aim was to use the tracker to record a baseline of activity for some participants in the study, by asking them to carry around the tracker before they could see the data tracked by it.

Participants were to be divided into three groups: group 1, 16-week baseline (n=18); group 2, 4-week baseline (n=17); and group 3, no baseline (n=15). A Fitbit account and profile with undisclosed login details was set up for each participant in groups 1 and 2, to allow recorded data to be synchronised from the Fitbit to their servers. Additionally, the Fitbit screen was obscured with a custom printed tamper-evident sticker (Figure 3.6). This approach prevented participants in groups 1 and 2 from seeing data, but still allowed the device to record steps and synchronise with Fitbit servers. Group 3 was given access to the tracked data from the start.

Figure 3.6 – Fitbit with tamper evident sticker removed

Participants in both group 1 and 2 undertook some baseline measurement of their steps, but because of technical issues and low levels of engagement we decided to abandon the baseline comparison and fully concentrate on our participants' in the wild use of their trackers. Those participants who had begun recording a baseline measure had the sticker removed at the earliest possible opportunity, and full access to the tracking system was provided. Almost one third (n=16) of our participants experienced technical issues during the baseline period which prevented their activity from being properly recorded, and those participants in the two baseline-recording groups (group 1 and 2) had very low levels of engagement with the study, illustrating how critical access to data is. Further details of the challenges faced during this study were written up as a short publication on barriers and workarounds to continued use of tracking systems (Harrison et al., 2015).

Interviews. Six interviews were scheduled with each participant: one interview every four-weeks for the first 16-weeks and then a final interview at 28-weeks. During the first interview we provided each participant with their study pack and asked them to complete a consent form, before questioning them about their current lifestyle, their motivation for taking part in the study and any expectations that they had. The next four interviews were planned to take place every 4-weeks, but we were flexible to suit participants' schedules. These interviews were conducted to help us answer **RO2** and **RO3**, to better understand how people use trackers over time and any associated responses to tracker use. Interviews focused on each participant's usage of the device, any difficulties they were experiencing, any changes that were made as a result. Initial interviews were more structured than later ones, where participants would instead often present their own account of their usage since the previous meeting with minimal prompting. The sixth interview was then undertaken approximately after 28-weeks of use (with at 12-week gap between 5^{th} and 6^{th} interview). Interviews were either in person or over Skype, according to participant preferences. They lasted between ten minutes and over an hour and were recorded for later transcription and analysis.

Diary. In addition to interviews, participants were encouraged to complete a short daily diary entry in the workbook recording their activities and interactions with the device. Some participants failed to regularly complete the diary provided and chose to use alternatives that were a better fit for them, such as their personal diary or Outlook calendar. However, as diary entries were primarily used as an aide-memoir and to prompt discussion during interviews, this did not detract from the already rich data set we were collecting.

Survey. We asked participants to complete a standardised motivation to exercise survey, the BREQ2 exercise motivation questionnaire (Markland and Tobin, 2004; Appendix A), at four key points of the study: during the first (week 0) interview, the fifth (week 16) and the final (week 28) interview of the main study, and then again during the follow-up interview (between week 52 and week 73). This survey provides a score for individuals intrinsic and extrinsic motivations for exercise, we conducted this to guide the interview and help us understand the reasons participants were, or were not, motivated to change their behaviour. We scored their questionnaire responses and used them to aid our understanding of their behavioural responses throughout the study.

Data logging. Each participant's Fitbit recorded the number of steps they took throughout the study, so long as it was worn and working correctly. So that we could have a record of the number of steps recorded by their devices, we scraped each participant's step-data from the Fitbit servers, using the official API. Our script ran once a week for the first 28-weeks of the study, downloading the most up to date step-data from the Fitbit servers into a spreadsheet.

This data was intended to allow us to look at participants' recorded steps to identify trends, better understand the collected qualitative data, and to see if they were wearing their tracker. However, the data recorded and captured was incomplete for many participants. The device is described as storing 30 days of data, and synchronization at longer intervals resulted in lost data: days where 0-steps were recorded but the participant had been wearing the device. Data were also lost when synchronization was undertaken at intervals of less than 30 days. This problem did not affect all participants, but resulted in large amounts of lost data for some. Some participants were also affected by an issue with an unreliable battery connection, which resulted in the device repeatedly turning off and on, drastically lowering the number of steps recorded and often preventing synchronization. Other participants experienced issues with the battery in the device depleting within days, rather than the specified 6-months. This also resulted in activity not being recorded until the battery was replaced. As such, this logged data was deemed an unreliable source for in-depth analysis.

3.2.1.3.2 Follow-up interview procedure

To better understand how our participants used their trackers beyond the main part of the study, we invited them to take part in a follow-up interview at least 1-year after they started in the study. We invited all participants to take part (except for five who we lost contact with during the main part of the study), so that we could better understand the long-term effects of the study and tracking on all, not just those who remained engaged. Thirty of the 45 invited participants agreed to be interviewed and were compensated with a £5 Amazon.co.uk voucher for taking part.

Although the original information sheet indicated that we would retain participants' contact details for future studies, it is important to note that participants were not aware they would be invited to take part in a follow-up interview, and they were under no obligation to take part. Because participants had signed up to take part in the main part of our study, this may have artificially increased the likelihood of continued tracking, by conducting follow-up interviews with these we could better understand their real-world use over time and outcomes from tracking, by concentrating on what happened after our initial observations were complete: if they continued to use the technology, continued with any new behaviours they may have created; or, if they gave up tracking, or returned to their previous behaviours. As such, we suggest that participants used the devices (and generally acted) in a more natural way in the time between completing the study and taking part in the follow up interview - thus lessening one of the main limitations of the main part of our study.

Follow-up interviews were scheduled in autumn 2014, 52-73 weeks after each participant had first started using their tracker. All interviews were conducted over Skype, lasted approximately 30 minutes (MIN: 13, MAX: 56) and were recorded for later transcription. During this interview we asked participants general questions about their use of the tracker and their behaviour, along with more specific questions based on their time in the study. General questions covered: if they were still using the device, if they were tracking with a different device or application, their use of other personal informatics tools and their feelings about tracking in general. On an individual level, we asked participants about their daily routine, physical activity and lifestyle - if these had changed since their time in the study, and if any changes in their behaviour had a lasting effect.

3.2.1.3.3 Participant details

Table 3.1, below, presents a summary of participant demographics from the point that they signed up for the study. Some of these details (such as their age and occupation) will have changed over the course of the study.

#	Gender	Age	Occupation	Took part in Follow-up
P1	Female	18-25	UX Architect	Yes
P2	Female	18-25	Consultant	Yes
P3	Female	26-35	Researcher	Yes
P4	Female	18-25	Account Executive	No
P5	Male	18-25	Financial services professional	No
P6	Female	26-35	Designer	Yes
P7	Female	26-35	Relocation Consultant	Yes
P8	Female	26-35	IT Consultant	No
P9	Female	18-25	Account Executive	No
P10	Male	26-35	UX Consultant	Yes
P11	Female	18-25	UX Consultant	No
P12	Female	26-35	Student	Yes
P13	Female	26-35	Practitioner	Yes
P14	Male	36-45	Researcher	Yes
P15	Female	26-35	Full time parent	No
P16	Male	26-35	Unemployed	Yes
P17	Female	26-35	Unemployed	No
P18	Female	36-45	Project Manager	Yes
P19	Male	26-35	Web and Communities Manager	No
P20	Female	26-35	Software Engineer	Yes
P21	Male	26-35	Financial Consultant	No
P22	Male	26-35	Illustrator	Yes
P23	Male	36-45	Web Designer	Yes
P24	Male	18-25	Risk Consultant	Yes
P25	Female	36-45	Lecturer	Yes
P26	Female	18-25	Student	Yes
P27	Male	18-25	Student	Yes
P28	Female	18-25	Project Manager	Yes
P29	Female	18-25	Designer	Yes
P30	Female	18-25	Student	Yes
P31	Male	18-25	Mechanical Engineer	No
P32	Male	18-25	Software Sales	Yes
P33	Female	26-35	Media relations manager	No
P34	Female	26-35	Student	Yes
P35	Female	26-35	Fashion Editor	No
P36	Male	65+	Retiree	Yes
P37	Female	46-55	Project Development Manager	No
P38	Female	26-35	Software Developer	No
P39	Female	26-35	Student	No
P40	Female	36-45	Student	Yes
P41	Male	26-35	Managing Director	No
P42	Female	26-35	Company Director	No
P43	Male	26-35	Researcher	Yes
P44	Female	36-45	Nurse Manager	No
P45	Male	26-35	Researcher	Yes
P46	Female	26-35	Web Developer	No
P47	Female	26-35	Student	Yes
P48	Female	36-45	Office Administrator	Yes
P49	Female	26-35	Student	Yes
P50	Male	36-45	UX Consultant	No

Table 3.1 – Longitudinal participant details

3.2.2 Study 2. Comparison study

We undertook our second study to triangulate and better understand the findings from our longitudinal study, along with moving beyond its limitations by taking a broader approach. Whereas participants in our longitudinal study all used the same, researcher-supplied, commercial device (the Fitbit Zip), participants in our comparison study used a wider variety of devices. Additionally, they had all started using their trackers of their own volition, and some participants had stopped tracking by the time of the study.

The comparison study included participants in two locations – London and Atlanta (GA, USA). Atlanta was chosen as a second field-study location, as the author had an opportunity to spend 3-months at the Georgia Institute of Technology, which offered a significant and interesting contrast with London, where the remainder of the research was carried out. Studying use of activity tracking systems across two locations allow us to understand some elements of how context influences people's engagement with these systems, and behavioural outcomes.

In total we recruited 48 existing or previous trackers, who were using, or had used, a variety of different tracking technologies.

3.2.2.1 Participants

In total, 48 participants took part in this study (24 women), with 24 participants recruited in each location. Potential participants were recruited through word-of-mouth, posts on social media and targeted paid-for online advertisements, publicised through Facebook and Twitter, which called for "current and previous users of activity trackers" to take part (Figure 3.7).

Figure 3.7 – Example of an online recruitment advertisement

Potential participants were directed to complete a survey, which asked them general demographic questions such as their name and age, an exercise Stage of Change survey (Marcus et al., 1992), along with questions ascertaining their suitability to take part, including their home and workplace locations, and details of any tracking systems they had used (Appendix B). Participants were rewarded with a $20 Amazon.com gift card (£10 Amazon.co.uk gift card in London) for taking part. Our participants had a variety of different reasons for taking part in this study. The incentive for taking part was a draw for most participants and many were simply interested in helping out by sharing their, sometimes negative, experiences of using their trackers – treating the interview as a way of airing their grievances.

Our sample included 37 people who were currently tracking their activity, and 11 who had stopped tracking (8 Atlanta (ATL), 3 London (LDN)). 7 (3 ATL, 4 LDN) of those tracking had previously stopped for at least 4-weeks before returning, 23 (9 ATL, 14 LDN) reported having previously used a different tracker, and 3 (1 ATL, 2 LDN) were currently tracking using more than one technology (be this a wearable, or app). Recruiting both those who were currently tracking, along with those who had stopped allowed us to gain insights into the reasons for abandonment, along with barriers to use and the reasons that might encourage them to return to tracking. Including those devices that they had abandoned, our participants had tracked with a wide range of wearables, including various models of *Fitbit* (n=25), *Jawbone* (n=8), *Nike Fuelband* (n=2), *Garmin VivoFit* (n=2) and *Misfit* (n=2), and with smartphone apps such as *Moves* (n=4), Apple's *Health* app (n=2) and *Argus* (n=1). The most experienced participant reported having used a tracker for almost three years, while the least experienced had used it for only two weeks. Over half (n=13) reported using their tracker for more than 6-months. Many participants also reported using other personal informatics tools in addition to activity trackers, including food journaling tools like MyFitnessPal and sleep tracking tools, such as Sleep Cycle Alarm Clock.

3.2.2.1.1 Atlanta Participant details

Twenty-four participants (13 women) in Atlanta, GA, took part in our survey and contextual interviews. Participants' ages ranged from 18-55. The majority (n=13) were in full time work, seven were either graduate or undergraduate students and four were self-employed.

#	Gender	Age	Occupation	Stage of change	Primary Tracker	Use length
A1	Female	18-25	Transportation Engineer	Maintenance	No longer tracking	
A2	Male	26-35	Accountant	Maintenance	No longer tracking	
A3	Male	36-45	Recording engineer	Action	Fitbit One	3-6 months
A4	Male	18-25	Student	Pre-contemplation	Moves	6-12 months
A5	Female	36-45	IT Consultant	Preparation	Fitbit Flex	12+ months
A6	Male	46-55	Supervisor	Maintenance	Fitbit Flex	6-12 months
A7	Male	36-45	Researcher	Maintenance	No longer tracking	
A8	Male	18-25	Logistics Analyst	Contemplation	No longer tracking	
A9	Male	18-25	Logistics Analyst	Preparation	Misfit Shine	3-6 months
A10	Female	18-25	Health Communication Specialist	Maintenance	Fitbit Flex	<1 month
A11	Female	36-45	Record/Comic book store	Preparation	Fitbit One	3-6 months
A12	Male	36-45	Woodworker, Homemaker, Investor	Preparation	No longer tracking	
A13	Male	26-35	Musician	Maintenance	No longer tracking	
A14	Female	46-55	Director, Content & Data Strategy	Maintenance	Runkeeper	12+ months
A15	Female	26-35	Research Scientist	Maintenance	Fitbit One	12+ months
A16	Female	18-25	Student	Maintenance	No longer tracking	
A17	Male	18-25	Student	Preparation	No longer tracking	
A18	Female	18-25	Student	Preparation	Argus	12+ months
A19	Female	26-35	PhD Student	Maintenance	Jawbone UP24	<1 month
A20	Female	18-25	Freelance Social Media Manager	Action	Fitbit Flex	6-12 months
A21	Female	26-35	Teacher	Preparation	Fitbit One	6-12 months
A22	Male	18-25	PhD Student	Maintenance	Jawbone UP24	1-3 months
A23	Female	18-25	Graduate Student	Maintenance	Fitbit One	6-12 months
A24	Female	46-55	Faculty	Maintenance	Active link by Philips	12+ months

Table 3.2 – Atlanta participant details

3.2.2.1.2 London Participant details

A further 24 participants (11 women) located in London took part in the London-based part of the study, again completing surveys and interviews. Participants' ages ranged between 18-45. 21 of our 24 participants were in full time employment, along with 2 students and 1 retiree.

#	Gender	Age	Occupation	Stage of change	Primary Tracker	Use length
L1	Female	36-45	Senior Manager	Maintenance	Moves	3-6 months
L2	Male	26-35	UX Designer	Maintenance	Fitbit Flex	3-6 months
L3	Male	26-35	Web Developer	Maintenance	Garmin Vivofit	6-12 months
L4	Female	26-35	UX Consultant	Preparation	Fitbit Flex	6-12 months
L5	Female	26-35	PhD Student	Contemplation	Fitbit Flex	3-6 months
L6	Female	26-35	QA administrator	Maintenance	Fitbit One	12+ months
L7	Male	36-45	Managing Director	Maintenance	Breeze	3-6 months
L8	Male	36-45	Sales	Maintenance	Garmin Vivofit	6-12 months
L9	Male	56-65	Retiree	Maintenance	Fitbit One	3-6 months
L10	Male	26-35	Student	Maintenance	Nike Fuelband SE	12+ months
L11	Female	36-45	Owner/ fundraiser	Preparation	Fitbit Flex	1-3 months
L12	Male	26-35	Facilities manager	Contemplation	Apple Watch/ Healthkit	3-6 months
L13	Female	46-55	Book keeper	Maintenance	Fitbit One	12+ months
L14	Male	18-25	Educational Developer	Preparation	Fitbit Flex	1-3 months
L15	Female	36-45	Executive Assistant	Maintenance	Fitbit Flex	1-3 months
L16	Female	18-25	Trainee Counselling Psychologist	Maintenance	Fitbit Charge	3-6 months
L17	Male	36-45	Consultancy Business Manager	Action	Fitbit One	12+ months
L18	Female	26-35	Admin	Maintenance	Fitbit Flex	1-3 months
L19	Female	26-35	Researcher	Maintenance	Polar M400	1-3 months
L20	Male	26-35	Software Test Engineer	Contemplation	No longer tracking	
L21	Male	26-35	Developer	Contemplation	No longer tracking	
L22	Male	36-45	Tech Support	Precontemplation	No longer tracking	
L23	Female	18-25	Office Manager	Preparation	Jawbone UP24	
L24	Male	26-35	Research Associate	Contemplation	Basis Peak	3-6 months

Table 3.3 – London participant details

3.2.2.2 Materials

Beyond the stage of change questionnaire for physical activity[15] that potential participants completed when signing up for the study, participants also completed a second survey (see Appendix B) which took approximately 15 minutes to complete and comprised two further standardised questionnaires: the long-form International Physical Activity Questionnaire (IPAQ)[16], which provides a measure of physical activity; and the Barriers to Being Active Quiz[17], which assesses perceived barriers to physical activity.

[15] Cancer Prevention Research Center. Exercise: Stages of Change - Short Form. Retrieved from: http://www.uri.edu/research/cprc/Measures/Exercise02.htm
[16] International Physical Activity Questionnaire. Retrieved from: http://www.ipaq.ki.se
[17] Centers for Disease Control and Prevention. Barriers to being active Quiz: What keeps you from being more active? Retrieved from: http://www.cdc.gov/diabetes/ndep/pdfs/8-road-tohealth-barriers-quiz-508.pdf

3.2.2.3 Procedure

Each participant completed two online surveys and then took part in an interview of approximately one hour (range: 00:35-01:30). Beyond the Stage of Change Questionnaire for Physical Activity mentioned in the previous section, the recruitment survey also asked potential participants for general demographic data (age, sex, contact details, etc.), details of the tracking technologies they were previously and currently using, and their home and work Zip codes (post codes in the UK), to help us better understand their context of use and a typical journey they might make. Once participants had been selected to take part in the study (based on their eligibility to do so) they were invited to complete a second survey, including measures detailed in the previous section. These surveys were scored and data collated before each interview, to help inform the direction of our interviews with each participant, along with being useful to support our qualitative analysis by providing comparable measures to engagement and barriers to physical activity. Additionally, these surveys were useful to sensitize the participants to their physical activity and our research areas before their interview.

Semi-structured interviews were undertaken between November 2014 and April 2015 (November – December 2014 for participants in Atlanta, and March 2015 - April 2015 for participants in London). Participants were encouraged to either send their tracked data before the interview, or bring it along to the interview to share with us and act as an aide-memoir for themselves. Where possible, and if participants were willing, we took a record of their previously tracked data to aid our qualitative analysis. Interview questions covered: reasons for wanting an activity tracker; reasons for choosing a specific one; physical activity habits and transport regime; activity tracker use and barriers; other personal informatics use; and unmet needs and desires. Interviews either took place over Skype (Atlanta n=12, London n=17) or in person (Atlanta n=12, London n=7), depending on the participant's availability and preference. Notes were taken during these interviews, which were either recorded using a portable voice recorder, or with Audacity if conducted on Skype.

3.3 Summary of all collected data and participants

Because we present the findings of this thesis by theme, rather than by study, we now remind the reader of the totality of data collected, which is presented throughout the remainder of this work. This thesis is based on data collected from 98 participants, across the two studies detailed in the previous sections. Our sample included: 57 females and 41 males; those aged from 18 to over-65; a range of occupations from students to the retired; with a broad range of health goals and capabilities; and, using a wide range of tracking technologies. Though 74 of our participants were regularly located in London, and 24 were regularly located in Atlanta, they also had a wide range of nationalities.

In total, 228 interviews were conducted (150 in the main part of the longitudinal study, 30 in the longitudinal study follow-up, and 48 in the comparison interview), and in addition to this rich qualitative data we also have completed survey data from all 98 participants, and quantitative data logs of recorded steps from over 60 participants (few participants from the comparison study provided us with logged data, although most showed us this data during the interviews).

3.3.1 Participant nomenclature

Throughout this thesis we present data from participants who took part in both of our studies. To more easily identify the origin of these different data points, the table below provides a reference to our shortened participant identifiers, which is used to refer to our participants throughout the remainder of this thesis.

Identifier	**# participants**	**Study**	**Tracker**	**Location**
P* (1-50)	50	Longitudinal study	Fitbit Zip	London, UK
P*FU (1-50)	30 (subset of above)	Longitudinal (follow-up)	Fitbit Zip	London, UK
L* (1-24)	24	Comparison (London)	Mixed	London, UK
A* (1-24)	24	Comparison (Atlanta)	Mixed	Atlanta, US

Table 3.4 – Participant identifiers

3.3.2 Summary of collected data

The summary table below provides an overview of the number of participants, the data collected, and methods used across both of our studies.

Study		Participants	Gender	Data Collected	Timeframe
Longitudinal Study 1	**Main**	50	F = 33, M = 17	Interviews, Periodic Breq-2 exercise motivation survey, Logged step-data.	05/13 – 04/14
	Follow-up	30 (subset of above)	F = 19, M = 11	Interviews, Breq-2 exercise motivation survey.	10/14 – 11/14
Comparison Study 2	**Atlanta**	24	F = 13, M = 11	Interviews, Stage of Change Survey, IPAQ (long form) survey, Barriers to being active quiz, Recorded data (some).	11/14 – 12/14
	London	24	F = 11, M = 11	Interviews, Stage of Change Survey, IPAQ (long form) survey, Barriers to being active quiz, Recorded data (some).	03/15 – 04/15

Table 3.5 – Summary of collected data

Table 3.6 provides a summary of the variety of motivations that participants reported in using activity trackers. It's important to note that although participants in the longitudinal study were provided with a tracker, and thus their motivations might also include wanting to help research and the incentive of the study (in the form of a free activity tracker and a voucher), they also reported several other motivations. While some motivations were more common in some participants (e.g. those in the US in the Atlanta study) due to the nature of healthcare provision, we found that there were in fact commonalities across all our participants when it came to their motivations. These are explored in greater detail in section 4.1, but are reported here as an overview, with examples from individual participants. As the reader will notice, the various types of motivations were not necessarily mutually exclusive and even for those who developed a more emotional connection with their devices (e.g. P40 from the longitudinal study and L6 from London comparative study), this was not determined by the type of study they took part in or the motivations attached to it.

General motivation for using the tracker	Example characteristics of motivation	Example participants
Desire to change behaviour	Diet	P4 (Longitudinal study)
	Cycling training	L3, L8 (London study)
	Healthier lifestyle	P40 (Longitudinal study)
Desire to gain insights into their own behaviour	Visualise personal stats	P17, P24 (both longitudinal study)
	Improve recovery	P18 (Longitudinal study)
	Compare with partner	L4 (London study)
Curiosity	For the technology and its potential	P21, A7, L6 (Longitudinal study, Atlanta study, London study)
	For additional personal data	A10 (Atlanta study)
	For insider research knowledge	P40, A15 (Longitudinal study and Atlanta study)
Financial incentive	Gym discount	P18 (Longitudinal study)
	Health insurance discount	A9 (Atlanta study)
	Corporate wellness program	A8 (Atlanta study)

Table 3.6 – Summary of participants' motivations

3.4 Overall analysis

In this thesis, we have carefully analysed all data from the main study (longitudinal study), its follow up, and the comparison study (both Atlanta and London interviews). To do this, we followed Braun and Clarke's (2006) guidelines on conducting thematic analysis, combining both inductive and deductive approaches.

The themes constructed from our data build a detailed picture of the self-tracker's journey over time. As such, we have organised the findings based on our themes, starting from how participants started tracking, including their motivations, how they initially engaged with trackers and their initial responses. We then move on to use and engagement over time, covering phases of tracking, barriers and workarounds, and individual differences. Finally, we discuss the affective and behavioural responses to tracking. In reporting our findings and themes, we have followed guidelines from APA standards (Leavitt et al., 2018) and specifically, Braun and Clarke's (2006) guidelines for reporting thematic analysis. This means that when reporting a particular theme or experiences from participants, the prevalence of such theme or perspective is not necessarily quantified. As Levitt et al. (2018, p.28) state, *"qualitative reports need to be evaluated in terms of their own logic of inquiry. The data or findings from these analyses may or may not be transformed into future numerical quantification in quantitative or mixed methods analyses"*. Similarly, Braun and Clarke (2006, p.82) expand with how, *"the 'keyness' of a theme is not necessarily dependent on quantifiable measures but rather on whether it captures something imexpportant in relation to the overall research question".* In fact, the prevalence of a theme in thematic analysis can be determined in a number of ways, with *"no right or wrong method"* (p.83) including having statements such as *" 'the majority of participants' (Meehan et al., 2000: 372), 'many participants' (Taylor and Ussher, 2001: 298), or 'a number of participants' (Braun et al., 2003: 249)"* (Braun and Clarke, 2006, p.83). As a result, in this thesis we do not quantify how many participants reported particular feelings, experiences or any responses to use, but rather we use expressions such as 'few', 'many', 'the majority' and the alike to determine the prevalence of the theme. Furthermore, because all our interviews were conducted in a semi-structured way, the conversations that was raised with each participant were dependent on the content shared and thus were not necessarily identical to one another. This means that while a question might have been asked to a number of participants, it might have not been raised with others. This further impedes the ability to quantify instances of experiences reported across our sample, but as APA guidelines suggest (Leavitt et al., 2018), does not invalidate or decontextualise its findings.

In this section, we will first report on how each study was analysed individually using an inductive approach. Then, we will present out combined analysis – guided by our research question and the insights that emerged from the first stage of inductive analysis. As such, for this second phase of analysis, we combined all datasets in order to better account for similarities and differences and create a richer picture of the findings.

3.4.1 Individual analysis of studies

Below we describe the analysis conducted within each of the studies, before further justifying and outlining our combined analysis in the following section.

3.4.1.1 Study 1. Longitudinal study analysis

All interviews from the longitudinal study were audio-recorded and then transcribed for inductive thematic analysis (Braun and Clarke, 2006). All initial interviews were transcribed verbatim, to help us better understand the background and motivations of each of our participants had for taking part in the study and using their tracking technologies. From then on, approximately 10-15 randomly chosen interviews were fully transcribed (verbatim) at each stage of the study (second interview, third interview, etc.) and other interviews were fully reviewed and then partially transcribed, providing re-familiarisation with all the data. In addition to the interview data itself, participants' BREQ2 tests were scored to look for patterns and aid our analysis, and individual graphs of participants' step data where possible were produced and used to support findings from the interviews in conjunction with the interview transcripts and codes. This record of previous activity was used as an aide-memoir for participants during interviews. These data were analysed using a combination of paper-based and electronic tools, including paper printouts of interviews which we manually highlighted and annotated, then moving on to Microsoft Office tools including Microsoft Word and Microsoft Excel for managing codes and themes. An initial set of codes was developed based on our ongoing analysis of the transcriptions, a recursive process which was completed throughout the study because of the potential effects of study duration (e.g. participant's attitudes or behaviours changing over time, and us wanting to have this knowledge to hand during interviews). Once initial codes were produced, they were iteratively organised into higher level themes. These initial themes were then reviewed and refined using affinity diagrams and informed an initial model of participants' responses to tracking. This initial model of participants' responses was presented at the UCL Behaviour Change conference in 2015. The results from this analysis also informed the direction of the follow-upinterviews, which allowed us to verify our hypothesis and findings from the main study.

3.4.1.2 Study 1. Longitudinal study, follow-up analysis

Each of the follow-up interviews was recorded and then fully transcribed prior to loading into the CAQDAS software Atlas.Ti. For this study, the analysis took part in two stages. Initially, the analysis of the follow-up interviews was conducted independently from the main study data, to ensure that our results were not artificially influenced by our participants' use of their trackers in the main study. Then, in a second, iterative, stage of analysis, we compared follow-up findings with our existing analysis of each participants' engagement in the longitudinal study, with a particular concentration on the outcomes from use and their use of personal informatics systems over time, in order to uncover any evidence of long-term or continued changes in behavior, even after the main study had finished. Ultimately, this allowed us to start building up a more complete and nuanced understanding of how people use their tracking technologies, temporally, over time, the challenges they face, and any outcomes that may exist from use.

3.4.1.3 Study 2. Comparison study Analysis

For the comparative study, the interviews were either fully or partially transcribed and loaded into Atlas.ti for bottom-up open coding and thematic analysis. To subsidies the transcripts, we used the scored survey data (IPAQ) to provide comparable measures of physical activity levels and barriers to exercise between the participants in each city (Atlanta and London). Similarly, the collected data shared by our participants was used to provide further context on their interview data and activities and together with the survey data were useful for giving further context to our participants' use of their trackers, used to look for patterns in the data, and triangulate our results. Here, codes and subsequent themes generated focused on participants' use and non-use of their tracking technologies over time, and the factors that affected this. Specific themes around barriers and workarounds to continued use of tracking systems that were constructed from this analysis were published and presented at Ubicomp 2015 (Harrison et al., 2015).

3.4.2 Combined analysis of studies

Once the inductive analysis of all our corpus of data was conducted individually per study, we reviewed it and noticed that there were several similarities and crossovers across themes. For example, participants "not tracking over Christmas" in study 1 and "not tracking over thanksgiving" in study 2. Therefore, the decision to combine the whole data set (longitudinal study, follow-up, and comparative study) to re-analyse the data through a deductive approach was made. This would allow us to merge themes across data sets to avoid duplicates, create a richer picture of participants' situated and lived experience over time, and ultimately better answer our research question.

In carrying out this deductive analysis, we gave participants new identifiers (Table 3.4) and all transcribed interview data, along with any other notes or analysis on other recorded data was loaded into a new project in Atlas.ti for fresh coding and analysis. A comprehensive history of each participant's tracker use and physical activity was then built-up using the various data we had gathered from them (interviews, diary, recorded data, survey responses, etc.), which was particularly useful in comparing and better understanding of these participants' self-tracking journey. This data was then coded both inductively and deductively, both looking for fresh codes and data, along with using the existing coding schemes we had used when analysing these data independently.

This second, combined analysis process resulted in us finding new themes in the data, as well as merging existing themes. New themes included the effects of external, environmental and social factors on use (section 5.4.2), and how participants changed trackers and tracked with other tools (section 5.3.3.3). Existing themes were combined when detailing "phases of tracking over time" (section 5.1) and "responses to tracker use" categorisations (presented throughout Chapter 6), which we had previously defined based on our analysis of longitudinal study data alone, but were now enriched also by data from the comparison study. This not only included a more nuanced view of how participants changed their behaviour, based on the additional examples we saw in this larger data set, but also resulted in a clearer model of outcomes including our "affective responses and outcomes", which we had previously not presented as a category in itself.

On the note of affective responses, when coding the data in this second, combined analysis, we looked to better classify experiences based on participants' emotional responses, intended as their opinion and attitudes towards the various trackers. One could argue that in order to capture this information, sentiment analysis is an appropriate method. *"Sentiment analysis, also called opinion mining, is the field of study that analyzes people's opinions, sentiments, evaluations, appraisals, attitudes, and emotions towards entities such as products, services, organizations, individuals, issues, events, topics, and their attributes"* (Liu, 2012, p.7). It is primarily used in information retrieval research and more recently in social media research, where large datasets of thousands of data points are available and cannot be easily analysed in order to extract users' opinions. For these data sets, Liu (2012) argues that algorithms are most appropriate to compile and classify the lexicon used.

As our sample size in this thesis is comprised of only 98 participants and our overall research question is centred around building an in-depth, qualitative understanding of the lived and situated experience of activity trackers over time, a thematic approach (Braun and Clarke, 2006) to our analysis is more appropriate. As such, we did not apply sentiment analysis in order to gauge whether participants' experiences were positive or negative. However, this does not prevent us from thematically classifying experiences as positive and negative depending on the tone and context of the quotes. For example, when a participant expressed a statement such as *"Wow, I'm impressed – 24k! Nicely done!"* (P6), we coded this as a "positive emotional response". Similarly, when participants made claims such as *"It's really upsetting, I thought I walked way more"* (P29) we coded these as a "negative emotional response".

One final point we would like to make with regards to the combined analysis is how the data is reported throughout the thesis. Although we have combined the data and re-analysed it as a single corpus, this does not mean that all themes presented in this thesis apply to all studies carried out or that the prevalence of a theme is equally distributed in each study. Because we had already previously analysed each study independently, the knowledge and understanding that emerged from that process was not disregarded in the combined analysis. Rather, we still wish to highlight differences that emerged in our studies, particularly through our individual analysis, whilst at the same time providing a more comprehensive understanding of situated use over time which has primarily emerged from our combined analysis.

3.5 Limitations

The approach we have taken in this work has been to largely base our findings on subjective, qualitative, self-reported data from new and existing users of these technologies. Qualitative work such as ours is often criticised because of a lack of objectivity with self-reported data, but to lessen these limitations as much as possible, limit any bias and ensure validity in our data we took a mixed-method approach to include more objective, quantitative, data in the form of survey results and data recorded from the tracking technologies to validating our participant's subjective accounts with objective data. Although this helped, collection of mixed-methods data did not always go to plan and we were not always able to collect the complete quantitative data records that we could, but where it did, it did help us triangulate our results and we found participants' self-report to be generally accurate. Specific limitations from the two studies are detailed below.

3.5.1 Main study limitations

Although our longitudinal study is considerably longer than most other studies of behaviour-change related (Brynjarsdottir et al., 2012) and also included a considerably larger number of participants than most qualitative studies in HCI. One obvious limitation of our longitudinal study is that it is entirely based on self-selected users of one particular researcher-supplied device (the Fitbit Zip), with 50 participants all in a fairly similar context (fulfilling the requirements of the study: located in London, using a fairly modern smartphone, having not tracked before, and being willing to participate in our fairly lengthy study for relatively little reward). Because the study was conducted with a single activity tracking system this offered a single set of behaviour change techniques and a particular implementation of each. Different activity tracking systems include different behaviour change techniques and implement them in different ways which may be more or less successful. Additionally, people may respond to specific implementations differently. However, we undertook the study mindful of these limitations, and designed our second study to move beyond these limitations.

Another limitation with this study was the lack of objective data to triangulate and verify personal accounts from participants. Because we repeatedly spoke to our participants, building some sort of relationship with them, they may have acted differently or reported untruthfully, so as to not disappoint us. Repeated interviews also allowed us to cross-reference participants' responses and ask for clarification if needed (which normal interviews would not allow). The study was designed to include mixed methods, using both objective records of physical activity completed (in the form of steps recorded by the devices) along with subjective reporting from participants (from interviews and diary entries). We intended to use the step-data recorded by participants to verify their qualitative accounts of interactions over time, but much of this recorded data proved to be unreliable and was incomplete. In addition to five participants who dropped out of the study entirely, almost one third (n=16) experienced technical issues at some point of the which prevented them from recording a complete set of activity data, as detailed in (Harrison et al., 2014). However, despite not all participants recording a complete set of data we still collected a large amount of data from all our participants, which enabled us to better understand their use over time when combined with the repeated interviews we undertook with them.

Although our follow-up interviews allowed us to progress past one of the main limitations of the main part of our study, including the issues of "observer effects" from the fact that our participants were aware that we were monitoring their activity and regularly speaking to them (which, in itself may have acted as an intervention and encouraged participants to be more active), one limitation here is that not all participants took part in the study, and we are unaware of the reasons why. In total, 15 participants who started the study and were invited to take part in the follow up, did not respond to our enquiries. From the remaining 15 participants, 8 did not complete the main study and may have not been happy to talk to us because of this, but 6 of the remaining 7 did complete the main study without any notable gaps and would have been particularly interesting to talk. However, despite this limitation we were able to gain significant insights into the behaviours and longer-term engagement of the 30 participants who did take part in the follow-up.

3.5.2 Comparison study limitations

Unlike in the longitudinal study where we repeatedly interviewed the same participants and built up a comprehensive picture of their use over time, in our comparison study we instead relied on individual "snapshot" style interviews (see section 3.1.3) with participants self-reporting data on interactions that may have happened weeks or months in the past. Because the main focus of this study was related to the effect of context on participants use of different trackers, rather than focusing on their use over time as in the longitudinal study, this was not as much of an issue as it would have been otherwise, but it does still bring potential issues with reliability into our findings.

Unfortunately, we were also limited in terms of the amount of objective tracked-data we were able to gain from participants, so we had to instead rely more heavily on our participants' self-reports. Our study design asked participants to provide us with their tracked data, and indeed most of our participants were happy to do so, however this was difficult to accomplish in the real world. This was mostly due to the fact that the manufacturers of the tracking systems our participants used did not provide tools to allow users to easily retrieve their data from these systems – those participants who did share their tracked data with us before the interviews did so through screenshots of data dashboards – not a particularly accurate way for us to get a record of historically tracked data.

One of the main aims of this study was to get an understanding of the ways that context and situation impacted how people used their trackers. To this end we recruited existing uses from two dissimilar cities in different continents. However, despite the many differences between these two cities, they were perhaps similar in more ways than they were different: both were relatively large, built-up, metropolitan areas in English-speaking western countries. The challenges faced by those living in rural areas, in countries or environments with poor infrastructure or connectivity, or with extreme weather conditions, may have had an even greater impact on their use of the trackers and would have probably yielded different results to ours. Indeed, comparisons of use between considerably more than two different areas, and with a greater variety of different users in different settings would be required to have a more complete understanding of the effects of context on use – our work here is instead intended to be a sensitising primer to the differences in engagement and use that arise as a result of differences in context.

We now move onto presentation of our findings, characterised over the next three chapters through the framing of a hypothetical "self-trackers journey". We begin the self-trackers journey by introducing participants motivations for **taking up tracking**, their choice of tracking technology and their initial responses to using these tracking systems. We then move on to our participant's **use and engagement over time**, which focuses on how participants used, and did not use, their tracking systems through their self-tracking journey, the barriers they were faced with and the workarounds they created, and the effects of context. Finally, we present our participants' **responses to tracker use**, which covers both affective responses as well as behavioural changes, which were not only related to the behaviour they had been tracking.

Chapter 4. Taking Up Tracking

This chapter presents the beginning of the self-tracker's journey: from motivations to tracking, through to the affective and behavioural responses that occur after first using their trackers. People's initial interactions with a new technology are generally different to their use over time, these so-called "novelty effects", along with the reactivity effects which may cause people to act differently when their behaviour is first quantified, mean that initial engagement and behaviours when using a tracking technology may be unrepresentative of longer-term use. Users of self-tracking technologies may have further initial concerns when using the technology, with challenges such as fitting the technologies into their lives, making sense of the provided data and evaluating the trustworthiness of the technology.

The core aim for this chapter is to provide answers to **RO1: Update the current understanding of how healthy adults initially engage with activity trackers.** In order to do so, we examine and unpack users' initial interactions with their trackers, and their responses to use. Overall, this chapter characterises the beginning of "the self-trackers journey" (visualised in Figure 4.1). Starting before a single step is even tracked, by examining motivations to track and their choice of tracker, moving on to their initial uses of their chosen trackers, focusing on how they used and adopted them over the first few weeks and months of their self-tracking journey. Along with data gathered at these very initial stages of use, throughout the chapter we have also included data from their longer use over time in order to help contextualise initial use from continued and ongoing use.

It's important to note here that when we refer to "longer use" throughout this thesis, we are not necessarily quantifying how much 'longer' means. Rather, we are using such comparative expressions (longer, shorter) to contrast experiences of participants and how lengths of use may have an impact on the overall experience and subsequent behaviour. As mentioned in chapter 2, previous research has used arbitrary boundaries to determine what constitute long-term use, with Shin et al. (2019) suggesting that anything over 6 months is long-term use, whereas Meyer et al. (2020) suggest that long-term use is in the realm of years. Just these two studies show how determining what constitutes long-term use is not a simple matter and there is not enough evidence to suggest a specific timeframe to determine the cut-off. Therefore, in this thesis, we specifically do not quantify such parameters, but rather always present experiences of long and short term use in contrast to one another, as our evidence suggest that this is highly personal and dependable on individual circumstances.

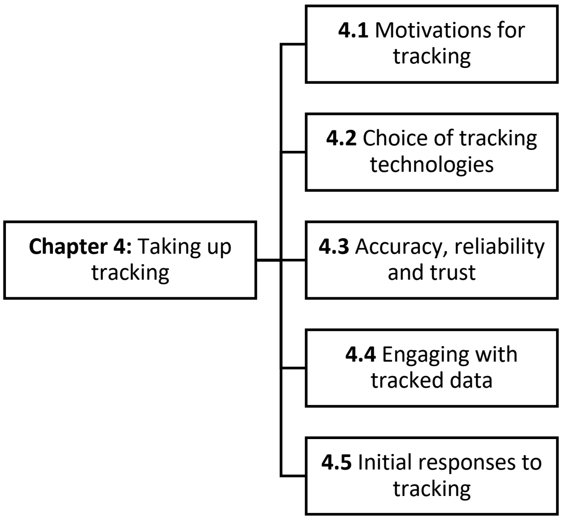

Figure 4.1 – Chapter outline

The next chapter describes how our participants' use and engagement with their tracking technologies changed and evolved over time, and then we describe the longer-term resulting psychological and behaviour outcomes of their use of these tracking technologies in Chapter 6.

4.1 Motivations for tracking

Our participants' initial motivations for using their tracker were varied, ranging from a general interest in the technology, to wanting to find out more about themselves (outlined in Figure 4.2). However, a considerable majority of participants across both studies chose to start tracking because of an association of tracking being useful for supporting some sort of behaviour-change goal. Although participants in study 1 were provided with devices as part of the study rather than selecting and purchasing their own devices, we did not see a significant difference in motivations for tracking between participants in the two studies. As further presented throughout Chapter 5 and 6, these initial motivations for tracking often do not reflect actual use over time.

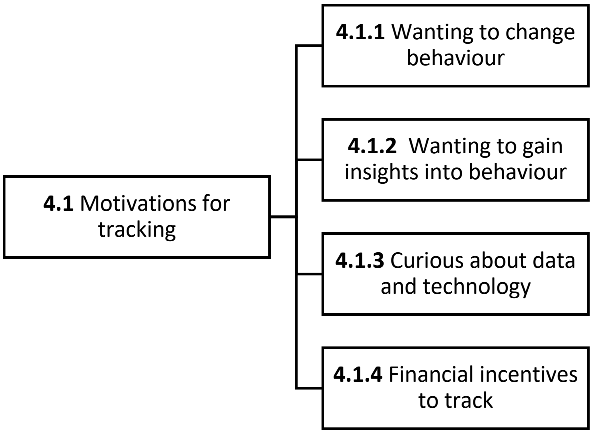

Figure 4.2 – Motivations for tracking outline

An important factor to consider when analysing motivations for use is the origin of the tracker. Whilst all 48 participants in our comparison study already owned their tracker before taking part in the study, we supplied the 50 participants in our longitudinal study with their tracking device - a Fitbit Zip. Because of this, some of the participants from the longitudinal study were motivated by altruistic factors such as "helping out with the study" and were perhaps less motivated by their ongoing use of the technology. Some participants from the comparison study received their tracker as a gift, and thus did not have a pre-conceived motivation for using it. Additionally, three participants (located in Atlanta) from our comparison study had been offered the trackers for a nominal cost in exchange for meeting activity goals to receive a discount on their health insurance policy. This fiscal reward represented a different extrinsic motivation to most of our other participants, who generally had intrinsic motivations. In general, we identified three main motivators across all participants, and we discuss each more in depth below: behaviour change, wanting more insight about one's behaviour, and curiosity.

4.1.1 Wanting to change behaviour

The majority of our participants adopted their activity tracker because they believed it would be useful in helping them meet a health-related goal, such as being more active or losing weight. These participants could be considered to be engaging in what Rooksby et al. (2014) describe as "*directive tracking*". This is not surprising given that these technologies are often marketed showing people dressed in sports clothes and being active whilst using the devices, and even the names of some of these devices (e.g. *Fitbit*) are suggestive of an aspiration to an active and healthy lifestyle. Generally, this usage was driven by an intrinsic motivation to change their behaviour in some way, but some participants were instead motivated by an external authority-figure such as a doctor, or either directly, or indirectly, by a friend or relative.

Participants' motivations and perceived self-efficacy depended largely on their physical activity levels. Our participants had wildly differing levels of physical activity before using their tracking technologies, ranging from those undergoing marathon training (e.g. L3, P44) to those who would rarely walk further than the closest bus stop (e.g. P11, P28). Therefore, depending on how active they were prior to using their tracker, the type of behaviour change that the activity tracker was supporting differed. To better understand this, along with qualitative data collected in both studies we utilised a Transtheoretical Model (TTM) survey in our second study (see section 3.2 for a complete overview of the methods used), to map participants' feelings towards physical activity behaviour change to the Transtheoretical Model (Prochaska, Johnson and Lee, 1998), and identified three main stages that related to taking up tracking in our sample: contemplation, preparation, and action.

4.1.1.1 Stages of change

We found that, perhaps unsurprisingly, the majority of participants looking to change their behaviour were in either the *contemplation* or *preparation* stages i.e. they were either getting ready, or ready to make a change. As a result, many of the participants interested in changing their behaviour considered themselves to be fairly inactive prior to using the technology, and hoped that using the technology would help them become more active. For example, we have classified P2 in the contemplation stage before getting the technology, as she explained *"I'm hoping I'll do more exercise* [when using the Fitbit]. *I ought to"*, showing an awareness of the importance of being more active, but not actually having a plan or a particular desire to change.

Other participants instead were much more ready to make a change, and fell into the preparation stage, having already an intention to change and a plan of how to do so. For example, P12, who prior to the study had been active, was planning to be more active in her day-to-day routine and *"thought anything to get me more motivated would be useful - to increase the activity I do day to day, because I don't really have time to do proper exercise".*

Other participants were in the *action* stage, suggesting that they were already primed to change and either looking for further motivation or support to aid them in changing. In fact, these participants had already started to make changes, but were hoping for the technology to offer them some more support. For example, P6 explained that shortly before the study commenced that she had decided that she wanted to be able to run 5 kilometres, but was struggling to meet this goal, *"I've been trying to get myself to exercise more for the last year and a half, it's really hard because I'm basically a couch potato so I've had to do a lot of things to encourage myself. So far, the only things that have* *made any difference whatsoever are either going running with friends* [...] *and using the game zombies run",* this participant hoped that the technology would provide some more motivation to help her change.

4.1.1.2 Behaviour Change Goals

Most participants who were interested in changing their behaviour had a broader goal in mind than just becoming more active: often, they wanted to maintain a healthy lifestyle and many were particularly interested in losing weight.

Some participants considered weight-loss to be a natural consequence of increasing their physical activity, whilst others were more interested in their tracking technology providing them with an estimation of calories burnt, rather than steps. Participant 4, from the longitudinal study, gave a typical explanation of this *"what does it mean in terms of how much more food I can eat - that's basically what I want to know!* [...] *we want to have a healthy lifestyle and not be prone to getting heart disease or anything like that, so that's my ultimate goal... to make myself as healthy as possible. So that's why I like the activity trackers, because it translates a bit more than a number alone".* Often, these participants would combine their use of the activity tracker with a food journaling application, most frequently MyFitnessPal[18]. Some of these participants were already tracking the number of calories they consumed and others started tracking their calories after using their activity tracking technology. Typically, these participants would link the two tracking technologies together, and those who were trying to lose weight would aim to have a calorie deficit. We explain participant's ongoing use of multiple tracking technologies in section 5.3.3.3.

Further showing the myriad ways in which, our participants hoped the technology would provide utility, others who were already active hoped that using a tracking technology would help keep them motivated, or otherwise support their training. For example, P44 was training for a marathon (which she ran during the study) and hoped that the step-count the Fitbit offered her would help with her training over time. Similarly, L3 and L8, who were both keen cyclists and used Garmin Edge cycle computers to track their riding, took up use of a Garmin Vivofit activity tracker to give them a more holistic view of their training – taking advantage of their tracker's integration in the Garmin Connect dashboard.

[18] https://www.myfitnesspal.com/

4.1.2 Wanting to gain insights into behaviours

Beyond hoping the technology would aid their behaviour change goals, other participants were more interested in using the technology to gain insight into their behaviours, without having a behaviour change goal in mind. This motivation for tracking is most similar to Rooksby et al. (2014)'s *"diagnostic tracking"* style, but rather than having a particular aim (*"looking for a link between one thing and another"* p.1168), our participants were keen to learn more about themselves for a variety of different reasons, as outlined below.

In some cases, these participants were augmenting an existing tracking activity (similarly to P4, L3 and L8 in the previous section), but instead of being driven by a behaviour-change goal, they were interested in getting a better understanding of themselves. For example, P24 was already tracking various aspects of his physical activity either manually, by writing his rock-climbing routes and activities in a notebook, or with technology, using Strava to record his bicycle rides. However, he was not recording his swimming or other activities, and explained that he would be interested in "*something that would record swimming, cycling and all activity*". He realised that the device he was getting (a Fitbit Zip) was not capable of recording all of these activities, including swimming, but felt that *"steps is an abstract measure anyway... Ultimately what you're trying to measure is how much activity you've done in a day. If you say we're going to give you points for having moved certain distances rather than how many times you've bobbed up and down that makes more sense",* but that it would be *"interesting to see the amount of stuff that stuff takes"*.

Some participants were instead curious to compare their existing levels of activity with that of their peers (who were sometimes already using tracking technologies), or against a known goal (frequently, participants would be aware of the 10,000-step goal before tracking their activity). For example, participant L4 bought her Fitbit *"because my boyfriend got one and I wanted to compete"*, and P17 explained, *"I like stats* […] *I like to know what I've done"*.

Some other participants were interested in using the technology to help them manage their post-operative recovery, or chronic health condition. For example, P18 underwent an operation and, in conjunction with her doctor, created a recovery plan, based on steps to get her back to full health, *"the Fitbit has been really useful because it* [the surgery] *was quite major. It's been really useful having the Fitbit during the day... I came out of hospital and the first two weeks was kinda shuffling around, holding on to the wall* […] *it was good that I ended up having the weekly email so I could go to the consultant and say, 'week 3 I did 4,000 steps a day, week 4, I did 6,000'"*.

4.1.3 Curious about data and technology

In addition to participants who wanted to change their behaviour, or learn something about themselves, other participants were purely interested in collecting data, or *"trying out"* (P21) the tracking technology to see what its capabilities were. These motivations fit well within what Rooksby et al. (2014) would consider as "*fetishised*" tracking, where *"some participants were tracking because of a purer interest in gadgets and technology"* (p.1169). One example of these fetishized trackers was participant A10, who had no health goals and was not interested in making comparisons with her data, explained, *"I kinda track a lot of stuff, so it made sense* […] *I have a calendar where I track running and stuff like that - how far I run and how many days a week*". Similarly, participant A4 explained, *"I'm an industrial engineering major here, it's all about the stats, the data and everything. I like that I can keep track of my records".*

Some participants had very specific reasons for their interest in using the tracking technology, such as A7 who worked for a big data company and was *"seeing what the possibilities with the devices were - seeing if they were things we could utilise in our own research"* and A15 who got the device so she *"could learn how to use it"* before helping run an academic study which used the device to collect data. Somewhat similarly, P7 was motivated to track so that he could capturing data which he could then practice creating visualisations with, in the statistics program R.

Other participants, such as P21, were more curious about the technology itself, and how it was progressing, *"part of the reason I want to get into the Fitbit is because I'm a big fan of the whole quantified self concept* […] *I used to be a complete fat-ass and I'm not anymore"*, but did not want to spend his own money on the device and did not have long-term aspirations for tracking.

4.1.4 Financial incentives to track

Some of our participants, primarily those from the comparison study located in Atlanta, started tracking because they received some sort of financial incentive. This was usually something that was offered through their workplace, or health insurance company, and was accomplished through earning "points" for remaining engaged with their tracker, or for reaching particular goals. Users could then earn discounts or other rewards, as P18 explained - *"points mean prizes!* […] *I get half price membership at Virgin active gym* […] *you can accrue other points and rewards - various bits and bobs"*.

Because of how public health insurance works in the US, a far greater proportion of the population, and by extension our sample, hold private health insurance policies compared to in the UK, where most of our participants were located (*"I don't have private health insurance, we've got the NHS ain't we!"* – L6). Many of these private health insurance companies would offer their customers a fitness tracking device free-of-charge, or for a nominal fee, in exchange for customers sharing their tracked data. Customers would then receive benefits if they engaged with the system or met goals set by the organisation. One participant (A4, who was not providing his tracked data at the point we spoke to him) gave us his interpretation of these policies, likening activity trackers to the "black boxes" that car insurance companies use to track driving standards and lower the premium for safe drivers: *"I feel like I wouldn't mind it if it helped me* [i.e. if he was to receive a discount]*, but if they charged me more because I haven't walked enough that would be kinda unfair* […] *I'd probably do more research now, to see if my health insurance does that. I know with car insurance you can get a tracker that sees how fast you brake and accelerate and you can get a reduction on your premium if you do safe driving. So if that helps insurance I think that would be pretty good".*

The potential of a discount, or other financial gain, was the primary motivation for many participants tracking through a wellness program. A9 explained the offer he had from his insurance company: *"if you wear it for so long and accumulate so many points per day you get points and then there's milestones along the way to get more and more as you do more activity. There were four tiers and every tier you got $100 off for this upcoming year's health insurance - so up to $400"*. He went on to explain that he was aware of activity trackers before being offered to take part in the program, "*but I had no interest in getting one before the incentive programme*". However, when we asked if he had any other goals in mind from using the device he explained, *"yeah, like, losing some weight - that would be good"* – although he started using the tracker because of the potential for some financial gain, he did also have other goals in mind from its use. A8 who also took advantage of the same scheme and did not have a pre-existing interest in tracking, explained that taking part in the scheme had some positive impact on his physical activity: *"For each tier you got $100 off, so that was definitely an incentive right there. I started walking, taking the stairs rather than the elevator at work and trying to be more active to reach that goal. It was more like a game for me I guess"*.

As a result of participation, or potential participation, in workplace wellness or similar programs, numerous participants mentioned concerns surrounding the privacy of their data, or what interest those running the schemes might have in the data. We received a mixed response from participants when further questioning them about this. Some participants, including both those located in Atlanta and London, were concerned about how this data might be used, about both the more immediate uses and about future repercussions arising from the data, such as A4 expressed above. However, most participants were initially unconcerned about sharing their data, and after some thought and questioning felt similarly to A17, who said, *"I think it's fine as long as we are able to confirm that it wouldn't have any negative impact to it… for example increasing insurance"*. It was these negative impacts, such as increasing insurance premiums or restricting access to healthcare facilities that other participants were more concerned about, as A17 continued to reflect: *"as pessimistic as it sounds, health insurance companies aren't the best people in the world. From what we've seen in the past they've done things like that all the time"*.

Many participants' were not concerned about what could be done with their data at the current point in time, but were instead more concerned about what the near future might bring, as A3 explained: *"I don't think the data is significant enough yet to be a danger. But I think something like the heart rate monitor that keeps track of you all day long and I definitely worry what if the insurance company gets hold of something like that and decided, 'hey, you're not looking too good we're gonna up your premiums $50 a month'"*. These concerns about use of potentially sensitive health data are further legitimised as we see the increased use of personal-tracking technologies beyond the wellness space and into healthcare, where much more sensitive data is beginning to be tracked.

Just one participant (P18) in the UK was sharing their tracked data with their health insurance company (though this was mostly because of the lack of offering in the UK), and had considered the benefits and drawbacks of doing so. She even considered if she might be able to take her data with her if she were to change insurance policy, explaining: *"I end up having to pay for my own insurance in the future and it's not the corporate policy, I've got something to show what activity I do* […] *if in the future he* [her husband] *no longer worked for the company, or he was no longer my partner and I had to have a policy of my own, then I'd be happy to share it"*. From our sample we recognised a tendency for many of the participants in the US to be happier about sharing their data with a third-party such as their employer or health insurance company, whereas many in the UK felt less inclined to do so.

Throughout this section we have seen that our participants' motivations for tracking were varied, but unsurprisingly they mostly stemmed from wanting to change their activity in some way. However, we note that ones' motivation for tracking might not necessarily match their actual use of the tracker, and that Rooksby et al (2014)'s styles of use are not a perfect match for the motivations we found our participants had for using these technologies. The ways in which users interact with their tracking devices changes over time and once they start to engage with the tracked data – something we explore in section 4.4 and throughout Chapter 5 and 6. We now move onto the next step in the self-trackers journey – selecting a tracker.

4.2 Choice of tracking technology

Having better understood how motivation impacts initial tracking, it is interesting to consider how our participants chose their tracker. At the time our studies were conducted (May 2013 - June 2015) there was a fairly broad range of trackers available, but the range was considerably more limited than today. The trackers came in a variety of form factors (e.g. clip, bracelet or even smartphone application), offered different metrics beyond steps to track (e.g. distance, heart rate, calories), and were available at a range of different costs. However, there was a lesser proliferation of inexpensive devices, and devices offering physiological tracking with heart-rate and other metrics. Some participants received their trackers as gifts and had little or no say in the choice of technology, and other participants received their tracker through their insurance company or a workplace wellness program, and therefore were similarly unable to choose the specific model.

All 50 participants who took part in our longitudinal study were given the same device, a Fitbit Zip, though they could choose the colour (a mix of devices in charcoal (34 devices), blue (10 devices) magenta (4 devices), and green (2 devices) were available). Two participants did not receive their first choice of colour (both instead received a green device). Despite not picking the specific tracker, these participants were self-selected and knew which device was being offered at the time of signing up. The 48 participants in our comparison study had a wider range of different devices, many (n=25) also choosing one of Fitbit's devices, and others including various models of *Jawbone* (n=8), *Garmin* (n=2), *Nike Fuelband* (n=2) and *Misfit* (n=2), and smartphone apps such as *Moves* (n=4), *Argus* (n=1) and Breeze (n=1). Participants in our comparison study sample included both those who were currently using an activity tracker (n=37) and those who had previously used one and had stopped using it (n=11). Recruiting both groups allowed us to gain insight into the reasons for abandonment and barriers to use. The most experienced participant reported having used an activity tracker for almost three years (and had used a pedometer before then), while the least experienced had used their tracker for only two weeks. Exactly half (n=24) reported using their tracker for more than 6 months. Many of these participants also reported using other personal informatics tools in addition to activity trackers, including dieting tools like MyFitnessPal and sleep tracking tools, such as Sleep Cycle Alarm Clock.

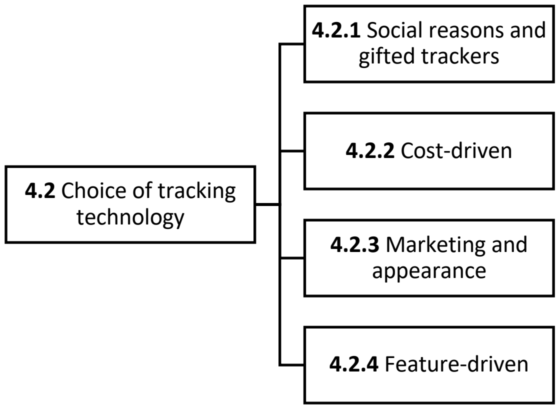

Figure 4.3 – Choice of tracking technology outline

The remainder of this section examines the reasoning behind our comparison study participants tracking system choices (visualised in Figure 4.3). This was not always a matter of choice, as some participants received their trackers as a gift, or were provided them through schemes such as workplace wellness programs, or through their health insurance company. However, the agency of this choice laid with many participants, for whom picking a tracker was thoughtful decision.

4.2.1 Social reasons and gifted trackers

Desires, and pressures, to track socially, or as part of a group, often had a large impact on a participant's choice of tracker. Those who were encouraged to track often bought the same device as their peers, to enable them to use social functionalities such as leader boards and competitions embedded in the trackers. Gifting trackers was also fairly common, some participants gave a tracker because they felt the recipient would somehow enjoy it, or benefit from its use. Other participants gifted trackers because they felt it would provide more social support and encouragement for themselves, a phenomenon that we explore in more depth in section 5.2.3.2.3. This section focuses on our participants choice of tracking technologies. We later return to discussing our participants ongoing use of these social features in Chapter 5.

The ability to use embedded social functionalities was a strong factor for many of our participants' when choosing a tracker, necessitating use of a similar device to their peers. Participants chose a similar device to their peers not only because of product recognition or herd mentality, but to allow them to leverage the social functionalities embodied in the systems, such as leader boards, time-limited competitions ("challenges") and messaging systems, which many participants found useful. For example, A10, who purchased a Fitbit Zip because her friends were also using Fitbits explained: "*what I've found to be a bigger motivator, is just competing against my friends*". Key to this choice, none of the tracking systems offered cross-platform functionalities, instead requiring users to use a tracker from the same manufacturer to use these functions. Similarly, A3 wanted to track *"just to get more activity into* [his] *day"* but wanted a Fitbit device as he felt the social support offered by his partner tracking with a similar device would help keep him motivated.

Many participants started tracking after a friend or colleague *encouraged* them to use a particular system. Often this recommendation came from a group of friends or workmates, such as with A12, who purchased Fitbit devices for himself and his wife: *"it* [the Fitbit] *became very popular at my wife's company, everyone was getting them. My father-in-law* […] *he got one and he was raving about it"*. A similar effect was true for many other participants, and again this was much more than a conformity effect and instead was related to users' wanting to compete with, and compare, the amount of activity they were doing with their peers through the social functionalities built-into the tracking devices and applications. After starting tracking many of our participants also either actively recommended a particular device to their peers, or even gave trackers as gifts to encourage others to track and create a larger social group. Gifting trackers removed one of the barriers some faced when choosing to track: the cost.

4.2.2 Cost driven

The financial outlay required to start tracking was an important consideration for most participants when choosing a tracker, many of whom chose their tracker because of its cost. Some participants started tracking with a free smartphone application rather than a dedicated device, or purchased an inexpensive device as an alternative to the one they would have preferred. Other participants did not choose their tracker as such, instead starting to track after receiving a large discount on a tracker, or receiving it free of charge, most frequently through a workplace wellness program or health insurance provider.

Four of our participants started tracking using a freely-available app on their smartphone, which for most then acted as a gateway to later purchasing a physical tracking device. For example, A4 first started using the smartphone app Moves, but then moved onto a physical device, noting *"I don't use Moves anymore because my app took up too much of my battery, then it was a while before I got a Fitbit"*. Many of our participants noted drawbacks of using smartphones for tracking, which we further discuss in section 5.2.3.5, but it is notable that newer devices such as the Apple iPhone 5S and above include low-power draw accelerometers, removing some of the barriers our participants experienced.

Receiving a discount was also a stimulus to encourage some to choose a particular device. For example, A10 chose a Fitbit Flex because her boyfriend received a large discount – *"I just had the* *opportunity to buy the Fitbit for 50% off, so I went with that".* Similarly, A21 picked her Fitbit Flex because she knew she would be purchasing further devices for her sister and mum, and wanted to save some money through a multipack offer on the Fitbit Zip: *"I found a deal where I got two Fitbits in one box that was cheaper than the other stuff"*.

Some participants received an incentive to track through a workplace wellness program or their health-insurance company, as described in section 4.1.4. Generally, these participants received their tracker free of charge or for a small, nominal, fee and had a limited choice of devices. Most of these participants were happy with the device that they were provided with, with the notable exception of A1, who explained *"I did not pick it - my company started a challenge for all of its employees",* and that she wore the device differently because she was unhappy with its appearance, *"you're supposed to wear it on your wrist, but I thought it was ugly so I wore it on the ankle"*. Unsurprisingly, considering that most trackers are intended to be visibly worn on the body, the appearance of these devices was an important consideration for many.

4.2.3 Marketing and appearance

As might be expected, the marketing of activity tracking devices was often a contributing factor in our participants' choice of tracker. This was particularly true for participants located in Atlanta, the majority of whom had seen televised adverts for different devices. Contrarily, participants in London did not mention seeing advertisements, this was likely because of the relative lack of advertisements in the UK when our studies took place (May 2013 - June 2015). Generally, the advertisements for these various tracking devices focused on people undertaking sports and other healthy lifestyle activities, thus some participants associated their tracker as a "sports" device, useful for tracking sports activities. These feelings were similarly borne out with the designs of the wearable activity trackers, the majority of which were clad in rubber and plastic portraying their functional and perhaps athletic, rather than aesthetic properties. In many cases, the appearance of the device led the participant to believe that it would be suitable for their use case, for example tracking gym activities, running or cycling, and some participants even mentioned that their device *"looked like it should be waterproof"* (A15, referring to the Fitbit Zip, which was not waterproof) and therefore suitable for tracking swimming. Whilst the appearance of these devices matched participants' expected use, or lifestyle aspirations, for many these aesthetics represented a challenge for ongoing use and engagement with the tracker, which we further unpack and explore in section 5.3.2.4.

4.2.4 Feature-driven

Wanting a particular feature, either related to the device's function as a tracking device (such as vibration-alerts for inactivity), or as an additional function (such as a silent alarm clock, or smartphone notifications), also had a strong influence on participants choice of tracker. In particular, many participants were interested in trackers from Jawbone, because they offered *"the vibration alert for the inactivity"* (A7), a reminder to move when one has not been active for a period of time. In addition to tracking their activity, participants often stated, *"*[I] *liked the idea that it would alert me to inactivity"* (A13), and this feature was only available on devices manufactured and sold by Jawbone at the time of the study.

Other participants were interested in the device offering sleep-related functionality, such as a silent, vibrating-alarm that would not wake their partner up in the morning (*"The main thing is that it has a silent buzz alarm on it. I'm married and my husband doesn't want to wake up at 4 in the morning when I go out to catch a flight on Monday mornings, so that's one thing that appealed to me about the Flex"* (A5)), smart alarm functionality (*"the biggest selling point for me, for the jawbone was the sleep timer and the fact that it would wake you up in the right stage of sleep by vibrating"* (A13)), or sleep-tracking functionality (*"the sleep I like to track because I can tell with the Fitbit, it can tell me if I'm restless or not at night. That kinda gives an indicator of how cranky I'm gunna be that day. It's also nice to know how many hours of sleep I get, because I know now that I need about 7.5 and so I'm ok when I get that"* and further explored in section 5.3.3.1).

Thus far this chapter has concentrated on our participants' motivations for choosing their tracker, in Chapter 5 chapter we examine our participants' longer-term engagements with, and feelings about, their choices of tracking technology, including challenges they faced and solutions they created in section 5.2.3.5. The remainder of this chapter continues to focus on the beginning of the self-trackers' journey, moving on from our participants choice of tracking technology to their initial interactions with their chosen trackers over their first few weeks and months of use.

4.3 Accuracy, reliability and trust

When first using their trackers many of our participants were interested in better understanding how well they tracked their activity and wanted to establish a level of trust. Some participants had prior experience with *"really bad pedometers in the 90's"* (A15) which had been unreliable or inaccurate, and other participants had *"friends* [that] *told* [them] *it* [activity trackers] *gives a lot of error"* (P16). This, along with our participants' general curiosity of the technology, resulted in many doubting the ability of their trackers to be reliable and some had concerns about how useful trackers might be if they provide an inaccurate measure.

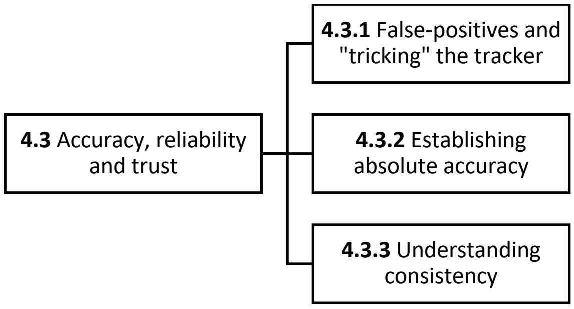

Figure 4.4 – Accuracy, reliability and trust outline

This section explores our participants' concerns around the accuracy of their tracking systems and their feelings about their absolute accuracy and consistency (visualised in Figure 4.4). A large proportion of our participants were initially concerned about their tracking technology recording false-positives for steps (i.e. recording steps being taken when they hadn't been), or mis-tracking non-step-movements. After a period of use, participants tended to be more concerned about their devices being consistent, rather than having absolute accuracy. Although the majority of the tracking systems our participants used were marketed as "activity tracking" devices, rather than step-trackers specifically, most heavily (or entirely) relied on step-counting as a measure of activity, but some participants were expecting a more holistic measure of activity beyond steps alone.

4.3.1 False-positives and "tricking" the tracker

When first receiving their tracker, many participants were keen to ascertain its reliability in counting steps. The approach we took in our longitudinal study meant that we were collocated with participants when they first started using the device, where we witnessed many of them testing their device by shaking it, or otherwise moving it in such a way to simulate a walking-pattern, exemplified by P2 shaking their tracker: *"is it counting like this* [shakes Fitbit]*? It's counted! It did like 8 steps at once!"*. Most participants were not "testing" that the tracker was working and counting steps, but instead seeing how easily it could be "tricked" into recoding steps from non-step movements. The counting of these so-called "false positives" ended up being of greater concern to participants, as we now explore.

Many participants discovered their tracker counting false-positives in a variety of different scenarios, which caused them to become concerned about the reliability of the device, sometimes feeling that these additional tracked steps undermined the usefulness of the device to some extent. For example, P16 found that his Fitbit was counting steps when he was on public transport, *"In case you get on the* *tube with this, it just runs continuously* […] *one of my friends told me it gives a lot of error, so we were on the tube and we tried it out, it runs continuously, like 20-30 steps at a time*", which caused him to further question the reliability and usefulness of his device, *"I started discounting the number of steps, like if it says 10,000 then I would think it was maybe 7,000. Like I've not lost trust in the device but then I might start reducing the actual steps... like I know that might not be true*". Other participants found similar issues with their device counting steps during non-step activities, such as when stirring soup (L5), doing carpentry (A12), or even masturbating (L24).

Over time and beyond their very initial use, we saw participants taking advantage of these false positives for various different reasons, such as: playing tricks on each other, *"my boyfriend shakes it on occasion, because he thinks it's really funny"* (P3); falsely meeting step goals, *"if it's the end of the day and it's 11,000 and if it's 50 short of the goal then I'll shake it to keep it going"* (A9); registering steps when they forgot to wear the device, "o*n the days when I forgot to wear it I was really disappointed it wouldn't show up, so I would shake it so that it registered more walks"* (P30); or even to get the device to count steps when they were doing other activities, *"I was trying to figure out where I could put my Fitbit to get what I thought was a good amount of steps* [while cycling]. *I was y'know, putting it my sock, putting it in my pants pocket, tying it to the cuff of my pants"* (A13). One participant even pointed us towards the website www.unfitbits.com and associated videos, which showcase a variety of different mechanical devices designed to falsely trick Fitbits and other activity trackers into counting steps. Participants often justified these activities to themselves in different ways, using these methods to add more steps to their record because of an inability to manually add activities, or because of limitations in the trackers' ability to reliably record different activities. Over time, we saw many participants taking advantage of these workarounds and changing their attitudes towards the importance of the absolute accuracy of the recorded step-count, as we further explore in section 5.3.3, and in section 4.3.2 below.

4.3.2 Establishing absolute accuracy

Whilst in the previous section we described how participants were concerned about their tracker recording false-positives, in this section we discuss concerns around ascertaining or understanding their trackers' absolute accuracy. This does not only refer to the tracker's ability to be "tricked" into counting false-positives, but also exploring how accurately it tracks the number of steps they take, and distance they travelled in different activities such as running and walking.

Some participants went to great lengths to explore the absolute accuracy of these measures, such as P45 who *"decided that we* [him and his partner] *should do a quick accuracy test on the Fitbit"*, and took it upon himself to manually verify the number of steps recorded by his Fitbit Zip. He tested the device whilst both running and walking around a park, explaining, "*I went around Regent's Park one day and I counted my steps, and found that the Fitbit was probably overestimating* […] *by somewhere between 10 and 20%, which I thought was definitely worth knowing"*. The participant, a keen runner who had previously tracked his running with the GPS tracking application MapMyRun, wanted an accurate measure of his steps and was concerned by this inaccuracy. Before conducting these experiments, he had considered using the Fitbit to track his running, but because of the inaccuracies he discovered, and the additional useful data that MapMyRun provided him with (a GPS breadcrumb trail, and a more accurate measurement of distance and pace), he instead decided to exclusively use the Fitbit for the day-to-day NEAT activities that he did not consider to be exercise, and use the MapMyRun app for when he was running. Similarly, other participants also had initial concerns about the absolute accuracy of their tracker, but few ran such rigorous experiments, instead undertaking more simple experiments, evaluating the tracker's performance "by feel", and reluctantly tolerating the devices' inaccuracies.

4.3.3 Understanding consistency

Whilst many of our participants had initial concerns about their tracker counting false-positives, or about the *absolute* accuracy, or lack of it, of their tracker, over time many changed their attitude. After some time using their trackers, most participants were more interested in their tracker being *consistent* in the way that it measured steps and prioritised this, placing less worth on accuracy, and generally found them to work well in this regard. For example L5, whose Fitbit counted false-positives whilst stirring soup, explained that although the number might not always accurately represent the steps that she took, *"*[it] *made me think, 'ok, so I know it's not necessarily accurate, the number that I get', but I'm interested that whatever number I get is consistent* […] *Like a baseline that I can compare different days"* (L5). Other participants who had initial concerns with the device recording false-positives similarly came to prioritise consistency. Participant P16's initial concerns about his device recording false-positives whilst on public transport (described in section 4.3.1), began to lessen over time as he too prioritised consistency, in a later interview stating, *"on the whole, over the last couple of days it's done pretty good I guess ... I still think it might be slightly inaccurate, but not very much"*, further going on to explain that *"you tune yourself to that particular number after a bit, you get used to it"*.

Those who were initially concerned with their device's absolute accuracy also changed their priorities over time. For example, P45 (as discussed in section 4.3.2), considered the importance of consistency throughout his participation the longitudinal study, *"we've had a long conversation about this Danny*

– *'is it consistent?'".* He found that even though the device did not provide him with an absolute representation of the number of steps he took, that it mostly proved to be consistent, which was useful for comparing his ambulatory activities over time. However, he still noted that he "*would really like to know whether that inaccuracy that I* [he] *found in Regent's Park exists all the time",* to better understand the reliability under different circumstances, wondering: *"so walking very, very, quickly it's maybe more accurate, or if I'm being conscious of the fact that I'm tracking my steps, maybe that's part of it... there could be so many things going on - types of footwear, going up and down stairs, carrying stuff…"* - suggesting that additional experimentation may have been useful for him to further trust his device.

For the most part, participants' interest in having a consistent measure of steps was to allow them to make sense of their activities and progress over time, where they were comparing within their own tracked data, where a consistent measure was more important than having absolute accuracy with the number of steps. However, despite participants generally accepting consistency over accuracy, one situation where participants were considerably more concerned about the absolute accuracy of their trackers were when they were using the social functionalities to directly compare and compete with others, particularly when using the leader boards and competing in challenges such as those offered by Fitbit. Whilst this was true for most participants who were engaged with these features, one particularly salient example of this came from L6, who explained, *"I was a bit cynical about the reliability of the wrist one* [Fitbit Flex] *compared to the Fitbit One, because I thought if you're shaking your hands around if you're talking for example, I was thinking that you potentially might earn extra steps, or it'll register as steps and in fact it isn't. I'm sure that these guys did their research, but it just struck me... I think quite a few people on my leader board don't have Fitbit One's, I think they are in fact using the more recent designs. I'm not that sad to only compete with the same model as me, that would be taking it too far. But I do sometimes wonder when I see high numbers..."*, showing that some participants are more concerned about absolute accuracy than consistency, even if this was not related to their own data. Participants use of their trackers was often different when they were highly engaged with the social functionalities, a phenomenon which we further discuss in section 5.2.2.

4.4 Engaging with tracked data

Most of our participants used trackers that allowed them to view their tracked data on the device itself, on a smartphone application, through a connected website, and in most cases, on all three. Additionally, most of the tracking systems our participants used, including the Fitbit, also allowed users to view their tracked data in a weekly email, on leader boards and competitions and through progress notifications (e.g. *"1,000 steps until you meet your 10,000 step goal!"*), and participants could also discover the number of steps they had taken through the word of mouth of peers they had shared their data with. Beyond the number of steps taken, many of the trackers our participants used also tracked or displayed other data, including: distance travelled; number of calories burnt, including an estimate of base metabolic rate; and sometimes an abstract representation of physical activity such as an emoticon, or "smiley face" (the ways our participants used these, and other abstract representations of physical activity are further covered in section 4.4.1.2).

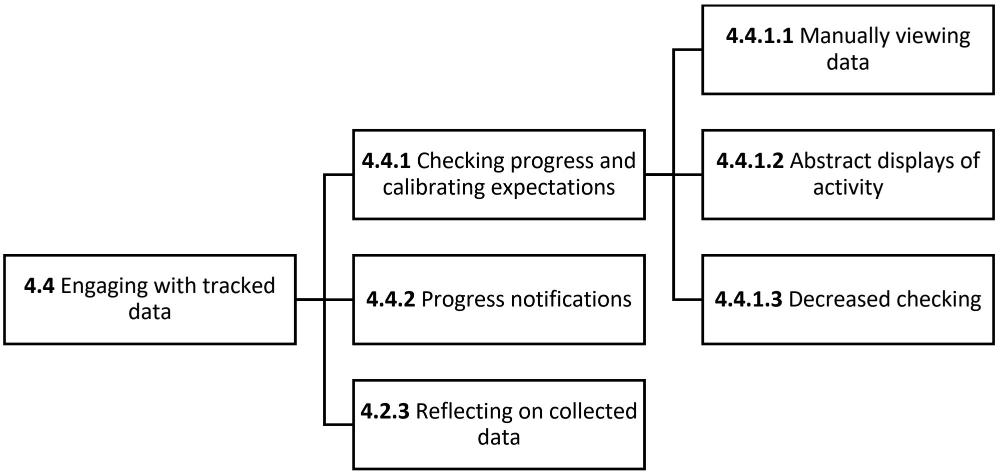

Figure 4.5 – Engaging with tracked data section outline

This section explains how and when participants viewed their tracked data when they first started using their device, and how this changed beyond their initial use (visualised in Figure 4.5). We begin with those participants in the longitudinal study who were in one of the groups with a baseline were initially unable to view their tracked data (see Chapter 3 for an overview of the method used), so where mentioned here, we refer to when these participants first had access to their data.

4.4.1 Checking progress and calibrating expectations

Initially, most participants reported regularly, manually, checking how many steps they were taking, often multiple times throughout the day, at opportune moments and during, or after, an activity. Most participants had not quantified their steps before getting their tracker and therefore did not have an accurate idea of how many steps they routinely took. Regular checking of recorded step data when first tracking helped participants better understand how many steps they were taking as part of their current and existing activities, helping them align and calibrate their step-taking expectations with reality. In addition, checking the number of steps taken would also help participants align themselves towards how many steps remained towards their step-goal for the day. Many participants were surprised to find out how many steps they were taking, often over- or underestimating how many steps they took. We asked those participants who recorded a baseline measure to predict how many steps had recorded and most underestimated significantly, such as P12 who recorded a 4-week baseline before having access to her recorded data: *"it's higher than I thought it would be, I'm really pleased about some of them over 10k, I think that's really good* […] *I was thinking that they'd be 4-5k every day"* (P12).

However, creating an understanding of how many steps make up an activity was only part of our participants' initial interest in checking their tracked data – they also wanted to better make sense of these numbers. Many of our participants were aware of a recommendation to take 10,000 steps and aligned their expectations against this, but before tracking were not sure how well they would compare against this target, as exemplified by P3, *"you're supposed to do 10,000 steps a day aren't you. I never know if I'm doing enough when I'm walking".* Some participants confused this *recommendation* with an *average* and were initially disappointed with the number of steps they were taking: *"I think I walk a bit more than the average person, so maybe around 13* [thousand]*?"*.

Beyond aligning themselves against a known goal, participants were also interested in comparing their activity levels against their peers, or people who are in a similar position to them. A13 explained that he, *"figured that they'd done enough research to say that 10,000 steps is a good thing to hit"*, but that he wanted to have a goal that was more tailored towards him - *"but then, knowing people who live similar lifestyles to me and looking at where they were, I kinda wanted to make sure that there were times in the week I was hitting the 10,000 but I also wanted to make sure that I wasn't too far below what my friends were doing"*. Some participants who were not aware of the recommendation to take 10,000 steps would positively react when first seeing the number of steps they had recorded, but would not immediately make sense of this number, requiring a goal or comparison before making judgement. For example, after comparing the number of tracked steps with those of his peers on the Fitbit app P23 stated, *"it made me realise that I actually walk more than I thought"*. Similarly, P25 wanted to get an idea of what her peers were doing, explaining: *"in order to get a sense of whether you are good or bad it's useful to know data about other people"*. Similarly, she wanted to ensure that this was a useful comparison: "*I would be disappointed if my data was compared to that of Olympic athletes because I would just feel shit"*.

4.4.1.1 Manually viewing data

Our participants had different routines for checking the number of steps they had completed, and their methods changed over time. At the beginning of the study participants would often manually check their steps, on either the device or the application, to some extent depending on the particular device they had, and where they wore it. Some participants, such as P10 had a preference to view the data directly from the device, *"because I know it's the most up to date data"*, whereas others concealed the wearable tracker about their person, making it inconvenient or impractical to view the data on the device, depending on where they were wearing it (e.g. if they were wearing the device in their underwear they could not easily view the device screen, see section 5.3.2 for a more complete description of how participants wore their devices). However, technical issues sometimes played a role here - many of our participants, and particularly those from the longitudinal study, experienced problems keeping their tracker synchronised with their smartphone, which might have otherwise been their preferred method. This meant that they were forced to check the screen on the device, which was a challenge for participants who had chosen to conceal the device on, or inside, their underwear, and were not able to readily access it. These participants would often say that they would only look at the step count at the end of the day, or sometimes even less frequently.

Of additional note, some participants (including P2, P40 and P42) chose to only use the display on the device to monitor how many steps they had completed and deliberately did not synchronise the device with the Fitbit servers. This meant they did not have a record of the number of steps they had taken each day, and instead only used the device on a day-by-day basis, similarly to how a traditional pedometer would be used. These participants believed that quantifying their daily step data was enough for them, they were either not interested in, or specifically did not want, other included functionality such as the social influence and goal-setting. In some cases this was because participants had peers who also using the Fitbit with whom they did not want to share step data. Two of these participants also experienced technical issues with synchronising, a barrier which may have contributed to their reduced usage.

4.4.1.2 Abstract displays of physical activity

Beyond the numerical presentation of data, some of the systems our participants used also offered an abstracted representation, or display, of their physical activity. Consolvo et al. (2008) famously designed and assessed such an *“glanceable display”* (p.1799) of physical activity in the Ubifit Garden, providing a visualisation showing a user’s progress towards their tracking goal. Although often used in academic projects, relatively few commercially-available trackers include an abstract display, instead showing a progress bar, cycle, or a numerical display of the number of steps taken. Exceptions include some of the Fitbit devices, including the Ultra and One (both of which include a somewhat similar abstract representation, displaying a flower whose ten leaves represent the amount of activity one has done over the previous three hours), and the Zip, which includes an abstract display, showing a emoticon face that would show a variety of different emotions (such as smiling, or frowning) depending on the user's progress (Figure 4.6).

Figure 4.6 – Fitbit Zip emoticon

Although over half of our participants used the Fitbit Zip tracker, relatively few engaged with the abstract emoticon display beyond their very first interactions with the device. Some participants expressed joy at the emoticon when they first saw it: P2 said the smiley face would *"cheer her up"* and P49 suggested it might encourage her to do more activity *"you want to go on and change the face. I suppose it's encouraging in a way and it's a good reminder to keep you on track"*. Other participants stated that they felt more attached to the device because of it. Some participants had different feelings about this abstract display: P48 exclaimed, *"my Fitbit's an arsehole!"* because she would frequently find it was *"pulling a sad face"* at her in the mornings when she had not completed many steps. Other participants felt the smiley face icon was an unnecessary distraction from the step count. For example, P10 changed the settings of his device to remove the smiley face, calories, time and distance walked displays from the screen, leaving only the step-count in order to make viewing this quicker: "*steps are the only thing that interest me. The smiley face just pissed me off - sometimes it was smiling, sometimes it was upset... I suppose it represents how on track to target you are... I don't really know, but I didn't want it"*. Similarly, P28 said, *"the smiley face is there, but it's just not very useful"*.

4.4.1.3 Decreased checking

Generally, over time, and as they became more accustomed to quantifying their steps, participants reported that they would check their recorded data less often. As P14, described, *"what I have noticed is that I'd stopped checking it every day, whereas I remember early on, and even mid-way through, that I was always checking how much I did"* (P14_FU). Most participants first started using their tracking technologies they were curious to learn how many steps they took in different activities. P49 explained how, *"you have this initial excitement and this initial kind of 'I wonder how many steps I do' - anywhere and everywhere, in the gym and outside",* but she went on to note that this, *"obviously stopped after a while"*. As the novelty of the technology wore-off, many participants became less engaged with tracking, but this was not the sole reason behind the general habit of checking steps less frequently – instead this was partly because participants were learning, or getting a *"grasp of"* (P34_FU) how their how their ambulatory activities translated into a specific number of steps, so they were less reliant on the technology to track the steps for them.

Most participants were curious to understand how their steps were distributed throughout the day, some would calculate the number of steps they took in different activities, such as going to the gym or walking to work. However, as P49 explained, *"once you know how many steps you do in half an hour on the treadmill that's it - you know it"* - by making these calculations many participants discovered that, even after just a short-period of tracking, they had an understanding of the number of steps they took in different activities, beginning to satisfy their curiosity. Participants in both studies regularly told us the number of steps, or distance, of their regular routes: *"I monitor all the walks, so I now know roughly - I know my morning walk now is 2 miles and I can make it 2.5 miles if I do a figure of 8 around the pond and things like that"* (P18), showing how they began to internalise this knowledge. This was particularly true for routine activities, as P47 explained, *"if you have a routine and you walk Monday-Friday, to the same place, every day, that's what you do, after a while you learn how many steps you do"*, further noting that *"maybe that's it - it's enough with you knowing that"* (P47). Further to this, many of our participants explained that as a result of their continued tracking, they had gained an internalised awareness of how many steps they were taking without even having to check their tracker: *"I can tell now... I've got a pretty good grasp of when I've done a 10,000 day. And when I've done a 3,000 day"* (P34). These participants started using their tracker to quantify the number of steps they were taking, but with continued use they learnt from it, and even began to assimilate some of its functionality, leading some to lose engagement or stop tracking, having learnt enough from the device.

Most participants checked their step-count less frequently as their time using the tracker progressed, which also often coincided with them becoming less engaged. Once the initial novelty wore off, many participants instead took a more reflective approach to engaging with their data, tending to rely more heavily on the notifications from the device, the weekly summary email and looking back over historically recorded data. During these periods of reflection, participants would compare their tracked data over time, making sense of it in relation to their expectations and considering if or how it might influence their behaviour. One could imagine that a lack of engagement with the tracker early on in the self-trackers journey could result in abandoning tracking, and indeed, some participants found that they learnt enough from a short-term use of the device to stop using it entirely. However, most trackers offered embedded functionalities which would encourage participants to remain engaged with, and aware of, their step-count for the day so far. These functionalities included push progress notifications and weekly round-up emails, which had the effect of encouraging continued awareness of the tracked activities.

4.4.2 Progress notifications

Many of the activity tracking technologies our participants used, including the Fitbit, provide a default (but changeable) daily goal of 10,000 steps, and can be configured to send a notification when users are close to their goal (e.g. *"only 500 steps to go!"*), or after the goal has been reached (e.g. *"Nailed it!"*). Many of our participants found these notifications useful for making them aware of how many steps they had taken and found that they might even encourage them to meet their goal if they were delivered at an appropriate time, in an appropriate context.

Unfortunately, most participants suggested that these notifications would usually appear at the wrong moment, for example at the end of the day, *"you get notifications on your phone: 'do 800 more steps and you will pass this person'* […] *but it usually happens towards the end of the day when it's useless information"* (L5), or after having arrived from home, as P34 explains, *"by that point I have no way to do it, I'm not going to go outside and do some steps for the sake of it"*. Many participants suggested that if these notifications were more contextually-aware that they might be more successful in encouraging them to change their habits, as further explained by P34, "*just occasionally I imagine there might be a situation where it catches me, just before I leave work and it goes 'go on, you're nearly there' and I go 'oh, go on then, I'll take the stairs'. It would have to catch me at that point"*. If, for example the notification appeared on their phone when they were about to step into a lift, or when they were waiting for a bus, these types of context aware notifications would be an opportunity for the system to successfully "nudge" participants at point of decision, tying into the System-1 behaviour change thought-process of fast, instinctive decisions as defined by Kahneman (2003).

4.4.3 Reflecting on collected data

So far in this chapter we have mostly concerned ourselves with discussing how participants interacted with their recently-tracked data, or their data tracked for the day so far. However, one of the key functionalities of personal informatics systems is the ability to allow their users to view historic data. These visualisations generally take the form of simple interactive graphs of historic data, usually using bar-charts or histograms, on a mobile application or website. However, despite the discussions and focus in the literature around reflecting on personal data, it is interesting to note that few of our participants reported being engaged in reflecting on their tracked data as a matter of course. This may be because of difficulties in interpreting and making sense of the data, or may perhaps be because of a lack of utility in doing so. In addition to the historic representations that participants must actively look for, some of the tracking technologies our participants used, including the Fitbit which was used by most of our participants, also offered a periodic (usually weekly) email containing a round-up of the prior week's activities – the number of steps taken on each day, how these compared between each another, and against previous weeks.

One obvious challenge for users when looking back over, and reflecting on, their data at the start of their self-tracking journey is the limited scope of their data – if one has only been tracking for 1-month, then one only has 1-month of data available. However, most participants were more interested in looking through their more recently tracked data anyway, as explained by A7: *"6 months or a year ago's data is not that interesting compared to now - really, the bigger comparison that I want to make is last week compared to now"*. A7 appeared to not find any utility in his historically tracked data, but we wished to better understand if or how other participants used and interacted with this data, and how important or useful they thought that it might prove to be. We further explored this point during interviews with participants who had been tracking for longer. A3 from the comparison study explained that for him, *"most of my interest is in it relative to where I started. In the grand scheme of things I don't care how many calories are in and out, I don't care how many steps I'm getting, I just want to know that I'm making progress and getting healthier. So as far as the actual data. No. I don't need to be able to check out every daily number for the last two years, no"*. His interest in seeing his progress over time suggests that there is potentially some worth in the knowledge, or meaning, embedded within his historically tracked data, but one could imagine that the data itself is inaccessible and difficult to make sense of. Perhaps supporting this interpretation, L3 explained, *"I kinda scroll through the past 2 or 3 days and stuff* […] *I'll look back not too far, maybe maximum week, just to see the trends and stuff* […] *almost looking at the step data reminds me what I've been doing in a way. But I don't look back too far really"*. Participant L3's explanation of his use of the historically tracked data adds further depth to our understanding – reflecting on his data helped him remember what he had been doing and perhaps contrarily to this, in order to make sense of the tracked one needs some context around it.

Having a knowledge of the context surrounding the tracked data is key to being able to make sense of and interpret it, as the data alone do not paint the whole picture. An example showing the importance of context when interpreting tracked data comes from L5, she explained: "w*hen I first got the Fitbit I noticed that on Tuesdays I walked more, because I was meeting students* […] *once the* *battery died and I didn't use it for one or two weeks I had already gained that knowledge".* With the knowledge of her schedule, knowing that she had been meeting students on Tuesdays, she was able to reflect on her tracked data and understand why her steps were higher on those days – which she, of course, still remembered 2-weeks later. However, without context this interpretation would be impossible to make - one could imagine forgetting the student meetings a year later and then failing to make the interpretation once the context around the activity has disappeared. In other situations this could lead to missed opportunities for making meaningful behavioural changes, for example with seasonal conditions effecting activities such as getting off the tube a stop earlier once the weather starts to improve. Understanding the miniature of patterns in tracked activity and then relating them to contextual factors such as these is difficult to achieve using the data visualisation tools currently available in personal informatics systems, and could perhaps be better accomplished by removing the burden from the user in making these associations, through the use of technologies such as artificial intelligence and machine learning.

Whilst the majority of our participants appeared to be relatively uninterested in looking through their historically tracked data (indeed some were unaware of how to look back at their historically tracked data: *"I will go back and look at the past week on the app. I'm sure there's a way on the website to see much more data, but I haven't done that and I probably should. I think that's an interesting idea"* – A5), some participants were more interested in the data and sometimes had particular wants or requites for it. For example, a particular want of two participants (P24 and P27) was to record personal data to practise visualisations with in the statistical programming language R, and another wanted to create a historical record of various personal and health data, conceiving this data to have some useful purpose in the future (P45). Perhaps unsurprisingly, given their relative disinterest in reviewing their historically tracked data, most participants were generally not concerned about being able to keep a historic record of their tracked activity, and were not worried about losing this if they were to change trackers.

Beyond participants manually checking and reflecting on their tracked data, most used tracking systems that provided a periodic weekly email providing an overview of: the number of steps they had completed in the previous 7 days; their most and least active days; any badges they had achieved; and a comparison with their friend's step count over the past week. Congruous with how we described our participants reflecting on their recently tracked data, participants enjoyed reading these emails as they *"give you a chance to reflect"* (P3) upon the previous week's activity. Some participants also suggested that these emails might be useful because, *"when you get your weekly email through that says 'you've only done this amount' that can spur you on to do more I think. It* *maybe made me… it brought it to my attention that perhaps that week you didn't do very much, and therefore this week you really need to do a bit more"* (P49), suggesting that bringing this recent data to the attention of a user might potentially be useful in encouraging them to change their behaviour. This appeared to be particularly useful for those participants who were becoming less engaged with tracking, and who were otherwise not checking the number of steps they were recording, as the email encouraged the participants to engage with their tracked data.

In this section we have described how our participants interacted with their tracked data during the start of their self-tracking journey. In the next section we instead focus on the *initial* effects that tracking had on our participants – their phycological, emotional and behavioural responses to using their tracking devices and interacting with their data.

4.5 Initial responses to tracking

When our participants first started using their activity tracking technologies most reacted to their use in some way, either reporting making changes to their physical activity, or reporting an affective reaction – a change in their feelings about the tracked activity. Earlier in this chapter, in section 4.4, we briefly touched upon the different ways our participants reacted when seeing their tracked data for the first time (often after recording a baseline period of activity), where they often had little point of reference to make sense of it. In this part of the chapter we instead focus on our participants responses and reactions at the beginning of their self-tracking journey – focusing on their behavioural and affective responses over the first few weeks and months of use.

The distinction we draw between affective and behavioural responses is similar to other work in personal informatics: Cox, Bird and Fleck (2013) coined the term "digital epiphany" to mean *"a striking realisation about something"* (p.2) which involves a digital behaviour (such as social media usage) and is the result of use of a digital personal informatics tool (the authors use Rescuetime and the Fitbit as examples). In their paper the authors present two types of epiphany, acceptance and change. These effects happen when, as a result of knowledge or a realisation gained through use of a personal informatics system, a person either accepts a behaviour they had previously considered undesirable or makes a conscious decision to change an existing behaviour. Similarly, in Singh et al. (2017), people suffering from chronic pain serendipitously discovered their movement range capabilities by wearing movement trackers on their back. Rather than acceptance, after an emotional response of positive surprise, the discovery initiated a process of learning about themselves and of discovering ways that the tracker feedback could support behavioural changes (e.g. increase awareness, movement pacing) that without was not possible.

When first tracking their activity, and seeing their tracked data, almost all our participants responded in some way – most commonly by increasing the number of steps they took. However, in addition to the changes in behaviour we witnessed, we also saw some participants having a more emotional response to tracking their activity. From our observations and interviews with participants after they first used their trackers, we categorised these initial effects into two broad types: affective responses (i.e. their feelings about their tracked activity and whether they accepted their exiting behaviour); and, behavioural responses (i.e. making a change to their activity in some way).

Participant's affective responses simply came in for form of a positive, or negative, response to their tracked data, and their behavioural response primarily came in the form of taking more steps – none of our participants reported taking fewer steps as a result of tracking their activity. However, we did also see some participants making other behavioural changes beyond increasing the number of steps they were taking, which we will discuss later in this chapter, and in more depth in section 6.2. We discuss these three response categories (positive, negative and change, as presented in Figure 4.7) in relation to participants' initial use throughout the following sections.

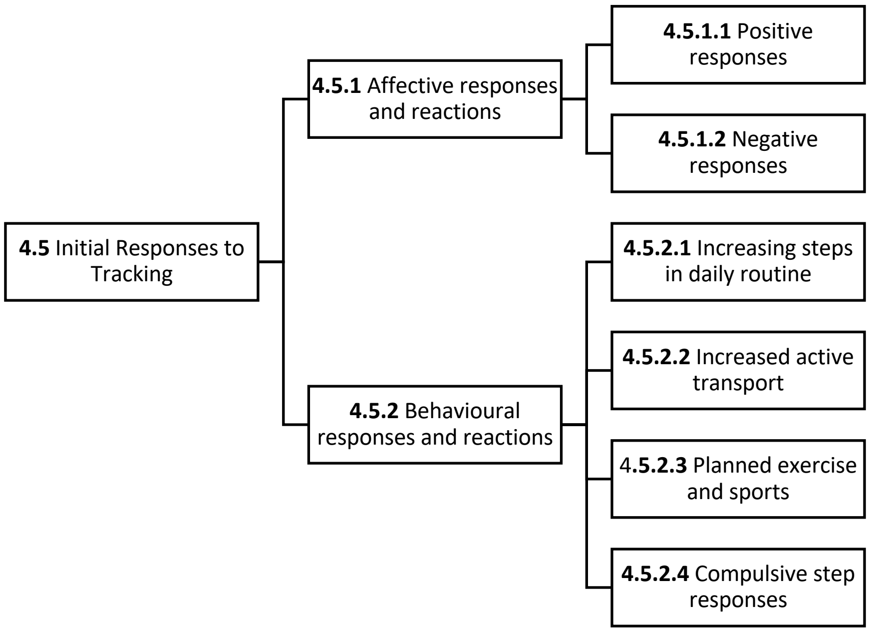

Figure 4.7 – Initial responses to tracking section outline

Much of the data in this section was collected from participants in our longitudinal study, where our approach allowed us to better understand these initial effects and their changing responses to use of the technology, whereas the majority of the participants in the comparison study were reflecting on their initial use, which may have occurred some time in the past.

4.5.1 Affective responses and reactions

As a result of using their tracker, and over the first few weeks and months of tracking, many of our participants had an affective response to seeing their recorded data. These responses generally arose soon after participants first accessed and made sense of their tracked data and were a direct reaction to their expectation of their performance compared with the recorded data. We classified our participants' affective responses as part of our overall thematic analysis (Braun and Clarke, 2006), appropriately coding their responses within the context of the semi-structured interview recording. Most frequently this was done when a participant was looking at, or reflecting on, their tracked data. We have classified positive responses as those where participants were pleased, or happy, with the number of steps they have recorded – often where this number was greater than they had expected. Instead, negative reactions are those where participants have indicated they were expecting to have taken more steps than the data indicated.

In this section we first examine those who had a positive reaction after tracking, before discussing those who were less happy. As one might expect, some of those participants who were satisfied with their tracked activity levels did not feel determined to make significant changes to their existing activities, but despite this the vast majority still reported changing their behaviour to take more steps. Similarly, we found that negative responses to tracking were often, but not always, linked with participants wanting to change their behaviour in some way. For example, some participants who were unhappy with the number of steps they were taking felt unable to increase their activity levels and thus felt *resigned* to continue without changing their behaviour.

4.5.1.1 Positive responses

After their initial interactions with their tracking systems, some participants reported being happy, or *satisfied,* with the number of steps they were taking. As we began to explain in section 4.4.1, participants often had these positive feelings after they discovered they were more active than they had anticipated, or were otherwise pleased with how active their trackers indicated they were. Many participants who were satisfied with their behaviour were aware of a recommendation to take 10,000 steps each day and often believed they would fall far short of this goal, but contrary to their expectations, either took more than this recommended level of steps, or took an amount that they were otherwise happy with. Some of those participants who were *satisfied* with their activity decided their previous level of activity, or steps, were "good enough" and therefore did not intend to make any conscious effort to take more steps. For example, P20, claimed the Fitbit had no effect on the number of steps she took, stating: *"no, I've not changed my behaviour. I have a friend who loves walking, so we try to once a week have a long walk… I already usually do enough of steps"*, and P27, who believed his existing routine provided him with enough steps (regularly going above the 10,000 step recommendation as a result of his commute to work): *"I've not changed my activity as a result of this, it's just my routine… I think I already do enough"*.

Some participants who had a positive affective response to tracking did not regularly meet the 10,000 step goal, but despite this were still satisfied with their existing activity. For example, upon seeing his baseline record of steps P16 said, *"I think I might start caring less about my walking habits now... It just occurred to me that when I do nothing I do 3,000 steps. Just coming to campus I've crossed 6,000 steps. Now that I know I do 6,000 steps without doing much I'm pretty sure I can easily cross the threshold of 10,000"*. However, the majority of those participants who were happy with their existing levels of activity still made changes to increase the number of steps they were taking during their initial uses of the tracker.

4.5.1.2 Negative responses

Other participants reported feeling negative towards their tracked data when first using with their tracker, generally after discovering that they were taking fewer steps than they expected, or after finding changing their behaviour to be more challenging than expected. One might expect that those who have a negative reaction might attempt to change their behaviour in some way, but this was not always the case in our sample. For example, P29 was disappointed to discover that she routinely took fewer than 10,000 steps, telling us *"it's really upsetting, I thought I walked way more, I thought I'd be above average…"*. However, instead of changing her behaviour and taking more steps, she continued with her existing routine, explaining *"I get annoyed when I get home and it's 9,000 or something... then I'm like 'oh, I'm going to bed'".* As we could see from her self-reported activities, as well as her survey data, this participant was already generally active (doing weekly yoga and cheerleading, and going for 5-10km runs most weeks) and she was not using the tracker because she was interested in changing her behaviour or losing weight. However, and perhaps because not all her existing activities were accurately recorded by the Fitbit (particularly yoga, where few movements are recorded as steps, and during cheerleading, where she was not able to wear the device through fear of injury), she still felt negatively towards her tracked data. Similarly, P2 from the longitudinal study also continued without changing her behaviour, but in this case she wanted to be more active (*"I always ought to do more exercise"*). After tracking she felt that her busy schedule meant she had a lack of opportunities to be more active: *"I find it hard to engineer reasons or time to do exercise unless it was at the weekend* […] [it] *doesn't happen often as I'm usually knackered"*, resulting in her feeling resigned to not change her behaviour.

However, not all examples of participants having an initial negative response to their tracked activity resulted in feelings of resignation and in many cases participants did change their behaviour after an initial negative response. We also found that although tracked data is central to the experience of using an activity tracker, responses to use of tracking technologies are not always directly related to the tracked data itself and may instead come about through use and other activities. For example, P40 from the longitudinal study had a negative reaction to use of her tracker soon after getting it, and as a result made a substantial lifestyle change. However, in this case, her negative response was not related to the tracked data itself, but instead to her experience of walking with her Fitbit when she first started using it, as she explains, *"I thought about my health, about the movement I get every day, and I realised that I can't breathe very well because I was a smoker for a long time* […] *I quit smoking the cigarettes"*. Giving up smoking was the first of many changes that P40 made during her self-tracking journey, we further characterise these responses and others, in Chapter 6, which looks beyond the initial responses to tracking, concentrating on responses over time.

Further to affective responses, the majority of our participants reported increasing the number of steps they were taking, perhaps as an almost reactive response to tracking them. This was true for those who were already satisfied with the number of steps they were taking, many of whom also chose to increase the number of steps they were taking, as described in the following section.

4.5.2 Behavioural responses and reactions

Almost all our participants reported increasing the number of the steps they took when they first started using their activity tracker. In some cases, participants only made small changes to the number of steps they were taking, whereas in others these behavioural changes were more significant, with participants making larger changes to their lifestyle. Interestingly, our participants' behavioural responses did not always tie in with their motivation for tracking – many of those participants who were not interested in tracking to change their behaviour ended up doing so anyway. In this section we describe the various ways our participants changed their behaviour, mostly by increasing the number of steps they were taking and making *"every step count"* (P14), and the role that the tracking technology played in this. Where possible we supplemented our participant's self-reported data from interviews and diaries, through our analysis of the data recorded by their tracking devices.

Many of the changes that participants made at the beginning of their self-tracking journey seemed to have been made as a reaction to them using their step tracking technology, where mechanisms such as nudges from the tracking, and the increased salience of taking steps resulted in them subconsciously making changes that they spontaneously fitted throughout their day. One might consider these unconscious behavioural changes to originate from the "System-1" mind (see section 2.5.3), ranging from the small (such as participants dancing whilst brushing their teeth, or P14 who told us that he would always *"step"* onto the bottom stop of an escalators), to the more impactful (again, P14, who also told us that he had started walking 3-miles from the underground station to pick his son up from nursery, instead of taking the bus).

Foremost, almost all our participants reported a heightened awareness of their physical activity, and the number of steps they were taking – even if they did not directly report having increased the number of steps they were taking. Some participants explained that this heightened awareness had initially encouraged them to initially take more steps, for example, P36 explained *"I think that awareness was heightened* […] *I think that initial period when I first had it and it made me think more, it got me into better habits if you like".* However, these initial changes did not always become habitual and sometimes when participants stopped tracking and the external reinforcement was removed their changes did not continue, P36 explaining: *"but then over the long-term I don't think it really changed a massive amount. It helped to sustain those habits, but then not having used it for a bit, I can definitely see that I'm slipping back again - I'm happier to just get the bus places"*. Throughout this section we discuss the different behavioural changes that our participants made during their first few weeks and months of using their activity trackers, from the more reactive responses to using the device, to those that appeared to be more considered, and even to those that might be considered negative.

4.5.2.1 Adding more steps into their daily routine

Many of the reactive changes that participants made were small and allowed them to fit more steps into their existing daily routines, through changes such as leaving their office for lunch instead of eating lunch at their desk, or taking the stairs instead of using lifts or escalators. For example, P12 explained that she would always go out for lunch instead of eating at her desk, despite bringing lunch from home: *"I've been trying to do is always go out and get lunch with people, even though I've got my own food. So I always go out with them to get food and then go back to the office* […] *I'm not specifically trying to do exercise to get my total up, I'm trying to look for opportunities where I can walk about a bit more as part of my daily routine, which I think has been a lot more helpful for me, it doesn't feel like exercise*". As this participant explained, making small changes that could easily be integrated into her daily routine helped her to get more steps without having to make large changes to their lifestyle.

Many participants made similar small changes, such as: walking to meet colleagues instead of emailing them (e.g. P28 who was jealous that her flatmate was able to walk to colleagues at work where she could not - "*most of my work is email and phone based so I've no reason to* [walk around the office] *whereas she's got loads of colleagues in the office she can go and visit, so she can get much closer to the 10k by still getting the bus every day*"); taking more breaks to walk around and use the stairs instead of using elevators or escalators (*"I take more breaks and walk around, and rather than taking the elevator I take the stairs"* - A10, and *"taking the stairs rather than using the lift, that sorta thing"* - P29); or, walking around campus instead of taking the campus trolley (*"*[I] *walk up and down the stairs and around campus*" - A8). The behaviour change and habit literature supports the benefit of taking up these small changes, as a change paired with an existing activity is more likely to become habitual, and these changes may offer an easy way to become active throughout the day (see 2.5.4 of the literature review).

The daily routine changes that participants made were not just limited to their work environment, as participants also attempted to change their social engagements, by, for example, encouraging friends to meet up to go for a walk, rather than going for a meal, or out for drinks, as explained by P6, *"whenever I see friends I try to do stuff that requires a lot of walking"*. Other participants mentioned that after they started tracking they would go for long walks with friends, though these changes to social activities tended to happen when multiple friends or peers were tracking steps. We further discuss how these groups manifested over time in section 5.2.2. Participant 6 went on to explain that she would also encourage her friends to walk instead of taking public transport, *"I'm always trying to encourage people to walk there instead of getting the bus"*, a common way in which our participants first changed their behaviour.

4.5.2.2 Increased active transport

By far the most common strategy that participants located in London used to increase their steps was to change to their transport routines to maximise walking opportunities. This strategy particularly illustrates the importance of considering the context of use when evaluating personal technologies such as activity trackers, as although this change was common amongst those located in London, comparatively few of our participants located in Atlanta increased their active transport, and when they did, they did so in very different ways. Three-quarters of our participants were located in London (74 out of 98), which has a popular and convenient public transport system which almost all of our London-based participants relied on. In contrast, the remaining 24 of our participants who were located in Atlanta mostly relied on using cars or taxis to get themselves around the city (as one of our participants, who proves the rule, explained *"yes, I'm walking. I think I'm the only pedestrian!"*

- A19). From the examples provided by our participants use and availability of a public transport system appeared to offer multiple opportunities to more easily integrate active transport into their routines: removing the need to be tethered to a car; allowing them to take different routes to take parts of a journey by foot; ultimately, allowing people to be more flexible in choosing their transport method. Indeed, this is what many of our participants in London did, by including more active transport in their everyday routine. Throughout our research we found that the context or situation of use had impacts on how participants engaged with and reacted to their tracking devices on many different levels. We provide further evidence of the importance of considering the context of use in section 5.3.3, where we also consider how differences in context effect participants engagement and their behavioural outcomes as a result of using their tracking technologies.

Another common reaction from participants when they first started tracking was to make small changes to their transport choices to take more steps, such as getting off the underground train, or the bus, a stop earlier than they needed. For example, L5 explained to us that after she started tracking that she, *"started getting off the tube a stop earlier when going to work, and getting on a stop later. I found out that it was cheaper and I was short on money, plus I was walking with my boyfriend so it was enjoyable"*. Typically, these behavioural changes relied on the participant being engaged with their tracker or the data provided by it, as P3 explained, *"there have been times when I've been thinking like 'oh I've not actually walked as much today as I normally do' so I'll get off the train early and walk the rest of the way. I think it's partly because I'm aware that it's being monitored. But also because it makes me feel better, like if I've not been as active as I normally would*". Participants would avoid making these changes when the weather was unfavourable (i.e. too hot, or too cold). And similarly, because these behaviours were not habitual or automatically triggered, and instead relied upon the participant deciding to get off the tube and walk (a decision scaffolded by use of the technology), they typically diminished as participants levels of interest in tracking fell, the new behaviours failing to become habitual.

Often participants would report replacing either part of, or an entire, journey they might have previously taken using public transport, with walking. Sometimes, participants reported doing this to *"simplify"* (P11) their journey and maximise the number of steps they could take. For example, P11 would do things such as walk to a different underground station if this could have meant she could avoid changing trains, or avoiding an extra bus journey if she could instead travel by foot. Similarly, P28 began walking to and from her home to the underground station, rather than taking the bus, allowing her to more easily achieve her 10,000 step goal each day explaining, *"by doing all of this walking I do feel better that I am doing some exercise, which is nice. Otherwise you just go from an* *office chair to the bus to a couch via a tube* [London Underground]". Similarly, P8 explained, "*a good example is my walk to work, it's a 5-minute walk to work, but if the bus was there I'd take the bus instead - <u>if it was there</u>. But since wearing the Fitbit I'll always walk. I don't even take the bus anymore*". Although these changes were still driven by use of the technology, and engagement with the step goal, contrary to the changes we described in the previous paragraph these changes tended to be more successful in lasting over time. Whereas participants had to make a conscious decision to get off the bus or tube a stop earlier (which was perhaps reliant on them using their technology), changing a part of their journey entirely could be an automatically triggered and scaffolded behaviour within their routine, proving to be more success even after participants had stopped tracking.

Sometimes the changes participants made were quite extreme, and some even caused them health issues. For example, P11 from the longitudinal study made some large changes to her transport routines after she started tracking, with her first large change occurring during the first week of using the device – *"The first week I was wearing the Fitbit I walked from the office to my place, which was an hour and a half almost* [locations anonymised – distance between two locations approximately 2.5 miles] *I totally did that because of the Fitbit. The time I did that I was really tired and it wasn't good for my back -it was really hurting".* This happened even though the screen on her device was obscured and she was unable to access her data to see how many steps she had been taking, attributing her behaviour as a reaction to having data recorded and "being tracked". Despite the pain she had caused herself after walking 2.5 miles from work, she continued to use the technology and change her behaviour, but instead made smaller changes, as she explained: *"the previous week* [the week after the previous walk] *we went to the Design museum, and I walked home* [approximately 1.5 miles] *that was because of the Fitbit, because of the weather and because I wasn't feeling tired"*.

This section describes the different ways in which our participants integrated more active transport into their daily routines, both through reactive, and more considered changes to their routine. The next section focuses on participants taking up, or changing, planned non-NEAT activities, such as gym exercises and sports.

4.5.2.3 Planned exercise and sports

Beyond those changes that were integrated into their everyday routines, we also saw participants taking up, or changing, exercise-like activities – generally a more deliberate, or considered, change in behaviour. Whilst this was true for participants located in London and Atlanta alike, a greater proportion of our participants in Atlanta initially made changes to their behaviour by doing more planned exercise activities, compared to our participants in London who generally took more steps by integrating more active transport into their everyday routines.

Unsurprisingly, the most common exercise activities that participants took up after tracking were those that accumulate a lot of steps, such as running. Participants who already ran would run more, and others started running. A8, who in our survey told us that he used a motorised vehicle for transportation 5 or more days of the week, told us that soon after he got his tracker, he was "*on track, running and trying to meet my goal".* He had run before in his life, before becoming more sedentary, and had taken up running again after using his Misfit Shine tracker, but after less than 6-months the battery in his device died and he stopped running when he was no longer tracking. Another participant, P10, joined a gym, taking advantage of a complimentary membership arranged through his work. He commented, *"on the treadmill, thousands of steps will go past in minutes it seems, it's awesome. I'll immediately come off and start taunting other people because I'd have overtaken them doing that many steps in half an hour"*. However, once again, this behaviour did not last over a longer time, he explained: *"because of having the Fitbit I didn't use any other machines other than the treadmill because I knew that would give me a load of good steps and I could show off the next morning, having done 15,000 or something like that. But when the Fitbit went away, the excitement of going to the gym went away as well".* In both these examples the participant's new activities failed to become habitual, with stopping their new exercise activity coinciding with stopping tracking.

Stopping tracking was not always a catalyst for stopping planned exercise. Other participants started exercising when they first started tracking, and then continued to do so for a longer term. Participant A1, who was already a gym member, and was using her tracker as part of a workplace wellness program, explained, "*I think it encouraged me. It made me get up and… I don't go to the gym, I hate gyms, but I do aerobics classes. It definitely motivated me when I thought 'I could just skip it and go straight home, but wait - I'm on a team for this'. We were in a team of 4 and I didn't want to let my team down. So, I would get up and go to dance class".* Being part of her workplace wellness scheme encouraged her to attend classes much more regularly, but she explained that when her workplace wellness scheme ended, she began to stop going to the classes again, and reverted to her previous behaviours.

Each of the three examples we have used above involved participants making a behavioural change soon after using their tracking technology, and then giving up that change. Here we have purposely focused on examples where a participant has changed their physical activity at the beginning of their tracking journey, rather than as a more considered response after use, where we had more positive examples (see Chapter 6 for a more detailed view of these changes). Indeed, from many of the examples in our studies, it seemed that the initial changes to planned exercise were made driven solely in the pursuit of tracking more steps, rather than being more active, and these changes to physical activity would oftentimes fail to become habitual. Countless examples in the literature point towards the difficulty in starting a new physical activity regime (e.g. Booth et al. 1997, Salmon et al. 2003), and how many fail to become habitual. Indeed, the longitudinal approach taken in our first study was designed to move beyond the problem of focusing on novelty effects in short-term studies of behaviour change technologies. From the above examples it appears that use of activity tracking technologies provides little resolution to the problems of unstained behaviour change. However, the changes we presented in sections 4.5.2.1 and 4.5.2.2 were positive and sustained over time. Throughout the remainder of this thesis we discuss our participants longer-term use of tracking technologies, the implications of their initial reactions and uses, and uncover a number of more positive outcomes.

4.5.2.4 Compulsive step responses

Some of the initial reactions our participants had when first using their technologies that could be considered compulsive, obsessive, or even in some cases, *harmful*. Similarly to the changes we saw participants make to their planned exercise activities, these behavioural responses happened because participants had a particularly strong focus on the tracked activity and a desire to improve it, sometimes at the expense of considering other activities and parts of their lifestyle. Some participants had borderline obsessive tendencies to increase the number of steps they were taking at any expense, resulting in behavioural changes which could sometimes be considered damaging, or negative, and which were frequently prioritised at the expense of alternative activities that could be considered more beneficial. The approach we took in our longitudinal study allowed us to see how participants' responses and behaviours changed over time, in some cases our participants were themselves critical of the initial responses they had to tracking, which we explain in this section.

Some of the compulsive responses our participants had involved them changing their behaviour solely to make their trackers record more steps. These changes could sometimes be considered less valuable than a more considered change in behaviour intended to make them healthier or generally more active. For example, some participants reported making changes to increase the number of steps they were tracking, without actually taking any more ambulatory activity. One extreme, yet interesting, example of this came from A16, who explained that she modified her gait when she first started tracking in order to record more steps from the same distance travelled: *"if you walk a certain way you can get more steps… it's like a more aggressive walking. It's like in between walking* *and speed walking, where you actually... It's like taking littler steps"*. Arguably, this change may have resulted in her being more active in terms of the number of calories burnt, and she was certainly being more active in terms of NEAT (see section 2.1.2 for a full review of the benefits of NEAT activities), but this was perhaps not the most meaningful of changes and indeed she did not sustain the change over time.

Other participants across both of our studies reported maximising the number of steps they were tracking by dancing, or fidgeting, in moments when they would have otherwise been inactive. These types of activities resulted in participants' trackers recording many steps - P28 was surprised by the number of steps recorded when she was dancing, noting *"by hell, you realise how many steps you're doing when you're busting a move"*, and set about maximising her steps by dancing in opportune moments. Similarly, P37 explained that since using the tracker she would dance and sing at home whilst cooking and cleaning, and P49 reported dancing around her home whilst vacuuming, so that she could get more steps without leaving her dormitory room. For some participants, at least, these types of behavioural change lasted beyond an initial novelty. For example, participant A11, who had been tracking for more than 6-months mentioned how she had recently discussed with a friend who was also tracking: "*hopping while brushing our teeth and pacing while doing other things at home or whatever* […] *I dance when I do the dishes, I feel like I'm standing there for 15-20 minutes not moving, so dancing gives me a few steps. I used Duolingo and just pace from one side of the other to get steps"*.

One common element amongst many of these responses was that participants would do them to get more steps at home, without leaving the house. Participants would do this for various reasons, in many cases this was because, like in the case of P1, they had not reached their step goal at the end of the day, and wanted to take steps to reach it - *"It did for a while... Like when I wanted to get over the 10,000 step mark I would deliberately not take the tube home, <u>or if I was missing a few steps I would just pace back and forth in my tiny flat... it was ridiculous</u>"* (emphasis ours). This behaviour was not harmful as such, but for most this was a change which did not continue beyond participants' initial interactions with the device. In other cases, participants took considerably more of their steps in their home, this was particularly true for participants who were students, or worked from home. For example, P32, who worked from home took the majority of his steps inside the house when he first started using his tracker. He explained that he would *"go for a walk"* in his shared house, telling us *"*[that] *if you run from the top of the stairs to here and back, that's 100 steps"*. During the interview where he told us this one of his flatmates (also a participant in our longitudinal study – P30) overheard the conversation and interrupted, exclaiming: *"you did 7k steps IN THIS HOUSE?*

You're like a hamster in a cage! […] *you need to get out of the house".* At this point in time P28 did not feel that there was any issue with his behaviour, explaining *"if I did 100 steps on a treadmill nobody would say a damn thing. How's it any different?"*. However, over time he changed his mind and behaviour, deciding to use the data recorded by the device differently, in his follow-up interview he explained that instead of taking his steps in the house that, "[it] *make*[s] *me remember that I haven't really moved, and therefore to get out of the house"*.

Other participants, similar to P10 in the previous section, would take up, or adapt, an exercise behaviour activity specifically in order to track more steps. Sometimes these changes appeared to be positive, such as P11 who explained, *"when I go to the gym, I used to walk fast* [on the treadmill] *but now I run instead, because it counts more on the Fitbit"*. However, other times these changes could be considered less positive – P49, who was already regularly going to the gym and doing a variety of different activities (including resistance activities with weights), changed her gym routine so that she was only doing cardio-vascular activities which registered as steps on her Fitbit Zip. At her follow-up interview she explained that she had returned to doing a variety of activities in the gym, recognising the problems with skipping strength training activities, *"the Fitbit didn't make me want to do strength training any more, I just know that you're meant to do a certain amount of strength-training and I wasn't doing that. When I initially got the Fitbit all I wanted to do was just get the 10,000 steps, so that made me do something different in the gym, but I just stopped doing that after a while* […] *I just ignored it a bit more I suppose, when I was in the gym really. I didn't consider using the Fitbit in the gym so much, it was really for when I was walking out and about, it was more about your daily general activity, rather than any particular fitness thing".*

Although the initial, reactive, changes participants made when they first started using their tracking technologies were not made as a result of considered reflection on their behaviour, this does not make these changes any less worthwhile. Furthermore, whilst many of the changes participants made when they first started using their tracking technologies lasted only for a short-term, others did have a positive and lasting impact. For example, whilst P14 was no longer walking 3-miles to his son's nursery, he was still attempting to make every step count and would walk up the stairs instead of using an escalator. Indeed, many participants reported continuing with the reactive changes they made when first tracking, even after they had stopped tracking, for example, *"I definitely always still walk up escalators now, and I didn't before... because I know that it is just that little bit of increase in exercise that I wasn't doing, so I think actually that has stuck with me, I do that every day"* (P7). Other participants continued with more meaningful changes to their activity, such as P6 who, 18-months after starting use of her Fitbit, was still leaving work to go for a walk during her lunch break, was still meeting her friends in the park for walks, and continued to make other changes to her activity after she more carefully considered her data and the different activities she was doing.

4.6 Summary and discussion

Throughout this chapter we have focused on presenting the beginning of the "self-tracker's journey". This characterisation started with an overview of our participants' reasons for taking up tracking, their motivations and expectations and their choice of tracking technologies. We then focused on their initial interactions over their first few weeks and months of use: the processes of establishing trust with; and, the ways in which they engaged with the tracked data. Finally, we presented the different ways in which our participants responded to their initial uses of the tracking technologies, both in terms of their feelings towards tracking (affective responses), and any behavioural changes they made.

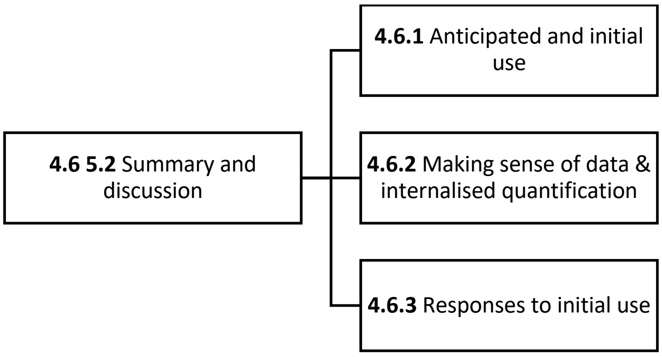

Figure 4.8 – Chapter 4 discussion outline

This discussion articulates our findings in relation to existing work, showing how our results confirm and extend previous research. In particular we focus on three contributions (outlined in Figure 4.8): a comparison between users initial motivations to track, and their actual initial use, showing how these systems can initially encourage interest in behavioural change; how users initially made sense of their tracked data, as they checked their quantified steps less frequently, particularly as they began to learn how many steps they were taking without needing to check – "internalising" this quantification of steps, even early in their tracking journey; and finally, the reactive and often little considered responses to initial use, often, but not always, resulting in an increase in steps. In each of these areas we build upon existing knowledge, extend our current understanding of the ways in which people begin their self-tracking journey and discuss recommendations for future design and practice.

Purposefully, the findings presented in this chapter represent only the beginning of the self-tracker's journey, and do not accurately represent longer-term use. Many existing studies are short term and equally only represent initial use, but often do not portray this choice as intentional. Instead, by deliberately separating results from initial use, and use over time, we are better able to characterise and understand the different phases of tracking, and how use and responses to tracking change over time. We go on to present participant's use over time and in Chapter 5 and Chapter 6 respectively.

4.6.1 Anticipated and initial use

Our participants had varied motivations for tracking, and whilst many had a behaviour change goal in mind (most frequently weight-loss), this was not always the case. Other participants were instead: tracking because they had been encouraged to by someone else or had received the tracker as a gift; interested in gaining insights into their behaviours; curious about the technology; or, tracking because of a financial incentive. It is a common misconception that people only track their behaviour because they are looking to change it, which we found was often not the case. Models (e.g. Li et al. 2010, Epstein et al. 2015) also suggest that those who *are* looking to change their behaviour choose to track in a systematic way, deciding what to track, and what to track it with, before acting upon this tracked data. However, we found that people's real-world motivations for tracking are much more complicated, perhaps better aligning with Rooksby et al. (2014)'s styles of tracking, which are based on people's *actual use of tracking technologies* in the real world (presented in 2.3.1). Furthermore, some of those who went on to change their behaviour had not initially started tracking with this intention, which the existing models of personal informatics systems do little to account for. The reality of use is much more complicated than much of the current literature suggests, which is not surprising given the way that these technologies are so personal, becoming part of everyday life, and real-world use does not suit reductionist models.

Interestingly, although participant's motivations for tracking aligned with Rooksby et al. (2014), their ongoing use of tracking systems did not always align with their motivations for tracking, and they often ended up tracking in a different *style*: even their very first interactions with the tracker could result in responses incongruous with their motivations. Frequently this resulted in participants chasing a behavioural change, as those not previously interested in changing their behaviour became motivated to do so. This was often either as a response to seeing the number of steps they were taking and comparing this to a goal of 10,000 steps, or because of engaging with some part of the social functionality (further discussed in the following chapter). Some of those who went on to change their behaviour had not initially started tracking with this intention, which the existing models of personal informatics systems do little to account for. The reality of people behaviour is much more complicated than much of the current literature suggests, which is not surprising given the way that these technologies are so personal, becoming part of everyday life.

Focusing on those participants who were using their trackers to aid them in a process of behaviour change, the transtheoretical model of behaviour change (Prochaska, Johnson and Lee, 1998) suggests five stages of change: precontemplation, contemplation, preparation, action and maintenance. Our findings show that those using, and considering use of, activity tracking technologies for behaviour change may fall in to any of these stages. This means that technologies should not just support those in the contemplation and preparation stages, where one might typically imagine those interested in behaviour change might sit within the model, but also in the precontemplation, action and maintenance stages. Those who are designing and studying self-tracking technologies should be aware of the many different reasons users are adopting these technologies, and consider these when designing and evaluating them.

4.6.2 Making sense of data and internalised quantification

We found that our participants, at least at the beginning of their tracking journey, rarely engaged with their historically tracked data beyond the previous week or two, instead tending to focus on more recently tracked data. Furthermore, as participants progressed beyond their first weeks of tracking, many became less engaged with even their more recently tracked data - this was often because they had claimed to have internalised the quantification of the number of steps they were taking, so were less reliant on the measurement provided by their tracker.

Participant's lack of engagement with more historically tracked data was in part because of the difficulties in understanding and interpreting this data, particularly as it lacked contextual information. Whereas, when used in the moment, the data provides users with additional information through the quantification of steps, the tracked data alone lacks any contextual information, making it difficult to engage with once memories have passed. Although multiple forms of personal data visualisation have been designed and evaluated in academia (e.g. Lee, Cha and Nam, 2015; Khot et al. 2017; Crossley et al. 2019), few other options were available in the commercial trackers our participants were using. These instead usually relied on a simple histogram, which may be difficult to make sense of and might not be appropriate for the questions self-trackers ask of their data, or the insights they are looking for (Li, Dey and Forlizzi, 2011; Huang et al. 2014).

Even during their initial uses with the tracking technologies, many participants reported gaining an understanding, or sense of, the number of steps they were taking without having to look at their tracker (i.e. "this felt like a 10,000 step day"). Initially participants reported checking the number of steps recorded by their tracker multiple times each day, particularly as they were ascertaining the accuracy of their tracker and building up an understanding of the number of steps they took.

However, as they began to internalise this understanding they checked their trackers less frequently, and ultimately decreased their levels of engagement. Similarly, to Mamykina et al. (2008), who designed and evaluated a system for newly diagnosed people with diabetes, this starts to indicate that participants can have meaningful interactions, and gain insights into their behaviours, even over a shorter period of use. In a longer time-frame this might result in participants stopping tracking (discussed in the next chapter), but in a shorter-time results in a loss of engagement, potentially resulting in participants not using other features. However, it also begins to illustrate how long-term use of these devices is not always necessary for meaningful interactions: these participants gained insights into their behaviours and learned new skills over a short-term, resulting in the technology becoming obsolete.

Although we saw little evidence of participants reflecting on their tracked data, they did instead reflect on their memories and experience of tracking, showing an appetite for gaining insights from their experience in self-tracking. When not engaging with their tracked data, self-trackers are missing the opportunity to discover potentially useful insights which could support them in meeting their goals. Use of different visualisations, more appropriate to their requirements, along with the collection of additional contextual information (such as calendar events, whereabouts of, and the types of activity done) could be useful. Additionally, machine learning techniques could be leveraged, to aid self-trackers in finding utility from their tracked data. These advancements could help participants move beyond the initial behavioural responses to tracking, which were not always well-considered and often seemed to be a reaction to tracking a particular behaviour, as we now discuss.

4.6.3 Responses to initial use

This chapter presented a framework of the initial responses to tracker use, including the affective (both positive and negative) and behavioural responses that participants made when first interacting with their trackers and accessing their tracked data. Many of these initial effects of tracking appeared to be reactive to the technology, rather than a considered change, resulting from subconscious “System-1” thinking, rather than from more-considered System-2 thinking (Kahneman, 2011). As such, changes were mostly directly related to the tracked activity (i.e. steps) and did not always align with participants broader goals (outlined in 4.1), which was usually something beyond “taking more steps”.

The responses we present build upon the *Digital Epiphanies* work by Cox, Bird and Fleck (2013), who defined digital epiphanies where a person either accepts, or changes, their behaviour after recording it with a personal informatics tool. We extend their categorisations by creating a more nuanced view of the initial effects of tracking by, in section 4.5, providing evidence to show that participants' affective responses to tracked data might not only represent *positive* emotions such as *acceptance* to their behaviour, but also *negative* responses. Furthermore, we show that these affective and behavioural responses are not mutually exclusive and might happen concurrently, at the same time. For example, a participant might feel happy about the amount of activity they have tracked, whilst at the same time as making a further change. This is contrary to Cox et al. (2013), whose participants who were happy with, or accepted, their previous activity levels were not inspired to go on to make changes to their tracked activity. A limitation of both the digital epiphanies work and the research we present in this chapter, is that they relate only to users' initial responses to tracking over a shorter time-period and as such may not be representative of longer-term use and reflection. We further enrich our characterisation by considering in longer-term use in Chapter 6.

When first using their trackers, the majority of our participants focused on increasing the number of steps they were taking each day, not surprising given the strong focus on steps that their activity trackers had. However, this change often appeared to be a reaction to tracking steps, rather than a considered change, and was often not completely aligned with their overall goals. Furthermore, these changes began to point towards unintended, and potentially even harmful, consequences of tracking. Previous work has begun to discuss the pitfalls of self-tracking, including overreliance (Attig and Franke, 2019), reduced enjoyment (Etkin, 2016) and negative reminders (Ancker et al. 2015), but has not discussed how positive changes in one aspect (i.e. steps or cardiovascular exercise) could result in a negative change in another (i.e. strength-training or weight-bearing activities). One could argue that any increase to physical activity is a positive change, but this is not always the case, particularly when a cardiovascular activity has been prioritised ahead of a more rounded exercise regime. Despite the benefits of increased NEAT activity, these activities alone are not enough – physical activity guidelines from across the world (e.g. NHS.uk, 2011) promote not just cardiovascular exercises, but also resistance, or weight-training activities. There are a wide range of negative outcomes related to a lack of resistance-bearing activities in certain populations, including muscle atrophy (Hunter, McCarthy and Bamman, 2004) and even osteoporosis (Bonaiuti et al. 2002). It is important that any potential unintended negative consequences of tracking are considered when designing and evaluating tracking technologies, especially if they are to be promoted as a potential solution to inactivity by health care professionals.

4.6.4 Chapter Summary

This chapter provides an overview of the beginning of the self-tracker's journey, focusing on participants' reasons for taking up tracking, their choice of tracking technologies, and their interactions and reactions to using their trackers over their first few weeks and months of use. By limiting the scope of this chapter, our approach is typical of other research in the field, where studies are often undertaken over a relatively short-term, or where interviews studies concentrate on a single point-in-time. The next chapter shifts focus to look at, in more detail, how people interacted with their trackers over a longer time frame, before we the final findings chapter where we better understand the various outcomes that result from using a tracker over time.

Chapter 5. Use and Engagement Over Time

So far, this thesis has concentrated on the beginning of the self-tracker's journey: the processes of deciding and starting to track, initial interactions with the tracker, and the ways in which users respond to initial use of their trackers. If parts of popular media are to be believed (e.g. Arthur, 2014, in *The Guardian*), wearable devices, and activity trackers in particular, are often "abandoned" after a short period of use and therefore, these initial interactions might the only ones that many users will have. Similarly, popular media and commercial reports often place focus on the importance of continued tracking: clearly beneficial for stakeholders selling trackers, or utilising the data in some way, but not necessarily for the end user. Academic research within personal informatics has begun to look at the use-length of personal informatics systems: Shin et al. (2019) classify use of 6-months or more as *long-term* and suggest novelty effects last up to 3-months. However, when considering use from a sustainability point of view (Vaajakari, 2018), or compared to use of other new technologies this figure does seem low (Rogers, 2003).

This chapter meets our second research objective, to **explore how healthy adults use, and not use, trackers over time and the factors that impact this**. Real-world use of tracking technologies is not as simple as picking a tracker, using it, and then becoming more active. Instead people's use of tracking technologies over time is complex and many people do not remain consistently engaged with their trackers over a long-term, but existing research does not ascertain the extent to which this is important. With a technology so closely enmeshed into people's everyday lives and behaviours, common occurrences such as extreme weather or depleted batteries can have a large effect on both behaviour change and continued use and engagement with the technologies. The ways people engage with their trackers changes over time, and is strongly related to situated use, which changes with the weather and seasons, with social events and activities, and with sickness and health. This chapter focuses on participants' use of their trackers over time, considering the technologies themselves and the functionalities built in to them, as well as external contextual factors.

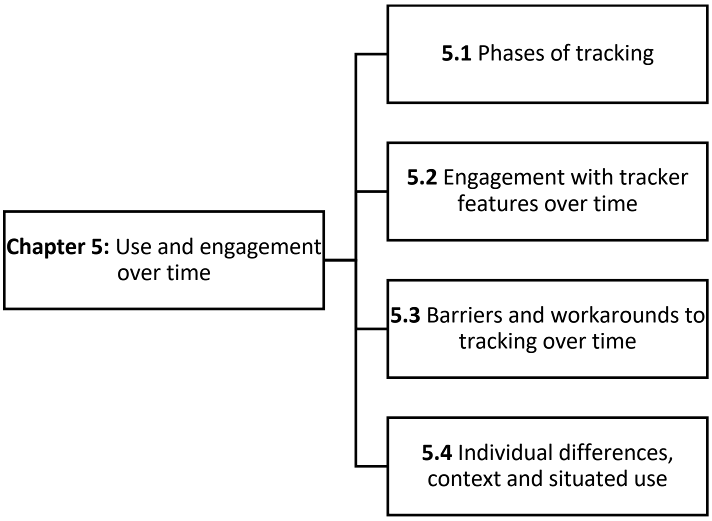

Figure 5.1 – Chapter 5 structure

One of our primary contributions from this chapter relates to temporality of use – something which has been previously characterised in the literature (see section 2.4 of the related work for a more comprehensive overview of models of use in personal informatics), but not in as much depth as we are able to offer, primarily because of the approach we took in our longitudinal study. The ways in which we found our participants used their trackers, and behaved, over time led us to find a very different and richer picture of how people use and embed trackers within their everyday lives than is reported in the current literature. Running the study over a long period with multiple interviews shows how participants' behaviour, motivations, use of, and feelings towards the tracking technology, physical activity and health changed over the duration of the study. Whilst some participants remained engaged for sustained periods of time, most had changing levels of engagement which resulted in them sometimes not tracking - either deliberately, or through circumstance. These periods of non-tracking were sometimes temporary lapses, and other times were more purposeful breaks. Of course, people's engagement over time is affected by their use of their tracking technology: the features and behaviour change techniques built into their trackers, and technical and social issues with using the trackers themselves. As with early adopters of many other new, and relatively untested, technologies (Rogers, 2003), our participants face issues, technical or otherwise, with using and integrating activity tracking technologies into their lives - what we have characterised as "barriers" to their ongoing use and adoption. However, rather than stopping entirely, many participants created "workarounds" to bypass these barriers, which we also characterise in this chapter.

The changes we observed were not caused by the tracker alone but were also affected by many other contextual and situational factors, both personal (health, interests, working and living arrangements, etc.) and environmental (weather, transport options, social norms, etc.). Human computer interaction researchers already understand the importance of considering context and situated use when evaluating engagements with technology (e.g. Suchman, 1987; Dourish, 2001), as these factors can have a large influence on how people use and engage with technology. When related to tracking technologies and physical activity, these contextual and situational factors influence people's engagement and behaviour on many levels, from their efficacy and actual capability of completing physical activity, to the location where they live and work, their socioeconomic status and the facilities they have access to, and even factors such as the weather. The importance of considering, or even manipulating, the environment and context when considering behaviour change is similarly well understood in health psychology, where nudging and choice architecture focus on making changes to the environment in order to influence people's behaviour (see Chapter 2 for a more in-depth review). This evidence points towards the importance of considering context of use when researching and evaluating self-tracking technologies, but this is something little considered in the HCI literature thus far. One exception is Bentley et al.'s *Health Mashups* paper (2013), where the researchers' novel system was studied with participants in two different cities in North America, and one city in Europe. However, the authors gave little focus to differences in use between these different cities in their study, instead utilising contextual and environmental differences as data points for their system (e.g. specific location in the city, and weather data).

To allow us to better understand the effects of context on use, in our comparison study we included a wide range of participants with different backgrounds and demographics, using a variety of trackers for different reasons, and located across two cities (London, UK, and Atlanta, GA, US) with different: social norms, weather conditions, and access to transport solutions. Along with these macro-level differences, contextual differences also existed at a more micro-level, such as differences in participants' work routines, leisure interests and perceived abilities.

In this chapter (visualised in Figure 5.1), we first offer a rich description of the different phases of tracking identified in our research: *continued engagement, lapsing, stopping*, and *returning* to tracking. These phases extend and further characterise previous models in the literature. We then present insights into how people's use of the various features and functionalities embodied in activity tracking technologies change over time and affect their overall use of the tracker. Then, in the next section, we characterise barriers, or challenges, users face when tracking with these technologies, and the workarounds some users have developed to lessen their effects. Finally in section 5.3.3, we provide an overview of the effects that context had on our participants' physical activity, use and engagement with their trackers, and behavioural outcomes.

Phases of tracking

The temporal and inconsistent nature of our participants' ongoing use of their trackers was strongly evident throughout both of our studies, where it was quickly apparent that participants did not consistently engage with tracking. There are many complexities in the ways in which participants engaged with their trackers. From our analysis of our participants' ongoing use of their trackers this section of the chapter characterises the different phases of tracking observed across our studies, along with describing the factors that influenced our participants to behave in these ways.

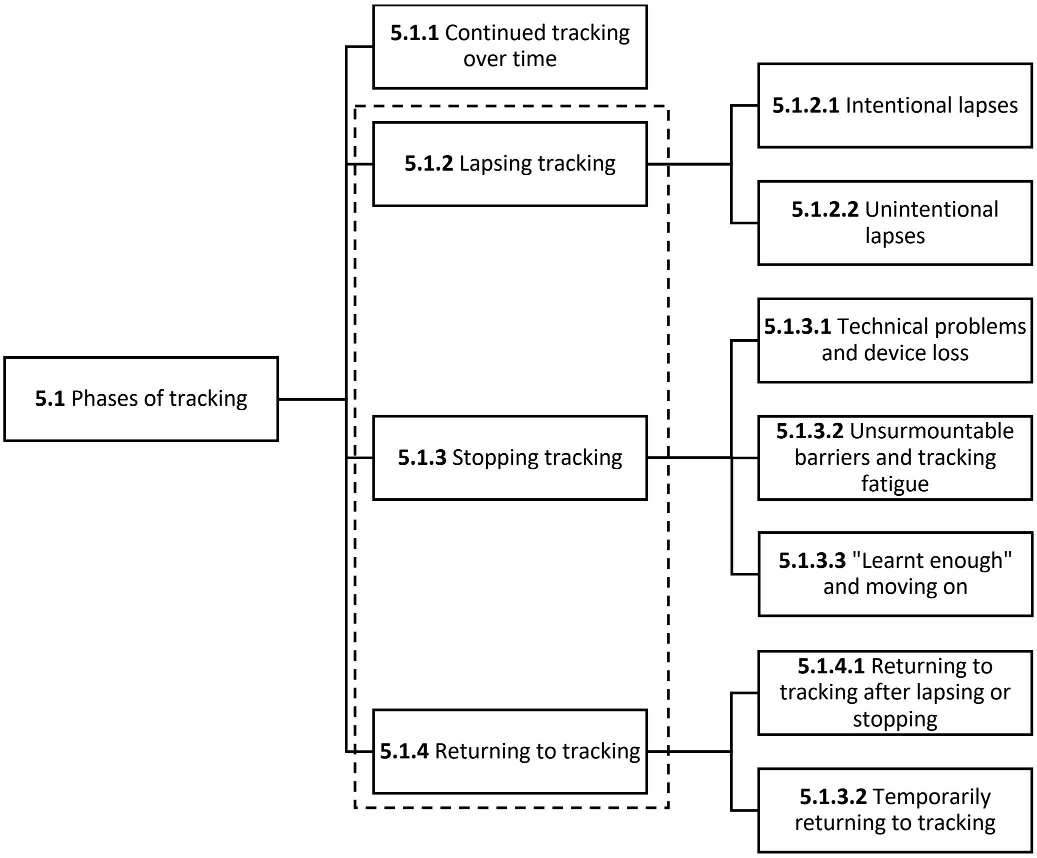

Figure 5.2 – Phases of tracking section outline

Figure 5.2 visualises our characterisation of the self-tracker's journey. The first level presents 4 temporalities of tracking: 5.1.1 *Continued Tracking*, where the user remains tracking over a longer term (in this case for over 6-months, as per Shin et al., 2019); 5.1.2 *Lapsing Tracking*, referring to all times when the user has stopped tracking for a period of fewer than 30-days – either through choice, or when externally enforced; 5.1.3 *Stopping Tracking*, where the user has deliberately stopped tracking, or has lapsed for a period of longer than 30-days; and, 5.1.4 *Returning to Tracking*, referring to occasions when a user returns to tracking: after a lapse, temporarily, and permanently, after stopping tracking. We generated this characterisation by creating a rich-picture of how each of our participants used their trackers over time, and the various influencing factors. Temporal change in use was immediately apparent - most frequently participants would initially be highly engaged, but then as their engagement lessened many began to lapse, or stop tracking entirely. However, this was not the only use pattern: some participants remained consistently engaged over a longer period; some participants would have frequent lapses throughout their use; and, other participants would return to tracking after previously appearing to have stopped.

Eleven of the 30 participants who took part in the follow-up interview were still tracking, though only 7 were still using their original device. Most had not consistently tracked their steps since the beginning of the study – some had periods where they had *lapsed* tracking, and others had *stopped* tracking and then later *returned*. Furthermore, many of the other 19 participants who were not tracking at the time of the follow-up interview had not simply *stopped* tracking and then never returned – some had periods where they had temporarily returned to tracking, such as when on holiday, or had even suggested that they intended to *return* to tracking again in the future - helping highlight the temporal and complex nature of tracking.

In our comparative study we were able to verify our findings from the longitudinal study with a cohort of participants who had starting tracking of their own volition, rather than being supplied with the technology. This moves beyond the limitations detailed above and in section 3.1.2. We now present further details of the various phases of tracking, based on our overall analysis of all 98-participants who took part in both studies.

5.1.1 Continued tracking over time

At the end of our longitudinal study only a handful of participants claimed to have remained engaged throughout the entire study, without periods where they had lapsed tracking. Most participants who considered themselves to have tracked consistently had still skipped at least a day or two, usually after forgetting to wear their tracker. For example, in his follow-up interview P32 explained, *"I only missed a couple of days I think! I occasionally miss a day when I forget to change it over when I get changed or something, but that's pretty much it"*. This figure may be "artificially" inflated from real-world results, as participants may have felt obliged to continue tracking as they had committed to do so when signing up to the study. Indeed, some participants mentioned this as a reason for their engagement with the device, and P11, who only missed tracking on 2 days during the main part of the study, stopped tracking less than 2 weeks after the final interview.

A small number of participants made considerable efforts to ensure they did not skip tracking on any days. Many of those who were highly engaged with the social competitions (see section 5.2.3.3) made more efforts to not skip days, because they wanted to maximise the number of tracked steps these competitions. For example, L6 insisted on continuing to wear her tracker during an extended hospital stay during, despite the fact that she was largely bed-bound. Interestingly, two of our participants who remained engaged with their tracker for the longest used the goal-setting functionality (further examined in section 5.2.2), and neither had a set daily routine: P32 worked flexibly from home, and P36 had recently retired. The lack of physical activity in their daily routines appeared to motivate their continued engagement: P36 said he relied on the device to remind him to keep active and claimed to have tracked consistently for over 381-days; and P32 explained, *"it's not essential for me to leave the house* […] *it's so easy to just sit here and not really do anything, so it's a good check on that"*. Their trackers provided them with support to remain active, resulting in them remain engaged with it, whereas other participants instead lapsed tracking more frequently: a phenomenon we now discuss.

5.1.2 Lapsing tracking

As we explained in the previous section, our participants' use of their trackers was generally inconsistent, even for those who remained using them over a longer term (over 6-months). Many of these participants had periods where they were less engaged, or not using the tracker at all – often for short periods of time. For example, as P32 explained in his follow-up interview: *"I only missed a couple of days I think! I occasionally miss a day when I forget to change it over when I get changed or something, but that's pretty much it"*. <u>We describe these periods of fewer than 30 days where a user is not tracking, but intends, or is considering to return, as *lapses*</u>. This term was first used in relation to personal informatics by Epstein et al. (2015), where they describe the temporal nature of tracking. Differently to Epstein's work, we further characterise *lapsing* and *stopping* tracking distinctly. Furthermore, we found that participants sometimes deliberately choose to not track for these short time-periods, whereas other times they are unable to track for reasons outside of their control - *intended* or chosen, and *unintended* or not-deliberate *lapses*, as outlined in Figure 5.3.

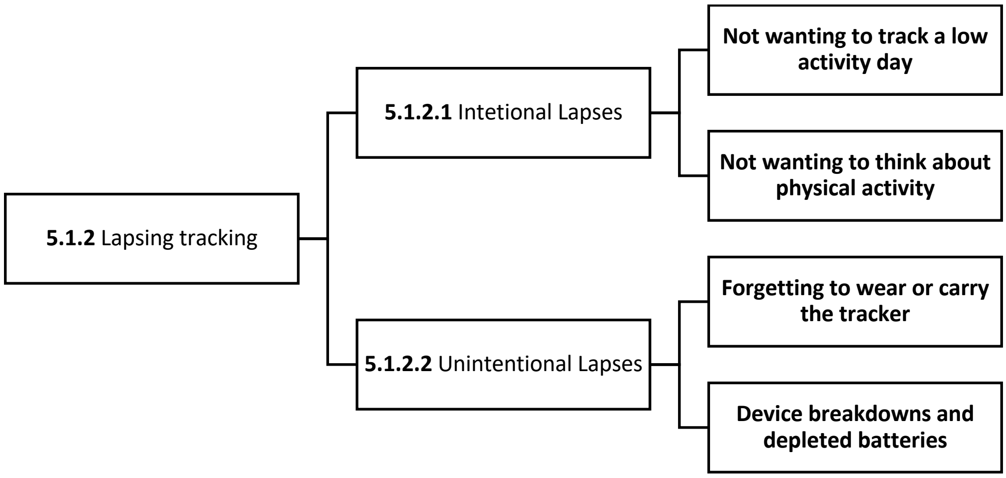

Figure 5.3 – Lapsing tracking section outline

An *intended* lapse might occur when an activity-tracker user consciously decides to not track, for example when recovering from an illness, or during a public holiday, as explained in the following section. *Unintended,* lapses are externally enforced, for example, if the user forgets to wear their tracker, or if the tracker has a technical fault and stops working. Ultimately, the intention of lapsing falls along a continuum between intended and unintended, where the agency of the decision is not always clear. For example, if one 'decides' not to track whilst they are unwell and unable to move from bed, is the agency really with the user? It could be argued otherwise. For the sake of clarity in this chapter we create a binary characterisation of lapses as intentional and unintentional, but the agency of decisions in each case is often much more nuanced.

5.1.2.1 Intentional Lapses

In our research, intentional lapses usually lasted fewer than 7-days, and sometimes even lasted for less than a day. Throughout our research some participants decided to not track during times outside of their normal routine. This was particularly true for days when they knew they would not be doing much activity, for example, during national holidays or when ill.

Some participants reported occasions where they would deliberately **not track a low activity day**, when they knew they would be relatively inactive, especially when they were not leaving their home. The most common examples of this were during national holidays such as Thanksgiving (for those located in the US) and the Christmas break. For example, P2 explained how she intentionally did not wear her tracker over Christmas because she was aware she would not be doing much activity: "*well when I'm working I remember most days because it's the routine* […] *but on holiday not at all, and not much over Christmas, but I didn't make an effort because I don't do any exercise over Christmas anyway*" (P2). Participant P26 also decided to not wear her tracker over Christmas, explaining: *"there* *were some days when I remembered it and thought 'all I'll be doing all day is reading the book I got for Christmas and shuffling around the house, it's just going to be disheartening if I get to the end of the day and it says 800 steps'..."*. Similarly, other participants would deliberately not track when they were unwell or injured, where their ability to take steps was perhaps lower than usual, *"There's the odd occasion where I don't wear it if I've been off sick and I've been at home all day and I've not even got dressed. Then I haven't worn it"* (P3_FU).

During periods of lower activity many participants stated that they would prefer to have no steps recorded to the small number they had actually taken. When further questioned, they explained that this was in part because of the social influences offered by the system: a step count of zero might indicate that the person had forgotten to wear the device, or it was not working, whereas a low step count might indicate that they had simply not moved much. For others this was more about preserving their record – when considering their own record of steps, they would prefer a gap in their activity history, rather than a low record of steps.

The other main reason for lapsing tracking was that some participants simply did **not want to think about their physical activity** on less active days, and wearing their tracker would act as a reminder of their activity, making them feel pressured to do more (further explained in section 5.3.2.6). We first observed participants deliberately not tracking after returning from holidays, when they would sometimes have a *"deliberate lazy day"* where they did not want to *"worry"* about tracking their activity (quotes from P34). When we asked P34 about a gap in her tracked activity she told us, *"I just came back from holiday and I didn't want to flipping wear it, because it was stupid. I wanted to relax and not worry about the step count".* She lapsed tracking for 4 days after the holiday, explaining, *"I decided I didn't wear the Fitbit, I wanted to relax and not worry about the step count* […] *relax means not care. I knew if I looked at my Fitbit it would show, well, previously I was used to it saying 20k, 20k, 20k, I would look at it and it would say 2k, I didn't want to feel like that"*. Other participants reported similarly: P14 lapsed for over two weeks after he returned from a 3-week trip visiting family, and P44, who ran a marathon at the beginning of a holiday abroad lapsed for 5 days after she returned. In both cases participants were unable to take as many steps after returning from their holidays and were uninterested in tracking the decreased number of steps, instead preferring to record no steps at all. Indeed, P44 had been training for the marathon for months previously, and after recording 61,322 steps on the day of the run did less activity for the following weeks, resulting in a considerably lower step count than she had previously been achieving.

Conversely, other participants reported wearing the tracker every day, even if they knew they would not be taking many steps, because they wanted to ensure they had a full and complete record. This desire for a complete record became problematic for some: P1 felt that her Fitbit was controlling her life, as she always wanted to have "full" bars on her activity visualisation: *"* [I was] *stuck in this loop of constantly having to have a perfect chart and count... It'd be this extra mental overload like yeah, of having to remember. I'm like OCD with being like 'yay, I can look at nice charts again'"*. She mentioned these feelings during the final interview in the main part of the study, after she had lost the device, and felt relieved to stop tracking. In the follow-up interview, she explained that she had since found the device, but did not return to tracking, reflecting: *"It became this external stressor - I got obsessed with the numbers, whereas without it I just walked for the sake of walking* […] *it became an obsession like that, which isn't good* […] *I would track my weight when I was younger and it would be the same thing - I would obsess about it"* (P1_FU). Other participants experienced similar feelings, wanting a consistent and complete record of their activity, but generally enjoyed using the device and felt that measuring their activity aided with their health and exercise.

5.1.2.2 Unintentional Lapses

Unintended lapses primarily came in two forms: those where the user was at "fault" and could be avoided; and those that were externally-enforced and therefore unavoidable. Examples of the former include lapses caused by forgetting to wear, or losing, the tracker, and examples of the latter include failed batteries and technical issues with the tracker, though again these factors lie on a continuum, rather than being a distinct classification. Typically, externally-enforced unintentional lapses lasted longer, this is primarily because of the time taken to get a replacement tracker after experiencing technical difficulties. Furthermore, some of participants *stopped tracking* after an unintentional lapse that prevented them from continuing without purchasing a new tracker, something that many were unwilling to do.

We found that lapsing sometimes influenced people's feelings towards their activity. Participants often wanted to minimise the length of unintentional lapses was because they felt that their physical activity *"didn't count"* (A6, A20, P2, P34) if it wasn't tracked: "*before, I have let the battery go down so it didn't count my steps it just bugged me* […] *it was a little off-putting. It felt like they didn't count because they weren't recorded"* (A6). Generally, participants reported that they would remain active, even when not being tracked, but they would feel less positive if their steps were not being quantified: *"I realised the other weekend that I went out and I'd forgotten it. I went 'uhh, thats a shame', and then I had to convince myself 'it's still ok, you're still doing the steps. Just because they're not being logged doesn't mean they don't count'* […] *I had to convince myself that steps are a good thing in themselves, rather than just measuring them. Where previously I'd have just felt good about* *doing lots of steps it was tinged slightly by not recording them and having proof that I'd done that many steps".*

The overall most frequent cause of lapses in our research was participants **forgetting to wear or carry their tracker.** When first tracking, many participants frequently forgot to wear their device, and short lapses were common. Once participants became more accustomed to tracking, unintentional lapses tended to mostly occur when they were outside of their normal routine. For example, P20 *"forgot to do it* [wear the tracker] *because it was outside of my normal routine"*, when she was visiting family in her home country, and other participants would forget to wear their trackers during public holidays or when staying at home: *"the hardest for me was wearing it on the weekend - I would sometimes forget when I wasn't going out"* (A8). A more comprehensive overview of the challenges and workarounds to remembering to wear the tracker is in section 5.3.2. After initially forgetting to wear their tracker at home, some participants chose not to wear their device when they were not leaving the house, as they found little utility in recording the steps they took inside their homes.

The other most common reason for an unintentional lapse was caused by **device breakdowns or depleted** batteries. Generally, these technology-breakdown related lapses were more externally enforced than forgetting to wear the tracker, although the problems with depleted batteries could often be mitigated by the user replacing or charging the battery when notified by the device. Some participants felt having a complete record of their steps was important and endeavoured to recharge, or replace, their battery as quickly as possible in order to minimise the disruption on their tracking history. For example, P24 went out of his way to replace the battery in his Fitbit Zip after it died on a week-long skiing holiday in France, *"this is how committed I am Danny - the Fitbit ran out of battery when I was there, and I bought a new battery in the Alps".* Conversely, other participants were in less of a rush, or had less inclination to purchase the battery themselves, and instead expected us to provide them with new batteries. In his follow-up interview P14 explained that his Fitbit battery had died after the main part of the study so he had stopped tracking, *"if I get a replacement battery, either through you or through myself, which I am inclined to get, I will use it"*. Crucially, despite stopping tracking, he had continued with some of his behavioural changes, *"I'm walking a bit more* […] *I walk up the stairs, I tend to take the longer route to work, especially if I've got time... So those minor adjustments to what I was doing before the Fitibt are still there. At least for me I think these things that I adopted when I had the Fitbit I have kept"*, indicating that continued tracking was not essential for these changes to remain.

Other participants felt more reliant on their trackers, and sought to minimise the length of lapses. After P6 had a problem with her Fitbit Zip the manufacturer offered to replace it, but she wanted a replacement more quickly: *"I actually rely on it a bit too much to wait for them to do it, so I just went to a shop and got a Fitbit One* […] *without Fitbit telling me how many calories I use every day it's sorta difficult to tell how active that day was"*. The Fitbit was a key component of her personal informatics ecology, along with her Fitbit Aria weight-scale, RunKeeper, and MyFitnessPal (*"the Fitbit app is like my central, go to place, to find out my level of activity for the day"*), which she had become reliant on using. A more detailed overview of the technical issues our participants faced when tracking is presented in section 5.3.1.

5.1.3 Stopping tracking

Further to lapsing, some participants chose to *stop* tracking entirely, we define stopping tracking as: "when someone has lapsed tracking for more than 30-days, **or** has stopped tracking and does not intend to continue", whereas our definition of lapsing is: "a period when someone has stopped tracking for 30-days or less **and** intends to continue tracking". The 30-day timescale was based on our participants use of their technologies: the effects of *lapsing* for longer time periods (over 30 days) often had consequences on the participant's engagement and motivation to continue tracking, and such a large gap in tracking often resulted in them *returning to tracking* with a different intention or motivation. Ultimately, the distinction between lapsing and stopping tracking falls along a continuum, rather than being a binary classification, where a user may be unsure of their intention, but for the interest of clarity we present this stricter definition.

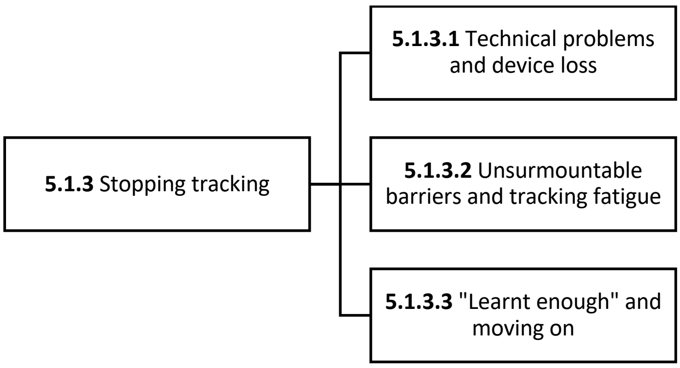

Figure 5.4 – Stopping tracking section outline

Similar to *lapsing*, *stopping* tracking was sometimes the participant's choice, and other times was outside their control. Participants reported various reasons for stopping tracking (as illustrated in Figure 5.4), sometimes because their tracker was no longer available, either because it was broken or they had lost it; because they felt "blocked" by barriers to engagement or got bored of tracking, or more positively, because they had learnt enough from tracking or had made a positive change and felt they no longer needed to track. Participants also stopped use of one tracking tool because they had found more utility in tracking something else. Stopping tracking is often associated with "abandonment", which is often negatively characterised as a failure of the technology, but stopping tracking was not always negative and could instead be the result of a positive, or meaningful, interaction.

Despite the positive outcomes that may come before stopping tracking, the disposable nature of technology could be a concern: *"I don't think it's ethically ok that we buy devices and chuck them in the bin every month"* (P47). Of the 50 devices we supplied to participants, just 7 were in use when we undertook our follow-up interviews. With the exception of one participant who had sold her Fitbit Zip on eBay, none of the other trackers were still functional, and in use. In our comparison study, 37 of the 48 we interviewed were still using their devices, though many of these participants had been using their devices for a shorter time-period compared to those in the longitudinal study. This trend is of concern, and new usage models could be explored to reduce the environmental impact of this high-level of turnover and relatively short-term use.

5.1.3.1 Technical problems and device loss

One common reasons for participants to stop tracking was because their tracker was unavailable, usually either because of a device breakdown (see section 5.3.1), or because they had misplaced their tracker (see section 5.3.2.2). Some participants simply *lapsed,* choosing to replace their tracker and continued tracking (sometimes with a different device), or in some cases the manufacturer replaced the device. However, more often a device breakdown or loss caused the participant to stop tracking.

Many of these participants wanted to continue tracking, but the cost of a replacement tracker prevented them from doing so, often because they felt the cost was not worth the benefit. For example, P7, who lost her Fitbit Zip explained, *"If I had the money I think I probably would* [replace the Fitbit]. *It is good for awareness and it is good for a bit of competition as well"*. A small number of participants felt relieved after losing their tracker, having no intention of replacing it, as presented at the end of section 5.1.2.1.

5.1.3.2 Unsurmountable barriers and tracking fatigue

Other participants stopped tracking because of unsurmountable **barriers preventing continued engagement**, or simply because they had become bored of tracking as the novelty had worn off.

Many participants complained of technical issues and problems with integrating their trackers into their lives, finding that: charging it, or changing the battery was too much effort; wearing it was uncomfortable or inconvenient; or, that they were unhappy with its visual appearance – we present a taxonomy of these barriers to tracking in section 5.3, along with the workarounds that some participants created in order to continue tracking with a lessened barrier.

Other participants stopped tracking because the novelty had worn off, explaining that whilst the data had been interesting to start with, they soon became **bored of tracking**. For example, P27 explained, *"I think for me it was just a novelty. I know it works for other people, for me, I kinda know what I want to do and then just do it…"*. Participants were often bored when there was a mismatch between their expectation of the tracker and its actual abilities – many participants thought the tracker would give them a more holistic measure of their physical activity, rather than focusing on the number of steps they were taking. Indeed this was the case for P27, who was disappointed that it did not have GPS for tracking his running, *"I used to use Runkeeper which was quite good, it recorded your route and gave you splits"*, nor give him credit when he was cycling, *"I think it would have worked better if I could have told it when I was cycling: when I was on the bike it didn't do anything really"*, resulting in him stopping tracking.

5.1.3.3 "Learnt enough" and moving on

Stopping tracking is generally associated as being negative, but we found this was not always the case: stopping tracking does not necessarily mean that they have "abandoned" the technology, and stopping tracking is not always a negative outcome. Some participants stopped tracking after experiencing a meaningful interaction, such as changing their behaviour, and others found that they had "learnt enough" or had otherwise gained all they needed from tracking a particular activity and wanted to move on.

In section 4.4.1.3 we explained how, even at the beginning of their tracking journey, some participants became less engaged with their tracked data as they began to learn how many steps they took without looking at the quantified data. Over time more participants began to get this sense of the number of steps they took and stopped relying on their device to quantify steps, having already **"learnt enough"** from their fairly short time tracking their activity. This was particularly true for those who had a fairly set routine, where they discovered they took a similar number of steps each day.

Other participants, particularly those who had a positive affective response to the data they were tracking, similarly felt no need to continue tracking and **moved on**. For example, P46 soon discovered that, *"it kinda just settled in that I probably do just walk a lot"*. He further explained that he did not have any particular desire to further change his activity, meaning the tracked data itself was not particularly important to him: *"I think in a way it's almost ambient data that's enjoyable, just something in the background that happens. I did enjoy having the information, it's definitely something nice to have there, to think about and to challenge, but I don't know that it ever became crucial enough"*.

For many participants, their decreased engagement with the technology, combined with the barriers of continued engagement with it (covered in section 5.3), provided reason enough for them to stop tracking. There would often be a catalyst for stopping tracking, for example P14 stopped tracking after *lapsing* when returning from a holiday, *"I took it off because of security and I left it in my bag and then didn't find it for two weeks* […] *you have a long break, you stop, you break the habit of checking it all the time, y'know, because you've had that break"*. In many of these cases, if the barriers to tracking were lessened then participants may have continued, but despite this, many had already had positive, meaningful, interactions with their tracker, which had resulted in behavioural or psychological responses.

Many of our participants stopping tracking was related to difficulties in their continued use, because of circumstance, or because they had moved beyond an initial novelty. Some participants moved on to using a different personal informatics tool, to track something more suited to their goals or interests (such their diet, or their weight-lifting activities - see section 5.3.3.3). However, as we discuss in the next section, some participants decided to later return to tracking, either with the same or a different tracker.

5.1.4 Returning to tracking

The final phase of tracking in our model is simply *returning* to tracking (outlined in Figure 5.5). Almost all our participants spent some time away from tracking during their journey (either *lapsing*, or *stopping* tracking), but many later returned. Sometimes they would return with a different tracking technology, sometimes even tracking a different behaviour.

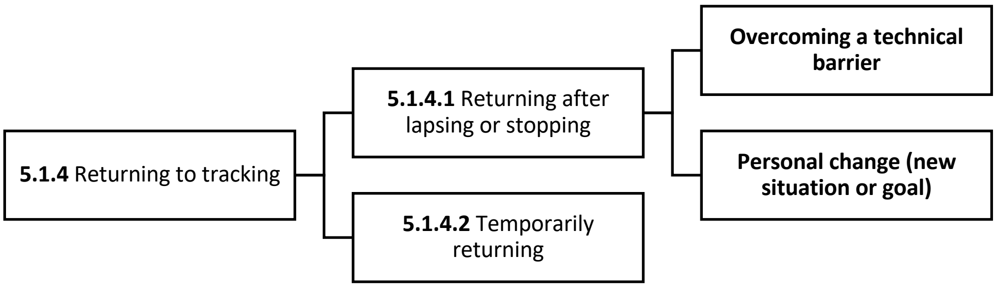

Figure 5.5 – Returning to tracking section outline

In most cases where a participant returned, after either lapsing or stopping tracking, they did so with an intention to continue tracking for a longer term, without a particular end date in mid. However, we also witnessed participants who would *temporarily return*, with an intention to track for a limited amount of time. For example, some participants were curious about the number of steps they would take on holiday, so would track for the duration of their break and then stop tracking again after they returned. These periods of *temporary* returning have not previously been studied in the literature.

5.1.4.1 Returning after lapsing or stopping

Many participants who stopped tracking later decided to return, either after a lapse in tracking, or after having stopped. These participants would either continue tracking with the same or a similar device (often a replacement for a broken or lost tracker), with a different activity tracker, or with a system tracking an entirely different behaviour. Importantly, to fall within this category participants must be intending to track continually, without an end date in mind.

Oftentimes participants who returned to tracking after a lapse would do so with a lower level of engagement than before, and some participants ended up stopping tracking entirely soon after having returned from a lapse. It seemed that the lapse would break their tracking habit, and then when returning they would reconsider the value they gained from tracking. Further research should be conducted to better understand this phenomenon, and tracking systems could be better designed to support users when returning from a lapse.

Some of those who returned to tracking did so because they had **overcome a technical barrier** which had previously caused them to lapse or stop tracking. This was not necessarily a complete device breakdown, or a loss, but instead may have been one of the many barriers characterised in section 5.3, such as frustration with charging the tracker, or disappointment with its accuracy. Participants may have bought a new tracker, or alternatively created a workaround for a barrier, as we characterise throughout section 5.3. Many of those participants who had stopped tracking because of a barrier told us that they "missed tracking" and considered returning – suggesting that there was scope for more prior trackers to return in the future.

Other participants returned to tracking because something had changed which meant they felt the benefits outweighed than the costs. Generally, this was because of a change in their **personal situation**, such as a large life event (e.g. breaking up with a partner), or having a new motivation, or goal. For example, in her the follow-up interview P48 explained that she recently returned to tracking after a significant gap, using a different activity-tracking device, in combination with tracking her diet with the app MyFitnessPal, after her doctor had advised her that she *"had to do some exercise"* – a strong extrinsic motivation for changing her behaviour.

5.1.4.2 Temporarily returning

Temporarily returning to tracking is an interesting phenomenon not previously discussed in the literature, whereby one returns to tracking for a short period of time, with an end-date in mind. This was generally driven by a participant's desire for data, or information, about a novel, or out-of-context activity, where they may have been doing something out of their usual routine, such as going on holiday, or moving to a new house.

Typically, these participants were doing something unusual and were interested to have a record and understanding of what they were doing. For example, A13 explained, *"I didn't use it* [his Jawbone Up] *for about 9-months or something like that, but then when I went to Spain last summer I wore it again because I knew I was going to do a whole load of walking and I kinda wanted to get a feel for comparing that to what that looked like against my typical walking in Atlanta".* Moving home was another typical example, whereby participants would use the tracker for a short time-period so that they could gain insight into their new routines and re-learn the number of steps they were taking, before stopping again. However, these temporary returns could sometimes result in a more permanent return to tracking, as in the case of P26, who ended up continuing to track for a longer time period (until she lost her tracker 6-10 weeks later) and engaging with her tracker: *"I've moved house and I can now walk to work which means I'm walking more* […] *I think I am making more of an effort: I keep getting the bus most mornings if I'm late or it's raining, but it means that I'm walking home almost every day because I haven't got time constraints on that"*.

This section has presented evidence and stages of the temporal, periodic, and sporadic nature of people's engagement with tracking systems, characterised in "the phases of tracking". These different stages are highly influenced both by factors related to the tracking technologies themselves (breakdowns, battery failures, aesthetics and others, as discussed in section 5.3), and external, contextual factors (such as weather, the built environment and social norms as discussed in section 5.3.3). These factors and others are further examined throughout the remainder of the chapter, starting in the next section where we focus on people's use of tracker features over time.

5.2 Engagement with tracker features over time

Activity tracking systems generally include a variety of features and functionalities intended to support and encourage people in changing their behaviour, commonly referred to as behaviour change techniques (BCTs). Numerous studies have evaluated commercial trackers against Michie et al. (2013)'s BCT taxonomy, but mostly focus on the *inclusion* of different BCTs, rather than their implementation and how they are used over time. These works are, however, useful in determining the prevalence of, and most popular, behaviour change techniques in different tracking systems, helping us better focus our efforts in understanding how these are used in the real world. In this section we focus on our participants engagement with the three most popular features in activity trackers: badges and achievements, behavioural goal setting, and the social functionalities (outlined in Figure 5.6).

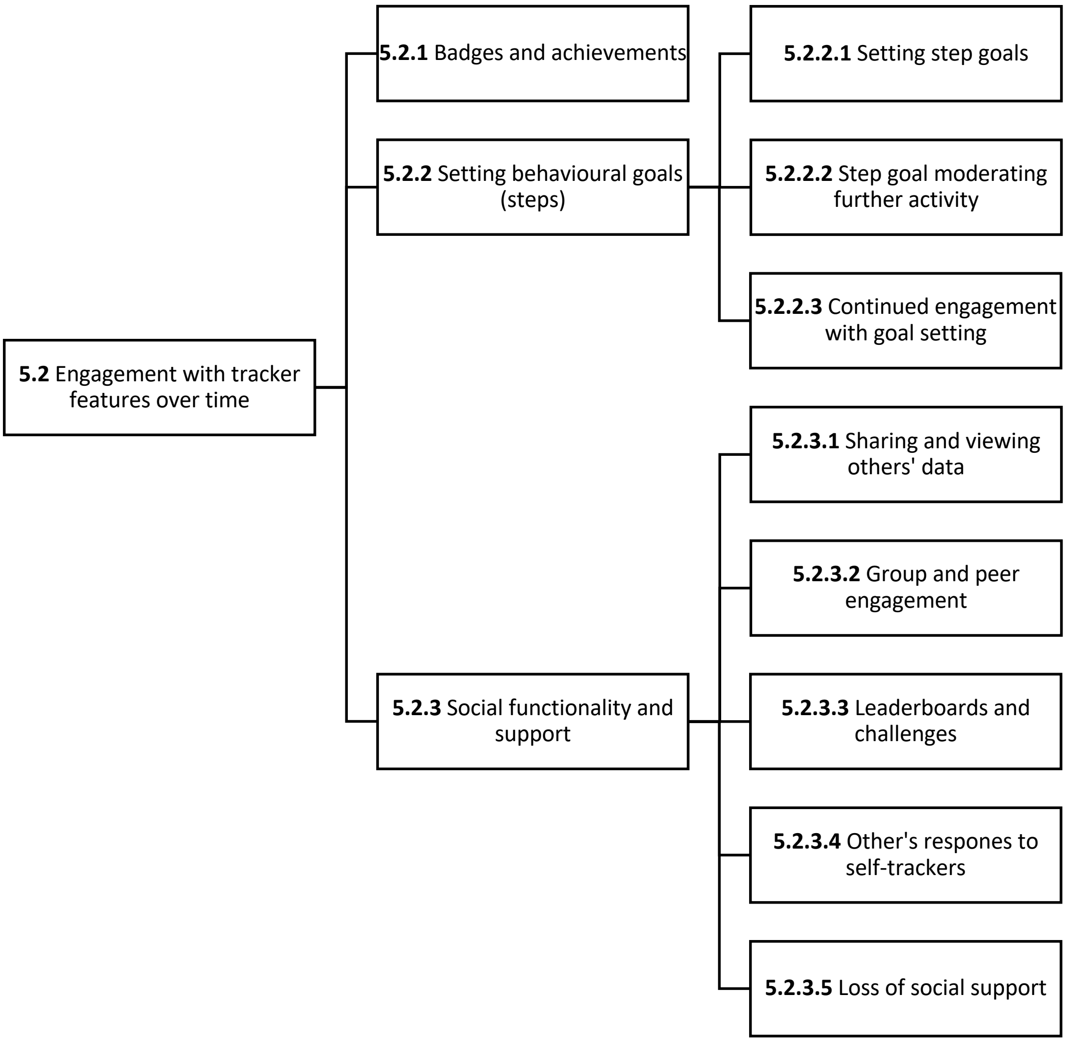

Figure 5.6 – Engagement with tracker features section outline

5.2.1 Badges and achievements

This section focuses on badges and achievements, elements of "gamification" that are provided in most activity tracking systems. Gamification, or the use of video game elements in non-gaming contexts (Deterding et al. 2011), has gained considerable attention in the personal informatics, with features embedded in many of the tracking technologies our participants were using. A 2014 review (Lister et al., 2014) found that *"most popular* [health and fitness] *apps showed widespread use of gamification principles"* (no page given), including features such as digital rewards or achievements that one could collect, real-world prizes, competitions and challenges. However, despite the apparent popularity of these features in health and fitness apps, our participants indicated relatively limited use of them, with the exception of the social functionalities which we have separated into section 5.2.3.

Figure 5.7 – Email confirming the Fitbit achievement badge for completing 30,000 steps

Badges are "digital rewards" that are generally earned the first time a user completes a certain challenge or achievement. For example, a user might earn a badge the first time they walk 30,000 steps in a day, or for travelling a cumulative distance of 500km (see Figure 5.7). Generally, our participants were uninterested in these badges, feeling that they were *"a bit of an afterthought"* (P10). In stark contrast to how badges usually work in games consoles, where they are highly visible to others and closely linked to social functionalities, these badges were kept private to the individual user. P12, a keen gamer familiar with badges (*"I used to love achievements, my Xbox achievements, I had so many"*), did not enjoy Fitbit's implementation and suggested they would be more effective if they *were* more visible, so that other users could easily see when a badge was earned: *"I think if it came up on here on the dashboard I'd pay more attention to it"*.

A small number of participants did find the idea of earning badges for particular step-goals aspirational, P28 explaining: *"There's a 20k step badge that I'm specifically aware of and I do not have, even though I've come close a couple of times… I want that"*. Some participants also enjoyed "accidentally" earning these badges, as P6 explained, *"I don't think I've been thinking about the badges, although there was a day when I went for a run, went out with friends and went dancing and accidentally I managed to do over 30,000 steps in one day... Then I got the badge and 'omg, 30,000 steps, I didn't even think that was possible'"*. Some participants also told us they enjoyed receiving emails with their "lifetime" achievement badges: badges that showed the number of steps they had recorded since starting tracking. They felt these provided an opportunity to *"reflect upon* [their] *time using the Fitbit"* (P3), when reflection was otherwise lacking. Whilst these badges were not directly responsible for encouraging our participants to be more active, they did aid engagement and encouraged reflection which could be useful for other changes.

5.2.2 Setting behavioural goals (steps)

Setting behavioural goals (*"Set or agree a goal defined in terms of the behaviour to be achieved"*, Michie, et al. 2013), is perhaps the most well-known BCT embedded in activity tracking systems, where the target of 10,000 steps is widely recognised. This section (outlined in Figure 5.8) specifically refers to users setting and work towards a measurable behavioural goal (i.e. the number of steps taken in a day) and is not the same as a participants' wider behavioural goals (e.g. "to lose weight"), which are covered in section 4.1.1.

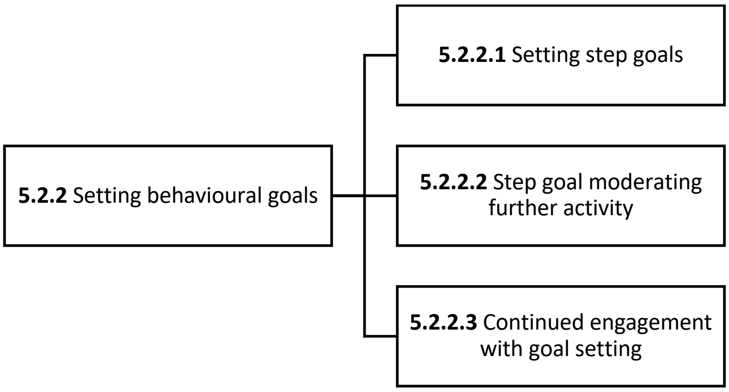

Figure 5.8 – Setting behavioural goals section outline

Almost all our participants engaged with goal-setting at some point, generally initially aiming to meet 10,000 steps a day, but then sometimes changing this goal to support their behaviour change. However, participants' engagement with this functionality generally declined over time, and some participants actually reported the step goal being detrimental to their activity: they would stop any further activity once they had reached their goal. However, we also describe two participants who continued to be engaged with the step-goal over a longer period of time, using it to ensure they were active and regularly left their home.

5.2.2.1 Setting step goals

The majority of activity tracking systems use the well-recognised 10,000 step goal as their default, though most allowed users to manually change this goal. As explained in section 4.4.1, some participants instead thought this goal was an *average* and thus were disappointed when they did not successfully meet this on a regularly basis. Indeed, many of our participants did struggle to fit 10,000 steps into their day to day activities, highlighting the challenges when increasing physical activity levels, which are often dictated by many external influences and other aspects of their lives (e.g. Pooley, et al. 2011).

However, although many felt the 10,000-step goal was unachievable, very few chose to decrease it. When participants did edit their step-goal, instead this was generally *increase* it, usually in attempts to "challenge" themselves more: *"I've set my minimum goal to 11,000 steps a day, because I thought 10,000 I was getting fairly often and it didn't seem like that much of a challenge"* - P6). One notable exception to this trend came from P18, who, after an operation on her back, used the step-goal, with the aid of her healthcare professional, to aid her rehabilitation: *"It's been really useful having the Fitbit during the day. I came out of hospital and the first two weeks was kinda shuffling around, holding on to the wall and then after that* […] *I could go to the consultant and say 'week 3 I did 4,000 steps a day, week 4, I did 6,000'"*.

Instead of the fixed goal that most systems provide, some participants used trackers that offered a dynamic goal based on their prior activity – if the goal was met one day, then it would increase the next. The participants who used these systems tended to find them motivating, P25 moved from a Fitbit Zip to the app Breeze: *"the goal is adaptive, which I really like. So instead of it being a set number, like... instead of it saying "you should do 10,000 steps" or whatever, today my goal is 5,500. I don't know exactly what algorithm it uses, but it's something - it clearly takes into account your history. So if I do some days with a lot, my goal goes up. And then if I'm really sedentary it falls back down again"*. She expanded, saying she felt the Breeze app would be more motivating: *"I think that perhaps Breeze is more likely to encourage me to hit the goal than the Fitbit did, purely because the goal often feels much more achievable"*.

5.2.2.2 Step goal moderating further activity

The general expectation is that goal-setting is intended to encourage a *greater* number of steps to be taken, but some participants reported to the contrary. Instead, the goal would sometimes negatively influence their activity, by discouraging them from taking more steps beyond the goal, seeing it as a "limit". For example P18 reached her 10,000 step goal when Christmas shopping, so skipped the swim she had planned for the evening: *"I went to Westfield shopping centre, by 4pm I had done 10k steps* […] *so it actually stopped me going for a swim, I thought, 'I've done my exercise for today!'"*. This was not an isolated incident, both P11 and P14 reported similarly: *"I don't know why I have in my mind the goal is 10k, it's no more... It's because the colour changes, it goes from orange to green and I'm like, it's okay now…"* (P11); *"if I'm close* [to the step goal] *I might just catch the bus, if I can meet the 10,000 then I'll walk home or to pick up my son"*. These responses feel similar to those discussed in section 5.1.2.2, where participants only take steps because they are being tracked. Users feel regret if their steps are not tracked, and they feel that activities beyond the goal are not necessary. In both cases participants' behaviours are in response to the technology, rather than the technology supporting their goals and desired behaviours.

The issue of participants treating the step goal as a limit, rather than a target, was also notable amongst those participating in workplace wellness schemes. Here, reaching a goal would often have some sort of a financial reward associated with it, but no further reward would be offered for exercise taken beyond the goal. Participant A8, who was working on rotation between warehouse and office work, would usually exercise in the evenings but found that, *"in the warehouse I knew I was going to hit my goal every day"*, so stopped exercise outside of work. However, this was not true when he was back working in the office, where instead he *"was having to rely on running after work to reach my goal, rather than reaching my goal while at work"*. This could be seen as a positive outcome, but the scheme did little to support his existing exercise habits. Further exacerbating this problem, the wellness schemes our participants took part in generally lasted 3-months or less, after which most participants stopped tracking and attempting to meet their goal. Although these participants created some increased awareness of their activity, they were only doing activity for financial gain, and often gave up when this financial reward was removed.

The examples above present the potential downsides to a person's step goal moderating their further activity, but one participant had an experience to the contrary: P12, who suffered from chronic pain, found that setting her step-goal to an appropriate level would help her in managing her condition to prevent her from over-exercising. Reflecting on a time when she failed to take notice of her step goal she explained: *"I felt tired at the end of that day and I knew I had pushed too hard* […] *It was hard work, I really enjoyed it at the time I just didn't think about it, the next day I really paid for it, I think if there had been some sort of alert system or it monitored it a bit more actively then it would have been fine".* Ayobi et al. (2017) had similar findings in their work focusing on those with multiple sclerosis.

The goal-setting functionalities in activity tracking systems could be better designed to support encouraging users in doing an appropriate amount of activity without making them feel discouraged about a distant goal, or encouraging them to do less with easily achievable goals. Activities beyond the goal should also be better supported, where appropriate. Adding additional incentives such as with workplace wellness schemes seems to make the goal an even greater target and should be carefully considered as it may further discourage people from doing activities beyond the goal. There also exists the problem of users deliberately tricking their tracker to meet their step-goals, something that many of our participants had ingenious ideas for, and some of our participants admitted to (see section 4.3.1).

5.2.2.3 Continued engagement with goal setting

A small number of participants were engaged with goal setting functionality throughout their interactions with the tracker, with two participants in particular making large changes to their activity as a result of using the goal setting functionality over a longer-term.

Both participants had considerable flexibility in the schedule of their day-to-day lives - P32 worked flexibly from home without set working hours, and P36 was a retiree. P32 (previously described in 4.5.2.4), explained that step-goal to be particularly useful for keeping him active because he rarely needed to leave the house (see Figure 5.9 for a chart and description). He explained how he initially walked around his home each day to reach his step goal, much to the dismay of his housemates (who, overhearing this shouted, "*you're like a hamster in a cage!*").

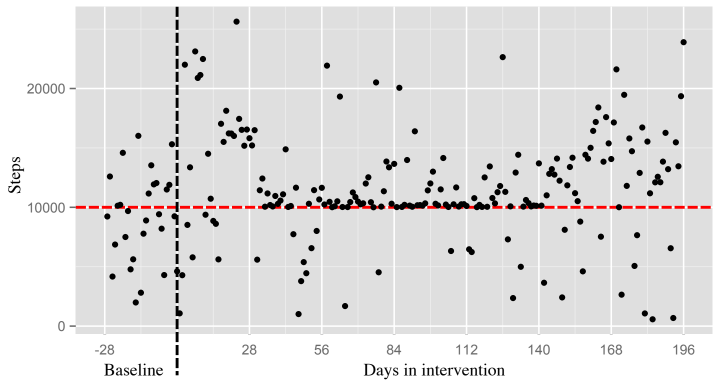

Figure 5.9 – Scatter-plot showing P32's recorded steps during the main part of the study. 10,000 steps is marked on the chart with a horizontal dotted line, the number of days with steps around this level are clearly visible.

Towards the end of the study his recorded steps varied much more, which he explained was because, *"I've just got a new job and it involves me going into an office".* Although the step goal proved to be a great motivator to stay active when he was working from home, when he had more structure to his day and needed to commute to work, he frequently met the goal without making an effort, gradually becoming less engaged with the goal-setting functionality. However, reflecting on his experience in the follow-up interview he explained that he was once again engaged with goal setting, as he had left his office job: *"it's definitely had an impact. It's made me consider a lot more, what I'm doing and how much I'm moving around. It's especially valuable at the moment, as again, for the second time in that 18-months, being in a position where it's not essential for me to leave the house during the day".* This example helps us better understand the relative lack of engagement that many had with the step goal: it was difficult to engage with meeting an arbitrary figure each day when the context of use and external events in their lives had far greater importance and influence.

From our small sample, those participants with a less-structured routine appeared to be more engaged with the step goal and made larger changes to their activity as a result. This was perhaps because they took fewer steps as part of their daily routine and had more opportunities to be active purely to reach their goal, by walking around the house (as in the case of P32), or going for daily leisure walks and taking trips by foot (as P36 reported). It is unsurprising that different behaviour change techniques may be more effective for particular user groups, and better understanding how particular techniques should be implemented for different users could help better tailor future interventions and devices to encourage physical activity.

5.2.3 Social functionality and support

The social functionalities embedded into activity tracking systems are one of the features that set them apart from traditional pedometers. Almost all the tracking systems our participants used included some sort of social functionality, and most of our participants engaged with this functionality, at least to some extent. The embedded functionalities are not consistent across all systems, but many allow users to: connect with others; send messages; view and compare tracked data; and, compete on leader boards, and in challenges.

This section (overview in Figure 5.10) focuses on our participants' use of these functionalities, their experiences of sharing data with others, and the influences that social use had on their behaviour. We begin by discussing how people shared their data with others, before describing the groups that some participants engaged in – including groups we deliberately put together, as well as those that grew more organically. We then discuss how our participants encouraged others to track, before moving onto an examination of how people engaged with the leaderboard and challenge functionalities, along with looking at some of the extreme behaviours these functions seemed to encourage in some participants. Finally, we focus on the concerns that some of our participants' close family and friends had about their tracking activities, as well as the effects of losing social support.

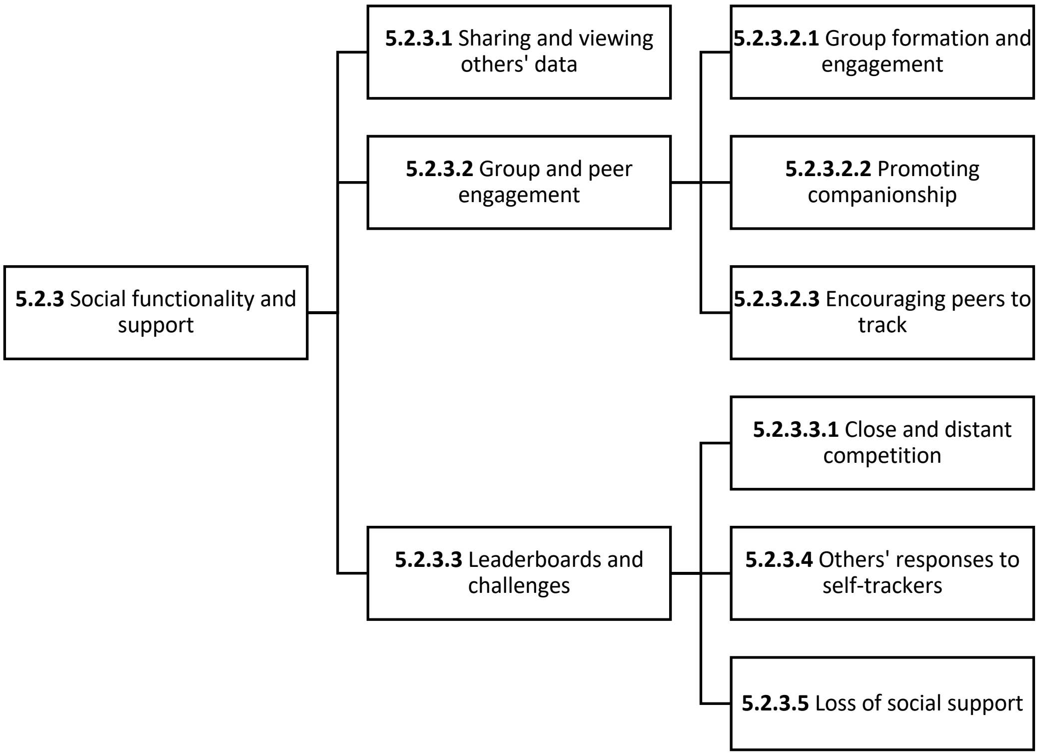

Figure 5.10 – Engagement with tracker features section outline

Our studies included multiple participants who knew each other and had the opportunity to share their tracked data with one another. In many cases we had multiple participants tracking within the same “group”, by interviewing multiple members of these groups, we were able to see different perspectives on these social practices. This included groups of friends and groups of colleagues, some of whom were collocated and others who instead used the social functionality remotely. Some participants in our longitudinal study were deliberately recruited in small groups so that they could, if they wished, used the social features, replicating real world use. We used a similar snowball sampling-approach to recruitment in our comparison study, leading us to recruit participants who knew each other, again allowing us to better understand the social aspects of their use from the perspectives of different users.

5.2.3.1 Sharing and viewing others’ data

A key component of social functionalities is the ability to share and view one another’s data (including the number of steps they have taken and sometimes personal data such as their weight or calories burned). Most participants were happy to share their tracked step data with others, but this was often not true for other data points.

Some participants avoided all use of the social features, even if requested to by their peers. Often this was because they were concerned about the repercussions of sharing their data, particularly if they felt they were less active than their peers. For example, P2 explained: *"if I'm really shit then no - I don't want other people seeing it",* she then told us that she would be happier to share the data with others who she did not regularly see, because: *"*[that] *wouldn't bother me as much, because they can't like take the piss out of me every day!"*. Interestingly, beyond concerns about "saving face" with others, no participants were concerned about the privacy of their data when sharing it with peers – contrarily to their feelings about sharing it with other stakeholders (such as insurance companies, see section 4.1.4).

Whilst most participants were happy to share their tracked steps with others, they were less inclined to share other personal information such as their weight, BMI, or even the number of calories they had burned or consumed, unless this was with very close family or friends. Most participants considered these data points to be more sensitive than their step count, understanding that calories burned was calculated using other personal data, including their BMI. This was sometimes incongruous with their goals, P3 explained that she would prefer the tracker to focus on calories instead of steps because*, "weight-loss is probably one of my main priorities"*, but that she would not be happy for calorie data to be used as the basis for the social functionality: *"probably not, no... well, it depends who I was sharing with. Me and my sister were both using MyFitnessPal....".* Even though steps are perhaps not the most reliable, or holistic measure of activity, and do not perfectly align with user goals, they are easy to comprehend and compare, and unlike other more personal data points, most participants are happy to share this data point with others (Kersten-Van Dijk et al. 2017).

5.2.3.2 Group and peer engagement

Our studies included multiple participants who considered themselves to be part of a group of trackers, either collocated (such as those sharing an office, or a house), or virtual (such as groups of friends, or those with another common interest). These groups of trackers grew virally, as P15 explained: *every time I show the Fitbit it's like viral - pretty soon everybody has one".* This section (structure visualised in Figure 5.11) presents how these social groups performed over time, their successes and failures, and the effect they had on participant's overall engagement.

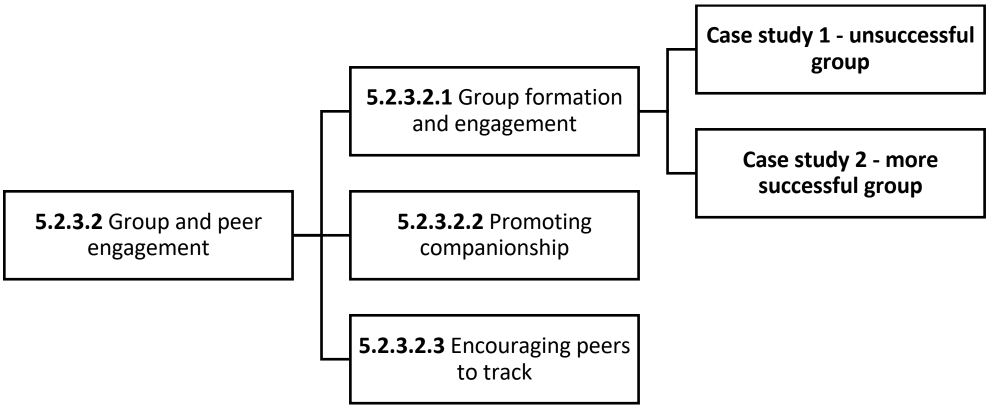

Figure 5.11 – Group and peer engagement section outline

Once they started using their trackers many participants discovered that they knew other people who were also tracking, and most chose to connect one another. Participants also often either encouraged friends to start tracking, or directly purchased them as gifts for others (see section 5.2.3.2.3), resulting in the viral organic growth of groups of close and distant peers, using similar self-tracking tools, engaging with the social functionality and eventually tracking as part of a group.

5.2.3.2.1 Group formation and engagement

Tracking as part of a group of supportive and encouraging peers is potentially a powerful way to engage people with self-tracking tools and to encourage more activity and positive healthy relationships with others. These types of engagement form the basis of many workplace wellness programmes, where a group of collocated participants use a tracking system to compete, support and encourage each other. However, whereas workplace wellness schemes require external support, and often rely on extrinsic motivations and a financial incentive, these organic groups could potentially encourage and empower participants in a longer-lasting and more engaging way, without the need for external support. However, as we present in this section, even when a group does come together like this, many fail to reach their potential and may quickly disband.

We primarily concentrate on two groups, which for the sake of clarity in the thesis we present as **two independent case studies**. Both groups formed from participants in the longitudinal study, so we could observe progress over time. Both groups were co-located, and each included four or more Fitbit users (not all of whom were participants) and at the outset of the study neither group were existing users of activity trackers. The first group was a group of five young adults, four of whom shared a house (which, during the study, had 5-8 occupants in total), and a fifth close friend who lived nearby. The second group was a group of colleagues in the office of a small company (approx. 20 employees total) and included 4-6 activity tracker users (after we supplied participants with their trackers other colleagues also bought Fitbit trackers and started tracking as part of the group).

Participants from both groups added each other as friends through the Fitbit system, but at least initially, one group appeared to be considerably more successful than the other, both in terms of engagement and in encouraging behaviour change. Whereas almost all the participants in the small-office group were engaged with their trackers and used the social functionality together, the group of young adults made very little use of the social features and most were less engaged with the technology. As a result, many of those in the office group made significant behavioural changes, at least in the shorter term.

Case study 1 – unsuccessful group. The group of young adult housemates was interesting to study, as they had an existing history of being competitive as a group, typically with physical activity, but they failed to engage with the Fitbits as a collective. When we first met, they explained how they maintained a spreadsheet detailing how long they could *"hold a plank"* (P30) and the number of pull-ups they could complete in 60-seconds, and others described a *"house weight loss competition"* (both P24 and P30), where they had competed with one another to lose the highest percentage of their body-mass. However, despite their high-hopes for using their activity trackers as a group, they did not appear to meet their expectations, and utilisation of the social functionalities between members of the group was low.

Some participants thought the lack of engagement may have initially been exacerbated by the Fitbit's inability to track all of their sporting activities. Although they lived together, each participant's daily routines, transport solutions, and preferred leisure activities were all very different. For example, P26 and P30 lived in the same house (at the beginning of the study) and had similar length journeys into work, but used different transport methods. Whilst P26 walked to a nearby bus stop and rode the bus for the majority of her journey, P30 cycled all the way to her destination. Even though her journey was less active, P26 routinely recorded more steps from her short walk to the bus stop. Participant P30 felt this was not representative and it led her to believe that social comparisons were not worthwhile. Soon after P30 became less engaged with the tracker, frequently forgot to wear it and subsequently stopped using it altogether.

Other members of the group believed the lack of engagement might have been because they were already fairly competitive and the step count *"hidden in their pockets"* (P27) was not salient enough to encourage further competition. They suggested that a more salient, perhaps public, display might have encouraged more competition (interestingly, in case study 2 the group of office workers created a public display of their activity, by copying a leaderboard of the group members onto a whiteboard in the office).

Ultimately, the group quickly failed because too few members of the group were engaged with the social functionality, despite four of the five participants continuing to track on an individual basis for some months. For example, P32 was highly-engaged with the goal-setting functionality (discussed in detail in section 5.2.2.3) and found it to be useful tool for changing and maintaining his physical activity, but did not use the social functionality with his housemates. He explained that he was interested in utilising the social functionality, but that this did not work if others were not engaged: *"I did not use the social thing that much in the end, because people started dropping out so there was no longer a consistent table happening. I would go on it, and then I would be at the top because everyone else had done 0"*, illustrating how the group cannot exist without engagement from a critical mass of participants.

Case study 2 – more successful group. In contrast to the group of young adults, the participants in the office were highly engaged with the social functionality offered by the system, at least in their initial interactions. This group eventually included four participants we had supplied with a device, and two other Fitbit user who were not participants in our study but had instead purchased the device as a result of their colleagues using it (see section 5.2.3.2.3 for more on this topic). During their first months of using the system they were considerably more engaged with it, being highly motivated to compete with one another, and put efforts into encouraging each other to take more steps. These participants were also engaged in regular dialogue about the study, the number of steps they were taking and the strategies and changes they were making to be more active, which increased awareness of steps throughout the entire office.

During the main part of the study, we witnessed norms in the office change, with changes not only affecting those who were tracking, but other members of staff too. For example, before the study started they would always use a taxi to attend meetings outside the office, even if the meeting was close by. After the study had started, they would instead walk wherever possible, if they had sufficient time and the weather was appropriate. P10 explained: *"in the office you get more of the banter and you're surrounded by these people all day… They're looking for any excuse to go for a walk to get extra steps".* Further illustrating the levels of engagement in the office he explained: *"I want to beat everybody else in the office. For example, today we ran out of writeable DVDs. So rather than the office manager going I immediately leapt and said 'I will get the DVDs!' just because I wanted to get extra steps"*.

Very soon after starting tracking this group became highly-competitive, P10 explaining: "*there was this thing for a while, especially when we first got them, where everyone was super, super competitive"*. Participants started using strategies to make the most of the competition in the office.

For example, they dedicated a whiteboard in the office as a public display of their step leader board. Some participants even strategically synchronised their device to mislead others about the number of steps they had taken, as explained by multiple participants: *"one person would come in being all smug going 'look at me at the top of the leader board' and then someone would wait for that moment to sync their Fitbit and then they'd jump to the top"* (P10); *"people started getting sneaky as well, they wouldn't update their Fitbit - they'd do something on a Sunday and then they wouldn't update, so you'd think that you'd beaten them, and then they'd come in on Monday and then suddenly BANG, they'd be like thousands of steps that they'd hidden from you over the weekend, that they'd been doing"* (P47). As the number of people tracking in the office grew (two more colleagues bought Fitbits to join in the *"entertainment"*), as did the *"fun"* and the *"not very friendly rivalry going around the office"* which resulted in members of the group making changes to their activity purely to record as many steps as possible, as P47 explained: *"It was really funny yeah, we all got into it... it was really nice, it was good fun. I found myself at home in the lounge, walking in the evenings. Just to try to beat someone else!"* (all quotes P47). This draws parallels with the notion of "seamful" design and interaction, whereby the "seams" in the technology are exploited in an interaction, in this case by a small number of our participants (Chalmers et al., 2004; Benford et al., 2006).

Despite the apparent initial success of this group and the changes that participants made throughout the main part of the longitudinal study, when we came to interview them at the follow-up we found a quite different story – nobody was tracking. The initial catalyst causing them to stop tracking appeared to be the batteries in their devices running out: *"but as people's batteries started to die they were too lazy and cheap to buy replacement ones* […] *so I think pretty much everyone has given up on it now"* (P10_FU). As we discovered, because the social support was such a significant component to their ongoing engagement, when some members of the group stopped tracking, *"the whole thing here in the office died out"* (P22_FU), as the social support diminished. Once some participants stopped tracking the entire group quickly disbanded, leaving the remaining participants without the social support they had been accustomed to, resulting in them also stopping tracking. Seeking to better understand the process of how, *"it slowly slowly started to kinda die out"* (P22) after members of the group stopped tracking. Participant P22, reflected on his experience in the group, further explaining: *"people were very encouraged at the beginning, they could see their progress, or see their activity* […] *as I said the whole social thing kinda died, there was no longer any banter or any... poking within the app or anything like that. I just didn't see the value anymore of me competing against, what, myself? No, I didn't see it that way, so I just stopped"*. This participant's experience was not atypical of others in this group, or elsewhere in our research, where loss of social support was responsible for participants losing engagement and stopping tracking. Some participants, including P22, attempted to circumvent this lack of support by encouraging others to track (see section 5.2.3.2.3), albeit in the case of P22, unsuccessfully. We further unpack the effect that loss of social support had on participants' engagement in section 5.2.3.5).

Throughout the period where participants in this group *were* engaged they made significant changes to track more steps, not only related to their day-to-day behaviour in the office and NEAT activities, but also to exercise. For example, P10 joined a gym to get more steps on the treadmill (*"on the treadmill, thousands of steps will go past in minutes it seems, it's awesome. I'll immediately come off and start taunting other people because I'd have overtaken them*"), and P22 took up badminton with his wife and some friends. However, once the *"whole social thing kinda died"* (P22) and participants stopped tracking, they also stopped many of the changes they made. Many participants appeared to be doing these activities *just* for the sake of tracking more steps for their competitions, which did not result in a sustained change, P22 explaining: *"I don't think the device really makes you change your habits, so you kind of fall back into your normal everyday life* […] *you hit the point where you hit the amount of steps that you think you can do"*. In the case of this group, most participants had little intrinsic motivation to be more active, instead the extrinsic motivation from the competition in the office was responsible for their changes in behaviour. When this extrinsic motivation was removed, they reverted to their previous behaviours.

The two case studies presented were not the only examples of participants tracking within a group, with other groups in our comparison studies also successfully utilising the social functionalities to compete and encourage each other to be more active. Amongst others: another group of collocated office workers in central London who used the Fitbit's social features to compete with one another, making changes to their activities to record as many steps as possible; and, a group in Atlanta, who were not collocated and instead knew each other through a common interest, who regularly used organised weekly step-challenges through the Fitbit app. Participant A3, who was part of the Atlanta group, when discussing the persuasiveness of the social aspects explained to us: *"I was commenting about this with friends* [some of whom were other participants and members of the group]*, it's weird how there's more initiative in trying to beat your friends in a weekly contest than there is in say, adding ten years to your life. I get more from the competition thing of it and it's more of an incentive to beat someone in that weekly competition"*. However, because of the approach we took in our comparison study, of using individual "snapshot" interviews, we were not able to see how these groups use changed over time – the groups may have either grown, or disbanded, after our interviews with participants.

One consequence of tracking as part of a group was the social relations it encouraged – using the tracker helped bring users together and encouraged them to have conversations and reflections that they otherwise might not have done. In the next section we discuss these unforeseen benefits in more depth.

5.2.3.2.2 Promoting companionship, support, and bringing people together

One positive, and perhaps unforeseen, result of engagement with the social functionality and tracking as part of a group was the promotion of companionship and support between users who may not have otherwise engaged each other. This use of the tracker resulted in changes beyond the device and the tracked activity, encouraging social interactions both though the tracker and face-to-face. These social engagements were particularly evident in two groups; the group of trackers in Atlanta who we introduced in the previous section, and a group with members of the University of the Third Age (U3A[19]). These participants both socialising and exercising together suggests positive mental health outcomes, along with physical ones.

The participants in the Atlanta group came together, at first virtually, through the Fitbit app after learning that each was tracking with a Fitbit and had a common interest centred around a shop in the community (details removed for anonymity). Each group member knew at least one other person in the group, but they had not met as a collective until they began to use the Fitbit challenges. The U3A group was initiated by P36 after he personally benefitting from tracking – through his prior involvement in the U3A group, he introduced participants to the concept of activity tracking and organised an initial meeting between all interested parties (some of whom had already purchased trackers). As he explained, "*the plan always was to meet up regularly, just meet face to face when we felt like it, and then communicate using the social aspect of Fitbit".* The group ended up not using the Fitbit's social features, feeling apprehensive of this functionality, and instead only discussed their physical activity in person: *"I meet people in the street every now and again, it's quite clear that using the Fitbit has become part of their normal lives"* (P36).

5.2.3.2.3 Encouraging others to track

Many of those who were strongly engaged with the social aspects of tracking wanted to track alongside their peers. Some *started* tracking alongside a friend, partner, or family member, but a greater number told us they had either encouraged their friends, family or colleagues to track, or purchased them trackers as a gift. Notably, social functionalities are not cross-platform compatible, limiting users to peers with a similar tracker. This resulted in participants wanting their particular

[19] https://u3a.org.uk/

tracker brand to become the most ubiquitous, which worked well for device manufacturers, who gained loyal customers supporting the brand, and recommending it to others.

However, this was sometimes frustrating for users: *"I had a friend who works at Jawbone and he uses one. My uncle uses Fitbit, but I try and use apps* [...] *it's annoying we can't compare"* (A24). We presented how wanting others to track effected people choice of tracker in 4.2.1, in this section we instead focus on why our participants wanted others to track, identifying three main reasons (outlined in Figure 5.12).

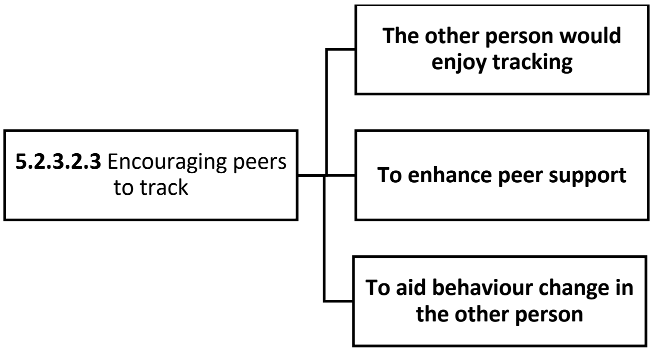

Figure 5.12 – Encouraging others to track outline

Some participants encouraged their friends, family and colleagues to track, or purchased them trackers, purely **because they thought they would enjoy tracking**. For example, P20 bought a tracker for her partner's father, because he walked a lot and she thought he would enjoy using it, *"I bought the Fitbit for* [partner's name] *father for Christmas, and then he loved the device"*. She later explained that the gift had been a success and he had indeed enjoyed using it, *"he's a person who walks a lot, and it's making him walk more I think. Every day he's telling us 'ok, today I walk 20,000'"* (P20_FU). Similarly, when we asked L5 why she wanted to gift her mum a tracker she told us that it was, *"just so she could see how great of a person she is"*, further explaining that, *"she walks <u>all</u> the time and eats well and she's lost tonnes of weight, so it would be nice if she could like, see it, just to congratulate herself"*.

Whilst some participants encouraged others to track for altruistic reasons, others had something to gain from it themselves: they wanted **to enhance peer support** for themselves. Some participants did this after losing their existing peer support (e.g. P22, who encouraged others to track when his social group collapsed: *"I've spoken about this with some of my friends and now three of them have bought them and they're putting pressure on my wife to buy one too")*, whereas others wanted to track with more peers, or had previously not used the social functionality. For example, P18 encouraged *"a friend at work* […] *her and her entire family"* to purchase Fitbits and found the social support she gained from this helped her: *"she went and bought one the same as mine and got completely addicted to it. She'd come into work in the morning and say 'Oh, I had to walk up and down my stairs 10 times last night to get to my 10,000 steps'"*.

Giving and receiving trackers was not always done for selfish reasons: other participants gifted trackers to **aid behaviour change in the other person**. For example P40, who made many changes to her physical activity and lifestyle after using her tracker, told us how she gave her tracker (named Chicco) up for "adoption" to a friend, because she thought it would be useful for her in becoming more active. Similarly, P7 encouraged her partner's parents to track because she was concerned about how inactive they were: *"off the back of this* [her partner's] *parents who we currently live with have bought one... not a Fitbit, but they've bought a pedometer because they wanted something quite basic just to see some steps"*. In the follow-up interview she told us that it had been useful, not only for changing their behaviour *"they've made a small change, but it is some change, so I think that was definitely an element of change"*, but also because *"they actually use it as a topic of conversation during the day"*, increasing their awareness of their activity.

Despite the potentially sensitive nature of encouraging someone to track, our participants generally said that this was well-received, though there was sometimes concern that this might not be the case. Often participants gifted trackers to others they thought "needed", or would benefit from using, them – such as P40 and P7, above – implying that the person giving the tracker thinks the person receiving it should be more active, or lose weight. For example, L5 bought a tracker for her dad, explaining, *"I'm also quite concerned about his health, because he says he walks and he cycles, but it doesn't work very much. He's overweight and I think he needs to do more physical activity"*. Similarly, L4 was interested in buying a tracker for her mum, explaining: *"she's just been diagnosed with type-2 diabetes, which is kind of totally her own fault. Also she's got IBS as well, so any of the sugar-replacement diabetic-friendly things would kick off the IBS. So she kinda can't eat anything but vegetables, she's still going out and checking herself in on Facebook with ice cream… it's really annoying me"*. One could imagine that the person receiving the technology might be offended, but, at least from the examples of in our sample, this did not seem to be the case. Instead, those who received trackers as gifts seemed to be pleased to receive them and most did not directly associate them as being a health-related tool, instead thinking of them as a more fun way to challenge themselves whilst increasing social connection. Additionally, in many cases the gift was not a complete surprise, instead having been discussed before purchase, and the receiver was often already aware, or prepared to change their behaviour.

5.2.3.3 Leader boards and challenges

A key part of the social functionality was the step leader boards, which arrange peers based on the number of steps taken over the past 7-days. Our participants used leader boards in different ways: whereas some used them to help gain an awareness of social norms and understand what others in a similar situation did, others used them much more competitively, taking steps to increase their position on the leader board and do better than their peers. The Fitbit, which many of our participants used, also offered the ability to arrange time-constrained step competitions (or "challenges") between a selection of up to 10 users, with a private messaging channel and leader board. This functionality, introduced in the summer of 2014 (before our longitudinal study follow-up interviews, and comparison study interviews), is similar to some workplace wellness programmes and was popular amongst our participants, who were sometimes very competitive: *" that's definitely been a catalyst for really going 'ok, I want to beat these people'"* (L6).

Most participants were initially interested in the leader boards so that they could better understand their activity levels in relation to their peers and understand norms around how many steps they "should" be taking. In one of our initial interviews P25 explained, *"clearly it is interesting and amusing to know the data of people you know, but in order to get a sense of whether you are good or bad it's useful to know data about other people"*. Participant A13 initially used the leader boards for peer comparison too, explaining: *"knowing people who live similar lifestyles to me and looking at where they were, I kinda wanted to make sure that there were times in the week I was hitting the 10,000 but I also wanted to make sure that I wasn't too far below what my friends were doing"*.

Although many participants started off using the leader boards to compare their activity with that of their peers, for some their usage soon turned competitive. P3 explained, *"I think I got a bit more competitive when I was running and doing more steps and I was able to be more competitive"*, but this was short-lived: *"that sort of wore-off quite quickly, partly because my sister* [who she was competing with] *has a very different lifestyle to me, so it's much easier for her to get more steps than me just in her day-to-day life, because she's a nanny running around after children and I'm sat at a desk all day"*. However, whilst the competitive element was short lived for some, others took it far more seriously and ended up making significant changes to maximise steps: *"my friends are crazy about these challenges. They're running in place in front of their TV to get 25 -26,000 steps just so they can be on top! For them, they're running in front of the TV, for me I'll go to one of these step classes. Then I won't sync until the end of the day or something to snipe it, because they'll think 'oooh, it's fine, we're only at 6,000 steps', then I'll sync it and then like 'yeah, 16,000 steps because I went to a class'* [laughing]*"* (A15).

The leader boards and challenges are fundamentally designed to encourage users to compete with, but some of our participants took this to extreme levels, becoming obsessed with taking as many steps as possible, and making choices solely for the purpose of tracking more steps. For example, L6, explained to us that she wanted to get her steps even during her pregnancy: *"when I was pregnant I was still quite adamant that I wanted to get my steps in, which until I was admitted to hospital - slightly earlier than anticipated - that was happening. In hospital my numbers dropped because I had to have my blood pressure taken every 15 minutes, so it wasn't really conducive for pounding the corridors. But given any opportunity, I did. I wasn't allowed to leave the hospital and I wasn't allowed to go outside sometimes, so I did just walk the corridors at night to get my numbers.* […] *But my numbers dropped and that bugged me, even during all that I was annoyed that I would be getting only 6,000".* However, she did make some exceptions for her pregnancy, admitting that she, *"took it off when I had my baby, because I was worried that it might get lost in all of the excitement".* She then told us, somewhat jokingly that, *"I think a counselling group might need to be set up. I think I've got an addiction!"*.

Others who were tracking alongside L6 also told us about the drastic changes they had made to their physical activity to be competitive with steps. For example, P15 stopped using public transport to commute to work, instead choosing to walk. She also explained that she would walk between meetings scheduled during her working day rather than take public transport. The unusual nature of this was only apparent when she explained that these meetings were typically between two offices over 3-miles apart, which represented a walk of approximately 1 hour – effectively removing two hours from her working day each time (which would happen at least once a week). Similarly, L17, who was often at the top of the leader board, took part in planned activities six-days of the week and marched on the spot in front of his TV in the evening, instead of sitting down – rarely giving himself a break to recover. However, not all those who were competing with the step-goal and Fitbit challenges were playing fair. Shortly after our completion of our interviews, participant L6 got in touch to tell us about a *"scandal"* with one of the other trackers in her social group (not a participant). Participant L17 had cast doubt on the high numbers one of their colleagues was tracking, who then admitted that she had purchased a second tracker for her husband and linked it to her account – effectively combining both her own and her husband's steps on her account. Other members of the office had decided this was cheating and ostracised her, removing her from the Fitbit app and any challenges they were running.

5.2.3.3.1 Close and distant competition

Social comparison and competition were important motivating factors for many participants. However, whilst close and achievable competitions could help motivate participants, distant or unachievable competition could be demotivating. For example, P20 decided to not add her boyfriend's father as a friend, *"because he would beat me* […] *what's the point if I cannot win!* […] *yeah, yeah. I only have friends who I can beat!* [laughing] *no, ok, that's not completely true, but he is doing like 20,000 steps per day, which is totally... I cannot reach him"*. Similarly, P25 explained: *"If someone is doing better than me, and they try to be competitive with me, if it's clear that they're better than me I just think 'well fine, go get on with it then'. It doesn't spur me on, because I don't think it's achievable for me"*.

Whilst some participants decided to either ignore the competition, or not add certain users as peers, others completely avoided the connected features of their activity tracker. For example, P2 decided to use her Fitbit offline, using it as a pedometer without connecting it to the Fitbit platform, after realising that other Fitbit users in her workspace routinely took more steps than her: *"I know they do it, but they're much more athletic so I don't see the point… I'd need to compare with someone like me who finds it hard to find the time or gets tired easily"*. This resulted in her also missing out on other functionalities offered by the tracker, which could have potentially motivated her to be more active.

5.2.3.4 Other's responses to self-trackers

Not all our participants' family and friends were interested in taking up tracking alongside them or were even supportive of their tracking practices. Tracking, and the resulting ways that our participants changed their behaviour, was sometimes the cause of tensions between our participants and their closest peers, colleagues, family and friends. For example, when we asked participant L6 if her partner also tracked his activity she told us *"no he doesn't. I've asked him if he'd want to and he just looked at me... I think he's seen what it's done to me".* He had originally bought the tracker for her as a gift, but she told us that she thought he sometimes regretted it: *"when I'm pacing the lounge at 11 o'clock, trying to get my steps in before midnight I think he perhaps regrets it. I think to be honest a few of my friends have also reported similar with their partners - 'for Christ's sake, just sit down and watch the programme'"*. Similarly, P36 mentioned tensions between himself and his wife, over his use of his Fitbit: he had made many changes to his lifestyle and physical activity, but she considered some of these to be too extreme (for example, he explained that instead of driving to his local supermarket as he had previously, he would instead make multiple trips by foot). At the point of the follow-up interview his wife no longer wanted to hear him talking about the Fitbit: "*I just don't mention this anymore. If I do mention this she says that I've become completely obsessional and it's* *not healthy!* […] *actually continuing to do what I am doing is in the face of considerably discouragement*!".

Whereas P36, above, continued tracking despite the discouragement from his partner, P22 became less engaged and then stopped tracking after his partner had complained about his use of it. In our second interview he explained that his partner was unhappy that he was taking part in the study – *"I think when I mentioned it she thought it will involve a lot of my time from my side"* - she thought that he already spent too much time away from her, doing physical activity, and that using the Fitbit would exacerbate this. However, he soon became less engaged with tracking and then stopped entirely, after which: *"she completely forgot about it...".* One could imagine that P22's partner's discouragement may have influenced his engagement with the device. Though peer support can be encouraging and help aid behaviour change and continued engagement, the opposite may also be true – if one is discouraged from tracking by one's peers it is very likely this will affect their engagement with the tracker.

5.2.3.5 Loss of social support

The loss of social support acted as a significant barrier for those who were highly reliant or engaged with the social functionality, often resulting in them stopping tracking. In section 5.2.3.2.1 we discussed how, when a social group of trackers disbanded, the individuals tracking would soon become less engaged, and often stop tracking. This was also true in other situations, for example, three participants who used their tracker as part of a wellness program (which provided a health insurance discount as an extrinsic motivation, by grouping participants together to meet activity goals, and providing peer support) also faced challenges when their social support was removed. Two of the three stopped tracking immediately after the programme finished, and the other stopped soon after: *"I've got very slack on continuing... the challenge is over"* (A1). This perhaps indicates that removal of an extrinsic reward decreased engagement – although these programmes appear to be useful in encouraging activity whilst they are active, further research on their long-term effectiveness should be undertaken. Participant A1 did discuss a potential workaround to continue tracking after her wellness program had finished - her "workaround" was to continue tracking using a new device that would offer her some social support: *"my husband has one* [a Fitbit]*, so, it would just like have the team aspect"* – something that other participants also attempted, as we discussed in section 5.2.3.2.3.

This section has described how our participants interacted with various functionalities embedded into their trackers over a longer time, and the effects this had on their physical activity. Some participants' levels of engagement with the behavioural goals and social functionality could be considered obsessive, or harmful (even by themselves and their peers); and, loss of the social functionality sometimes resulted in participants who were previously engaged stopping tracking. These negative interactions were unfortunately not unusual, with many of our participants experiencing challenges, or negative feelings towards their tracker at some point during their self-tracking journey. However, some participants created workarounds to lessen the effect of these challenges. The next section concentrates on other challenges - barriers to continued use - and discusses the other workarounds that some participants created to negate their effect.

5.3 Barriers and workarounds to tracking over time

Throughout our studies our participants experienced a variety of challenges, or "barriers", to continued engagement with their tracking systems. These barriers were the result of a wide range of challenges to continued engagement, both related to the tracking systems themselves (e.g. technical breakdowns, or problems with battery life), as well as the user's own behaviours and activities (e.g. forgetting to wear their tracker, or taking part in activities that the tracker was not designed to track), and the intersection between the two (e.g. participants feeling that the tracker was aesthetically inappropriate in certain settings, or feeling disappointed in their tracker's inability to accurately record activities it was not designed to), as shown in Figure 5.13.

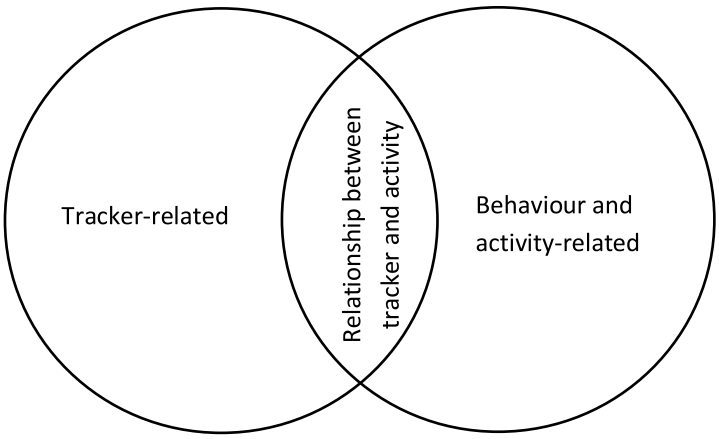

Figure 5.13 – Barriers related to tracking, behaviours, and the relationship between the two

As presented in the section 5.1, these barriers would sometimes affect participants engagement with their trackers to the point that they would *lapse* tracking, or even *stop* tracking altogether. However, removal, or lessening, of these barriers may encourage people to continue tracking, or return if they had stopped. Amongst our sample, some participants created and explored "workarounds" to overcome barriers and continue tracking over an extended time. Figure 5.14 presents an overview of these barriers and workarounds.

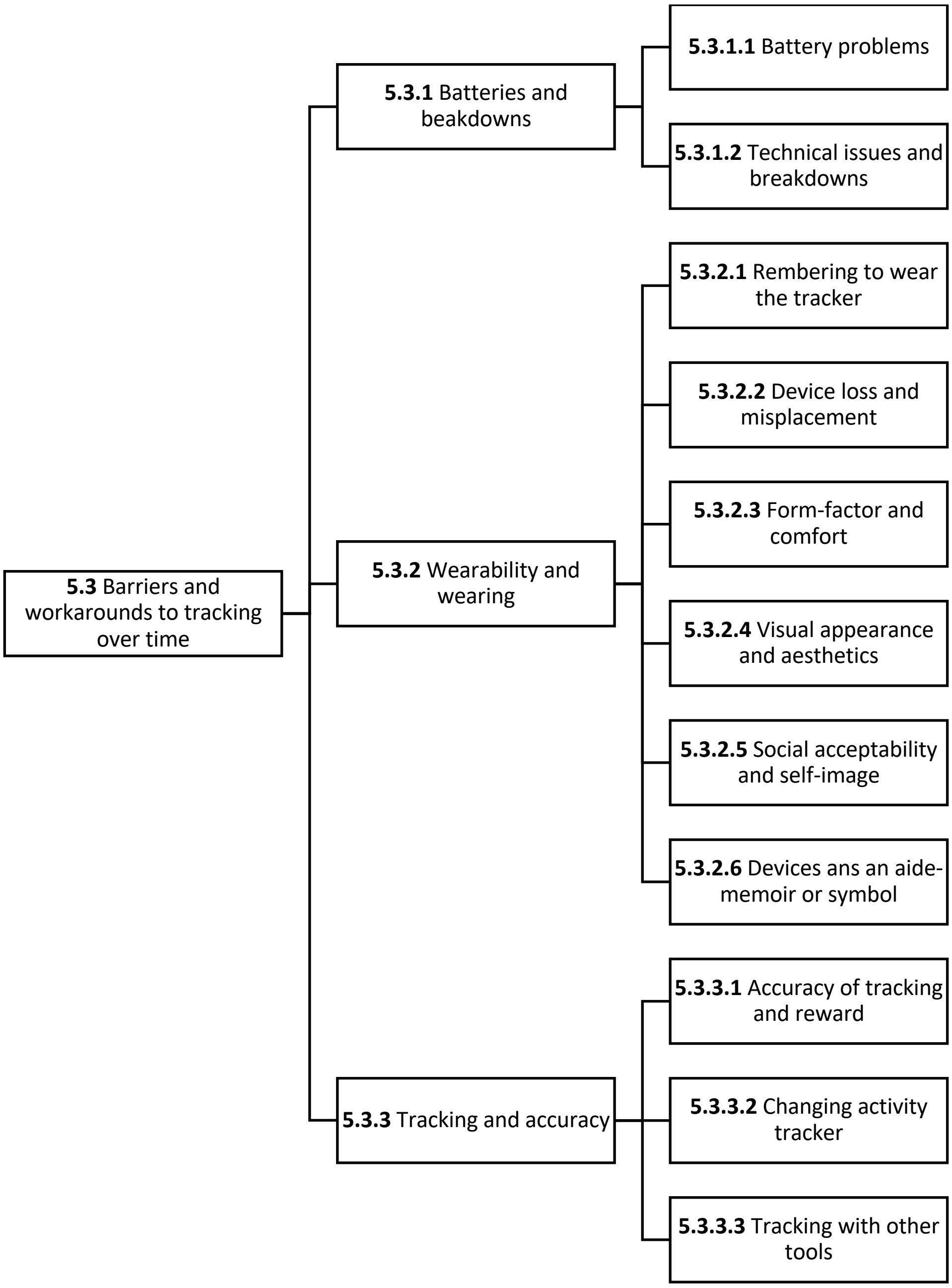

Figure 5.14 – Barriers and workarounds to tracking over time outline

The barriers related to continued engagement with wearables, "smart devices" and personal informatics tools have been increasingly well understood over the past 5-years, as a result of multiple studies, including our own (Harrison et al., 2015; Yang et al., 2015; Clawson et al., 2015; Lazar et al., 2015; Epstein et al., 2016a). Barriers that have been identified and characterised include: reliability and the tool breaking; battery life and charging the battery; comfort, physical form and aesthetics; quality of data and appropriateness of the tracked data; and, loss or removal of features, such as social support. As we present in this section, though some users stop tracking when faced with unsurmountable barriers, others have created "workarounds" to circumvent the barrier and continue tracking. Identified workarounds can be as obvious as purchasing a different tracker to better suit their needs (e.g. form factor, features, etc.), to something more creative such as wearing an "ugly" wrist-based tracker hidden on an ankle.

In this section of the chapter we characterise the various barriers our participants were faced with, the workarounds that they created to overcome these barriers, and how this impacted their ongoing engagement with the devices. Our approach, including longitudinal studies and recruiting those who had decided to stop tracking in the comparison study, allowed us to triangulate findings and gain data from different perspectives. It is important to note that although participants from the longitudinal study were provided with their devices as part of the study, and participants in the comparison study had purchased or acquired their devices of their own accord, there were not significant differences in their use over time and attrition. The barriers and workarounds presented in this section apply equally to participants in both studies, although of course participants in the comparison study used a wider variety of different devices.

5.3.1 Batteries and breakdowns

Even though our participants were using commercially-available activity tracking systems for their intended purpose, a large proportion experienced technical issues which impacted their use or found that the technical capabilities of the devices failed to meet their expectations.

5.3.1.1 Battery problems

Issues with their tracker's battery life was the most frequent, and often significant, barrier for our participants, who quickly grew tired of replacing batteries or regularly recharging their devices. Earlier in this chapter, in section 5.1.2, we described how issues with the battery life often resulted in participants *lapsing*, here we instead focus on the broader battery-related issues they experienced. These may have contributed to participants *stopping* tracking, as many struggled to find workarounds to this problem.

The Fitbit Zip was specified to have a battery life of 4-6 months, but in reality participants found that it would rarely last this long, *"I stopped using that because of the battery... it's really annoying, the life of the battery is too short* […] *just after you change it - 2 months"* (P40). Others experienced problems with the battery depleting within days, which often caused them to give up entirely, *"that battery died* […] *so in my mind the Fitbit was either broken or I needed a new battery and I couldn't* *be fussed"* (P34). We were unable to ascertain the cause of this. Other participants had issues with devices that used rechargeable batteries, finding that they would also deplete more quickly than they were expecting, causing them to lapse: *"the way the Fitbit charges, I usually attach it to my laptop in the office. So unless I see my email when I get to the office that says 'your Fitbit battery is low', I forget to charge it and plug it in"* (A14). The frustration of having to charge the device caused some participants to stop tracking: A22 stopped tracking because of this frustration, stating: *"I still plan on using it in the future. Once I get around to charging it"*.

When talking to participants about their unmet needs, many desired a longer battery life and we generally saw a decreased desire to keep the device charged as participants progressed through their tracking journey. For example, despite the fact that she had purchased her device herself, L5 told us that remembering to keep the device charged was not always a priority for her, as she had already learnt from it and felt that continued engagement was not necessary: *"once the battery died and I didn't use it for one or two weeks, I had already gained that knowledge and I already knew that if I wanted to do more steps in my daily routine. I had to go for a stroll in the afternoon* […] *so I wasn't really fussed by the fact that it wasn't tracking and I did keep changing my behaviour, meaning, if I could I did go out for a walk".* She went on to explain that she had, *"got a bit annoyed with charging it, because I'd just got my smartwatch as well and I had this sudden realisation that I had to charge all sorts of device, not just my phone anymore, but it was my watch and my Fitbit"*.

Participants using smartphone applications also experienced problems with short battery life. A5 started tracking with the smartphone app *Moves*, but explained, *"I don't use Moves anymore because my app took up too much of my* [smartphone] *battery".* He created a "workaround" of sorts by later returned to tracking with a wearable tracker with a longer battery life. Other participants already using devices were concerned about the impact of having their phone's Bluetooth turned on allow their tracker to synchronise data, *"I tend to have Bluetooth turned-off on my phone, because it rinses the battery"* (P3). This could cause an issue for continued engagement, as this meant that some participants did not receive notifications on their smartphone showing their progress throughout the day, and would sometimes forget to synchronise their device at all – effectively using it as a pedometer, rather than taking advantage of the extra activity-tracking functionalities offered through the mobile app and website.

5.3.1.2 Technical issues and device breakdowns

Beyond technical problems related to batteries, the other major technical issue participants experienced were device breakdowns, where a fault in the tracker would prevent them from using their tracker as intended, or in some cases, at all. These technical breakdowns were unfortunately common amongst our participants, coming in many different forms, and again often resulted in the participant *lapsing*, or *stopping*, tracking.

Connectivity problems between the tracker and the phone were a relatively common issue, whereby *"the little Bluetooth icon comes on but then the thing doesn't update"* (P10). Many participants had continual problems with their tracker disconnecting from their phone, reducing the functionality of their devices (they would no longer receive progress alerts throughout the day) and leading to disengagement. To move beyond this issue, some participants instead synchronised their tracker with their computer, using the USB dongle included with some trackers.

A large number of our participants also had problems with the physical durability of their devices, which did not appear to be robust enough for day-to-day use. Many of our participant's devices were held together with tape or glue, which was a particular problem for wrist-worn trackers, which could easily fall off and be lost if the strap had broken. Other participants had problems with the clips on their devices failing, with chargers stopping working, or with broken screens. Many participants using the Fitbit Zip experienced a problem where the device would repeatedly turn off and on throughout the day, drastically lowering the number of steps recorded and often preventing proper synchronisation.

Although device breakdowns often resulted in participants lapsing, or stopping tracking, sometimes lapses were only short, and participants would continue to track with a replacement device. Participant A15 explained to us the numerous problems she had experienced with her devices, all of which were quickly replaced by the manufacturer: *"I wrote them and said 'hey, this thing broke, it's a bad design for this, but I think it's pretty cool, what are you guys going to do about it' and they said 'here, try the one'. Then that one fell out, it's actually honestly my fault, but I contacted them again and they said 'oh we're really sorry, here have another one'. I think they've sent me four over the past three years"*, resulting in her continued tracking over a longer term.

5.3.2 Wearability and wearing

Activity tracking *devices* (which may be worn on the body, or clipped to clothing), rather than smartphone applications (which require the user to carry their smartphone to track steps), require users to adopt a new piece of technology which they must not only integrate into their daily routines and remember to wear, but also fit within their outfits and social activities. Given this, it is unsurprising that the wearability, visual aesthetics and social acceptability of tracking devices was of concern to participants across our studies. Breaking down wearability as a whole, in this section we cover remembering to wear the device, loss and misplacement, comfort and form factor, the visual appearance and aesthetics, and finally participants' perceptions and feelings around the social acceptability of tracking.

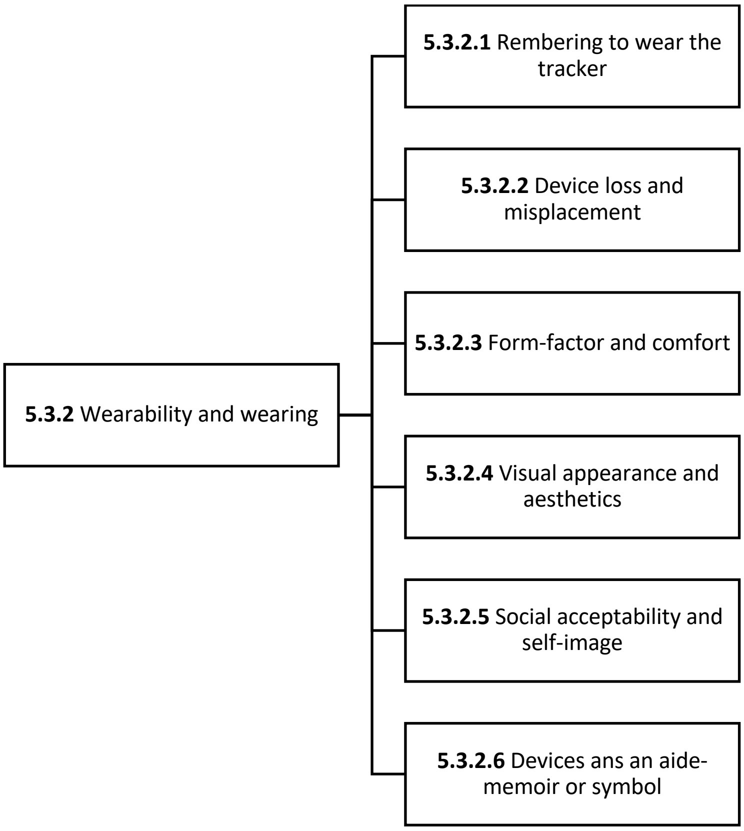

Figure 5.15 – Wearability and wearing outline

The tracking *devices* our participants used primarily came in one of two forms: clips, such as the Fitbit Zip, which offer flexible positioning allowing users to produce their own strategies for wearing it in a variety of locations around the body, including on pockets, waistbands, underwear and bags; and, wrist-worn devices, such as the Fitbit Flex, which are designed to be strapped around the wrist like a bracelet or watch. Smartwatches were only beginning to become widely available at the time we undertook our research, so although they are considered, they are less well represented than the other form-factors.

5.3.2.1 Remembering (and forgetting) to wear the tracker

Participants frequently brought up the topic of remembering to wear their tracker in interviews. Whether they used a clip or wrist-worn device, participants needed to remember to attach the tracker to either their clothing, or themselves, and as mentioned in 5.1.2.2 forgetting to wear the tracker was a common cause of unintentionally lapsing, particularly at the beginning of many participants' self-tracking journeys.

Most of our participants reported that forgetting to wear their tracker was a frustrating experience, as they generally wanted to make sure that all their activities were recorded. To make sure they did not forget the device some participants created workarounds, or strategies, to help them remember to wear their trackers. Some participants unknowingly used approaches previously mentioned in resilience and habit literature: integrating a new routine (in this case, the act of wearing the device) with a pre-existing habit (Lally and Gardner, 2011). These participants would, for example, report putting the Fitbit on after their watch in the morning, or use a pre-existing morning habit, such as taking a contraceptive pill, as a trigger. This approach worked well for P3, who explained to us that she routinely placed her Fitbit next to her contraceptive pill when she took it off in the evening, and then used her pre-existing habit of taking the contraceptive pill as a cue for attaching the Fitbit in the morning.

In both of our studies, participants generally reported that they forgot to wear their devices less frequently as they became more accustomed to wearing them. After this point, the unintentional lapses caused by forgetting to wear the tracker instead tended to mostly occur when participants were doing something outside of their usual day-to-day routine. For example, P20 who was generally very engaged with tracking, told us that she forgot to wear the tracker on multiple days one week, when she was visiting family in her home country: *"*[I] *forgot to do it because it was outside of my normal routine"*. Similarly, many other participants reported forgetting to wear their trackers during public holidays and other days that they spent at home: "*around the house I would sometimes forget to wear it*" (A8). This tended to be particularly true if participants did not get dressed at home, as many would habitually put their tracker on when they got dressed, as P12 explained, *"part of my routine is to wear it on my clothes, if I don't get dressed I don't wear it"*. This is not to be confused with those participants who would *intentionally* not wear their tracker on days spent at home, which is covered in 5.1.2.1.

Once participants had integrated wearing the tracker into their routine, it generally proved to be a strong habit. Some participants continued wearing their tracker when it was broken, or the battery had run out - we witnessed this phenomenon multiple times during our longitudinal study, where some participants continued to wear their tracker for weeks or even months when it was not functioning. For example, P27 continued to carry his Fitbit Zip tracker for over 4 weeks after it stopped working, having become accustomed to putting it in his pocket each morning. Somewhat similarly, P40's tracker was not working reliably from the beginning of the study, but she continued to wear it, even when it became completely non-functional. She explained how, *"*[the] *Fitbit helps me to really think about my health"*, and because she had associated it with her physical activity she continued to get some utility from wearing it each day, despite the fact it was technically non-functional (we look into this phenomenon in more depth in section 5.3.2.6).

Despite the fact that participants became better at remembering to wear their trackers as they progressed through their self-tracking journey, forgetting to wear it proved to be a frustrating barrier for some. This was particularly true of those participants who were keen to have a *complete* record of all their activity, who were frustrated even when they forgot to wear their tracker at home. For example, P28 who, at the time of this interview, had forgotten to wear her tracker just twice – once on a day spent watching the Lord of the Rings films at home all day, and the other when at home on holiday from work - explained: *"If I'm in my pyjamas until the afternoon then I'll forget to wear it then* […] *I feel annoyed at myself for forgetting to wear it"* (P28). Some participants even went as far to say that they felt "differently" about their activity if they had not tracked it, sometimes suggesting that untracked activities felt less worthwhile.

5.3.2.2 Device loss and misplacement

As previously discussed, one of the largest barriers to continued tracking was participants permanently losing, or temporarily misplacing, their device. Participants in all our studies reported losing their devices, but device loss was particularly evident amongst participants in our longitudinal study, where 14 devices were permanently lost during the main part of the study (the first 28 weeks, not including the follow-up).

Because of the insecure fixing mechanism used in the clip form-factor Fitbit Zip the device could more easily fall from clothing than wrist-worn devices, which were more common amongst the participants in our comparison study. Those participants who wore clip-based trackers frequently told us that their device would fall, or unclip, from their clothing when moving around, *"luckily I've noticed, but I've knocked it off my pocket or my man bag and it falls on the floor"* (P10). Generally, participants would notice the device falling, but not always. Temporarily misplacing the tracker in the home was a frequent occurrence, and was often responsible for unintentional lapses. For example, participant 30 regularly misplaced her tracker, telling us *"I will occasionally leave it on a skirt and it'll be in the wash basket so I won't be able to find it for a week. Like last week, I didn't wear it all week because it was in the wash basket. Every morning I'd be like 'where is it!?'"*. Misplacing the tracker was also a cause of anxiety for some participants. For example, L6 told us of an occasion when she thought she had lost her tracker, and the anguish this caused her: *"Obviously every step counts, and then I've got side tracked with* [her daughter] *and I've gone 'oh god, I've not got it clipped on' and I've gone out somewhere. I briefly lost it a couple of days ago and that was very, very stressful. I was* *thinking ‘I can't go out until I've found it’ - I was confident that it was in the house. I had an arrangement with a friend, and I was thinking ‘would it be crazy to cancel her?’. But she has a Fitbit as well, so she'd have understood”*.

The device falling was also responsible for participants permanently losing their device and stopping tracking; 4 of the 50 participants in our longitudinal study lost their device within the first week. After losing their tracker many participants chose to replace it, sometimes more than once. In our longitudinal study just seven of those who were still tracking their steps at the point of the follow up interview were using the original tracker, with six other participants still tracking, but with a different device. Some participants chose to replace their tracker like-for-like, whereas other participants chose a different model, with different features or form factor. We further discuss participants’ choice of replacements in section 5.3.3.2.

Some participants were anxious about losing their tracker, which was a considerable barrier to regular use. Some participants intentionally lapsed tracking when they perceived a considerable chance of losing their device, for example, when going on holiday or out for the evening. This was especially true for those who had either previously lost a device or knew somebody who had. P16, whose friend had lost a similar clip-on tracker told us, *"I'm not really comfortable with the clip-on thing. I'm conscious that I might just lose it one day"*. Some chose to leave their tracker at home when they went on holiday,: *"I didn't want to lose it, so I left it at home, on the side"* (P29). Fear of losing the device also caused some participants to wear their device in a manner that they wouldn’t have otherwise – often, with clip-based devices, this involved facing the screen towards their body, rather than outwards. This made checking the screen of the device more difficult and could result in less frequent monitoring of steps throughout the day, but these participants felt that if the tracker was to come unclipped that it would be more likely to fall within their clothing rather than onto the floor – a workaround with a negative consequence, but a lesser one than losing the device entirely.

5.3.2.3 Form-factor and comfort

The form factor of their trackers was an area of concern and interest for most of our participants, many of whom sometimes experienced barriers to continued use with their trackers and considered different solutions. At the time of our studies the most commonly available devices were clips and wrist-bands, with smartwatch trackers just beginning to become more widely available. Whereas wristband devices are only designed to be worn in one place, clip-based systems instead allow users to flexibly wear devices in a variety of different places. Physical comfort was also an important consideration for many participants, who found ergonomic issues in the design of their trackers.

Participants from our longitudinal study did not choose the tracker: they were supplied with a clip-based Fitbit Zip. Most other participants chose their tracker themselves (unless it was a gift, or part of a wellness program), but factors such as price and availability also played a role in their choice. Participants' choice of tracking technology is covered in more detail in section 4.2.

Despite the flexibility of clip-based devices, many participants struggled with finding somewhere appropriate to attach them, which sometimes prevented them from wearing them at all, and led to decreased engagement. Many participants chose to wear the device on their jeans or trousers, generally in a pocket or attached to a belt or belt loop and reported few difficulties with this practice, finding the device easy to wear and unobtrusive. However, some female participants reported problems finding somewhere to position the device, especially when wearing less substantial clothing, such as summer dresses or evening wear. This would sometimes result in them not wearing the tracker at all. Reflecting on the form of the device, P26 summarised the problems our participants experienced, *"there's probably been 2 or 3 occasions when I've not worn it because there hasn't been somewhere to wear it where it wouldn't be obvious. If you're wearing a really tight dress or something like that then it's going to show and there's no way of wearing it: you could wear it on a strap, but everybody would be able to see it. I've left it off for aesthetic reasons two or three* times". For some female participants this led to a reduction on the frequency which they wore the device.

As a workaround to the challenges of finding somewhere to attach the tracker, many women experimented with positioning the device in different places. Some participants settled on placing it in their bag (where it would measure only steps when the bag was being carried), or wearing it on their underwear, frequently on their bra, either on a shoulder strap, or over the sternum. Many female participants found wearing the tracker on their bra to be very convenient, P17 joked that it was *"one of the advantages of wearing a bra"*, as it was an item of clothing they almost always wore, and the device could generally be easily hidden. However, some participants were unhappy wearing the Fitbit on their underwear, telling us that it was uncomfortable and rubbed awkwardly. P13 simply did not like the idea of a piece of technology on her underwear and continued to struggle to wear the device. As we further describe in section 5.3.2.5, other participants also sometimes felt awkward wearing the device on their underwear – particularly if somebody saw the device and took an interest in their strategy for wearing it.

Some of those participants using clip-based devices wanted to swap to a wrist-worn device, citing the ease of wearing. However, many of these participants also had concerns with aspects of the other available devices, such as their visual aesthetics (see next section), cost, and comfort. P6 wanted a wrist-worn tracker, but when she replaced her Fitbit Zip she instead purchased a replacement clip-based device, explaining: *"Fitbit's wrist bands are quite chunky and quite ugly and they don't really offer more functionality than the clip one, so I thought I will save that extra £50 or whatever the difference is and go for the clip"*. However, other participants, such as P20, did swap from a clip to a wristband device, highlighting the individual taste around form factor and aesthetics.

The physical comfort and fit of their tracking devices were also important issues for many of our participants, especially for those using wrist-worn devices. Participant A9 explained to us that the discomfort he experienced when using his Jawbone wearable was one of the reasons he stopped tracking: *"I would take it off very frequently, sometimes because of typing, sometimes because of doing bedtime with the kids or whatever, it was just getting in the way* […] *it just wasn't practical for wearing all the time"*. He later explained that, *"I'd go back to one"*, if the device had, *"maybe a slightly longer battery life and it was more comfortable to wear"*, indicating the importance of these aspects for continued use.

5.3.2.4 Visual appearance and aesthetics

Activity trackers are designed to be integrated into all moments of one's life, and worn all day, every day. As such, it is unsurprising that the visual appearance and the physical design of these devices are important factors that could potentially act as barriers to continued use. The weight participants gave to the importance of an agreeable visual appearance did, however, vary.

Generally, those who were using clip-based devices were less concerned with appearance, as they were often able to wear them in such a way that they were concealed. In contrast, those who wore wristband devices were generally much more concerned with their tracker's appearance, as P3 explained, *"because actually, I know it's vain, but appearance... for something you wear on your wrist all the time how it looks is really important to me".*

P29, a woman working in the fashion industry, told us: *"technology companies aren't good at aesthetics and when they want to make something for girls they just make it pink".* In the follow-up interview some 10-months later, tracker aesthetics were still an important topic to her: *"they're* [activity trackers generally] *not very pretty, so with some outfits I wouldn't want to wear it. The Jawbone ones, and the wristband one that you've got* [the Fitbit Flex] *is quite chunky, so I'd want it to be a bit slimmer, a bit more discrete... I think also there's a trend of these wearable tracking things is definitely on the up, and if it becomes more of a... an accepted, not necessarily fashion bracelet or something, then it would be better, I think"*. Similar views about the appearance of the tracker were common amongst our female participants, but less common in our male participants, who were generally much less concerned about how their wearable looked, instead focusing on aspects such as comfort and functionality.

Similar to P29 above, many participants' concerns about the visual appearance of their tracker resulted in them sometimes lapsing tracking. For example, participants decided to not wear their tracker: when they decided it did not fit well with a certain outfit; when they did not want a piece of technology on show; or, when going to social occasions where they felt it was inappropriate (e.g. a wedding). Many participants had concerns about the device clashing with their outfit: *"If I was going out* [e.g. to a dinner party or restaurant] *I'd probably have it more concealed. Like, if I was wearing red I definitely wouldn't have it on show"* (P3 – user of a magenta coloured Fitbit). A potential workaround that some participants suggested, but did not follow-through with, was customising their tracker to change its appearance with DIY alterations and aftermarket accessories. For example, participant A13 wanted to change the appearance of her wearable as she does with jewellery and outfits, saying *"I wish they had more options, like rather than just the rubber band thing"*. She, and others, were interested in a jewellery-like Fitbit Flex cover available from popular fashion designer Tory Birch, but complained *"it's more expensive than the device itself, I cannot justify paying for it"*. However, other participants using the same device (the Fitbit Flex) were satisfied with its appearance, again highlighting that there is no one-size-fits-all solution when considering wearables.

Some participants were generally unhappy with the appearance of their device and would try to keep it hidden whenever they could. For example, A1 used a *"pretty ugly"* wristband device that was included in her workplace wellness scheme, but came up with a novel workaround to keep the device hidden: *"I wore it on my ankle"*. She explained, *"if I had been required to wear it on my wrist* […] *I wouldn't have worn it"*. However, when her wellness program ended she still stopped using the device, partially blaming poor aesthetics.

At the time of our research, smartwatches were only just beginning to become widely available, and the now-ubiquitous Apple Watch was not sold until the final weeks of our research. Instead, many of the devices available offered rudimentary visual feedback, often in the form of LEDs, rather than a display. Most of our participants expressed a desire for a numeric display on the device, to enable them to easily view step-count and other information. Participant A13 wanted a display so she could synchronise her device less frequently, explaining: *"I have to sync with my phone to check* […] *I realise that I check the number compulsively, multiple times every hour"*. Further to this, some participants felt that activity trackers should *"just replace the watch"* (A13), because they did not see the need for two devices. A15 agreed, *"if something was going to have that much real estate near my hand it should do more than just show me dots"*. However, others such as A22, who had previously used a smartwatch, were less keen with this idea, *"I like my normal watch more"*, further highlighting individual differences and the need to support these.

5.3.2.5 Social acceptability and self-image when tracking

Further to the visual appearance of the activity tracking devices themselves, some of our participants were more concerned about their own self-image and the social acceptability of tracking. This often manifested in participants being concerned about the visibility of their tracker, some of whom specifically did not want to be associated with the aesthetic of a "self-tracker", despite enjoying tracking. Further to this, a small number of participants specifically told us that they did not wish to be seen as *"one of those people who track their physical activity"* (P42), feeling that this was not an image they associated themselves with, and that it somehow reflected negatively upon them. Other participants were generally concerned about how one looks when using any wearable technology, such as P34 who said, *"it just looks showy-offy"*.

As previously mentioned in section 5.3.2.3, some participants chose to wear their tracker on their underwear to keep it concealed, but this could also lead to awkward social situations. For example, P1 usually wore the device hidden inside her bra but began to wonder if this was appropriate after discussing the Fitbit with a work client, *"he asked me where it was and I said 'it's in my bra' and then there became this awkward silence. He thought it was awkward and then I felt awkward and then I thought 'should I not wear it in my bra?' It said in the instructions you can put it in your bra. Because it's such a novel thing I became unsure about the social appropriateness"*. Indeed, P47 also experienced some social awkwardness when wearing her tracker on her bra: once under a close-fitting dress, *"they asked if I had a growth or something";* and then again in intimate situations after a date, *"it's happened a few times I've gone out with somebody and I've had the Fitbit clipped in my underwear. Then if you get in a hot situation he's like 'what is this?".* Participant P17 had very similar concerns, *"I'd prefer it to not be there if I was about to meet someone who might see it, they'd be like 'ooh, what's that' and I'd be like 'no, we're supposed to be doing something else here, not discussing my Fitbit'"*. Because of these issues some participants reported choosing to not wear the device when they thought they might get into an intimate situation, or when they were unable to conceal it within their clothing.

Although many participants were keen to keep their trackers hidden, others embraced them and discovered unexpected benefits to having them more readily visible. For example, P20 had some technical issues with her original clip-based device *"when it was broken I spent a few weeks without it and I was thinking 'ok, I need to buy another one'"*, but decided to swap to a wrist-worn device, the

Fitbit Flex. She explained that she used to wear her previous tracker "*in a place that nobody could see it"*, but now with her new device "*I have it visible and I've discovered that there are plenty of people here* [at work] *who are using it. So we have some group where we see the steps and the walking"*. This resulted in newfound social support, which aided her in continued engagement with the device – an unintended consequence of having the device visible to others.

5.3.2.6 Devices as an aide-memoir or symbol

Despite the difficulties of using tracking devices as outlined in this chapter, some participants found that wearing the device itself had a positive influence on their behaviour, even when it was not functional. Section 5.3.2.1 detailed how participants continued to wear their broken or non-functional trackers, some of whom suggested that the device acted as an embodiment, or reminder, of their commitment to be active. Generally, this was not just because of the physical appearance of the device, but also because of associations they had made towards its use.

Participant L6 (who was in the action stage of the TTM) told us, *"it's like a physical reminder that I'm making an effort to do more stuff. It made me think about the fact that I've already resolved to be more active"*. Similarly, P36, who made significant changes to his physical activity, explained that tracker itself influenced his behaviour: *"I do think it changed my behaviour, but it sort of... I don't think the data changed my behaviour, I think the device itself did"*. Again, P14 reported similarly but went a step further, contrasting his Fitbit Zip tracker with "the five Ks" – articles of faith from his religion: *"I draw parallels with this bangle that I wear. I wear a bangle because it's part of the Sikh religion, it's meant to be a reminder that life is infinite, that you shouldn't do bad things... it's supposed to represent the steel for the sword for example, and you're only meant to use that in just causes, so it's kinda meant to, it has this reminder... so maybe I'm already very conscious of the fact that it's a reminder and it's there so it means something. Also, I'm not someone who wears jewellery in that sense, so if I do wear something it has a meaning. So yeah, for me it would be very in the forefront of my mind that it's a reminder of something"*.

One could argue that this effect was partially because the device was providing them data, via the screen, rather than purely because they were wearing a physical device. However, whilst this is true, some of our participants attributed changes to non-functional devices, as seen in section 5.3.2.1. This also has implications for personal informatics devices as tracking functionalities become integrated into other multi-functional devices (for example smartphones and smartwatches), does the "aide-memoir" effect of having a physical, dedicated, tracking device lessen? This, and other potential benefits of having dedicated devices (e.g. more easily glanceable information, more appropriate form-factor), should be explored in future research.

5.3.3 Tracking and Accuracy

Of all the functionalities built into *activity trackers,* core is their ability to *track activity*. However, as many of our participants discovered, although these devices are marketed as general activity trackers, their virtues and tracking abilities primarily lie in the measurement of steps. This did not always meet our participants' expectations, goals and preferences, creating a barrier to their continued use, and led them to create workarounds in the form of alternate strategies for using their technologies, or seeking of alternative tracking solutions.

Although step tracking was usually the start of our participants' self-tracking journeys, their destination was not always the same. Throughout our studies participants reported moving on to other personal informatics tools beyond activity trackers, for tracking other aspects of their lives. Some participants wanted more holistic tracking of their physical activity, moving beyond step tracking to also consider other exercise, whereas others were more interested in tracking other aspects of their lives to better support their personal goals and interests. Sometimes use of these other tracking technologies pre-dated their activity tracking journey, but participants usually took up additional tracking tools *after* using their activity tracker. In some cases, a participant would abandon their activity tracker when taking up use of a new tracking technology, but more frequently the additional tracking was complimentary to their activity tracking.

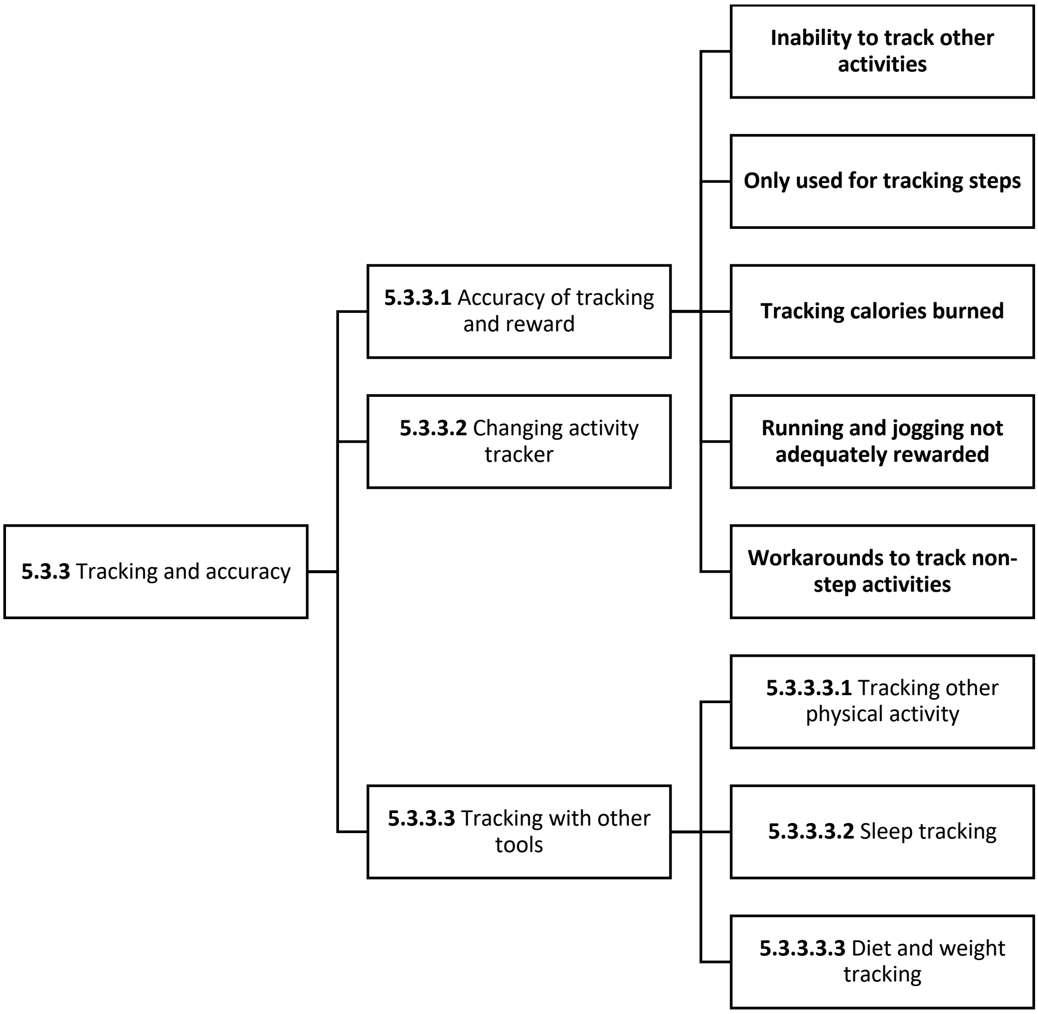

Figure 5.16 – Tracking and accuracy outline

In this section (outlined in Figure 5.16) we first discuss our participants' experience of using their trackers to record the various activities they undertook on a day to day basis, the barriers they faced and the workarounds they created. We then move on to the next steps of the self-tracker's journey by looking at the tracking technologies that some of our participants moved to including the various metrics our participants moved on to tracking and their motivations for doing so.

5.3.3.1 Accuracy of activity tracking and reward

The accuracy of tracking devices was a concern to most of our participants, some of whom complained that their tracker did not accurately record all their activities. This was especially true for those who routinely took part in non-step-based activities (such as cycling or yoga) and sought more holistic tracking – i.e. to have all of their activities tracked. Despite these devices being marketed as "activity trackers", their intended use is primarily to track step-based activities, which many participants found the devices were generally fairly accurate at recording (see section 4.3 for an overview of the how participants ascertained the accuracy and reliability of their devices, a process which generally happened at the start of the self-trackers journey). However, participants found that the devices were less adept at giving them credit for other, non-step based, activities.

Non-holistic tracking was an issue for many participants, for whom their trackers' **inability to track all their other activities** was a significant barrier to continued use. This was often because they perceived shortcomings with the device's ability to track other types of activity: many who took part in activities such as running, cycling, swimming, free-weights and fitness classes were disappointed and wished for a more holistic tracking solution to give "credit" (P8) for their effort. The extent to which this was a problem ranged from those who were mildly annoyed: *"on the longer* [bicycle] *rides* […] *I felt I should have gotten some steps"* (P15); to those who stopped tracking entirely because of these limitations: "[I] *stopped wearing it when I was doing a lot more stuff in the gym* […] *it's just like 'ok, you're not tracking this, now what's the point?'"* (P17). The severity of this barrier was particularly high amongst less-active participants and those who were hoping the tracker would help motivate them to be more physically active. These users potentially had much to gain from using the tracker but when they did non-step-based activities such as swimming (where the device could not be used at all) and cycling as part of their efforts, these were not properly recorded (although their trackers did record some steps during these activities, participants generally felt that the number of steps recorded was not representative of the effort they had put in). Many of the more active participants also wished the Fitbit provided them with reward for the different activities they were completing, this was often for the purposes of social comparison with the application, especially as they sometimes felt *"penalised"* (P30) for completing an activity that was not accurately recorded by the device.

The tracking technology's limitations in recording and giving credit for different activities sometimes even resulted in unintended, and potentially harmful outcomes. Some participants discussed how these limitations would change their behaviour, encouraging them to do an activity that would reward them with more steps, instead of doing their preferred activity. For example, P13 told us that she would, *"go for a run instead of doing yoga, because I know it'll increase my steps",* despite this not supporting her personal goals. However, other participants were more aware of the importance of doing different activities for good health. For example, P36, was acutely aware of the NHS guidelines suggesting that he should do both cardiovascular and resistance training activities (*"I am very aware that the reason someone of my age needs to do the strength exercises is that if I don't my muscles will atrophy - just because of the age I am"*), and even though his Fitbit Zip did not track nor encourage him, he always tried to do strength-training activities along with meeting his step goal.

Some participants were happy to **only use their tracker to record steps** - *"the other 23 hours"* (P18) of the day where they were completing NEAT activities (rather than a specific form of exercise), or regarded their tracker as being *"strictly a pedometer"* (P11) and did not consider it for tracking any other activities. Generally, these participants did not engage with the social functionalities, so were less interested in maximising the number of steps recorded. For example, P15 only wanted her steps tracked, explaining *"those* [fitness classes] *to me feel like a different type of thing, so I count them as an activity that I'm doing that I know is good exercise, whereas the Fitbit I'm more interested in the day to day stuff I wouldn't necessarily count as exercise".* Some participants, particularly those who tracked sports activity with other devices or applications, even removed the device when doing sports activities in order to not confuse steps recorded from their NEAT and sporting activities. However, most participants wanted these different activities tracked. Most tracking systems allowed this, to some extent at least, by letting users manually log other activities using the app or website: *"I know on the Fitbit website I can log certain kinds of activity and it'll give me a higher calorie burn"* (P15). However, as P15 pointed out, "*it doesn't necessarily give me more steps".* Indeed, because they were primarily interested in tracking more "steps" most participants felt that manually adding activities was not worthwhile – unsurprising, considering that most systems used steps as the main focus for records and comparison.

There was one subset of participants who *were* interested in manually recording their activities, namely those who were interesting in losing weight and were using other personal informatics tools to **track their diet and calories burned**. These participants compared the number of calories they consumed against the number they were burning, aiming for a calorie deficit. They sometimes used other personal informatics tools track their activities, to increase the accuracy of calories burned according to their tracking system: *"I go to the step class and yoga, which is a bit of a bummer because there's not a lot of Fitbit steps that I'm collecting for yoga. But I do put it into MyFitnessPal which gives me some calories back"* (P20). However, despite being pleased with having burnt calories recorded, participants still wanted steps as a reward, presumably because steps are the main focus in most activity trackers.

Beyond the issues above with activity tracking systems not accurately measuring all activities, some participants who *were* doing step-based activities, such as **running or jogging, also felt they were not adequately rewarded** for their efforts. As A11 explained, *"I discovered that I didn't get that many more steps running than I did walking, so I figured it wasn't really worth sweating and working that hard"*. She then suggested that, *"I guess a multiplier would be good. I know on the Fitbit website I can log certain kinds of activity and it'll give me a higher calorie burn for that activity, but it doesn't* *necessarily give me more steps"*. Generally, these were participants taking up running, who were perhaps putting a greater amount of effort in compared to more experienced runners, who were instead happy with the number of steps recorded.

Some of our participants explored **workarounds to make their tracker better track non-step activities**, and to give them more reward for completing these. For example, P13 tried wearing her Fitbit Zip on different parts of her body when practicing yoga, finding that putting it on her wrist resulted in a greater number of steps being recorded: *"I think it counts more steps when I have it on my wrist as to when I have it on my hips"*. Similarly, others, such as P15 who wanted to be awarded steps for cycling, experimented with workarounds to 'trick' their activity tracker into recording steps when they were doing other activities: *"I was trying to figure out where I could put my Fitbit to get what I thought was a good amount of steps. I was y'know, putting it my sock, putting it in my pants pocket, tying it to the cuff of my pants* […] *I was also pedalling backwards whilst going down hills"* (other workarounds that participants experimented with to "trick" their trackers are examined in section 4.3.1).

The lack of comprehensive tracking caused some participants to lose engagement as they felt their effort was not being recognised. The limited tracking abilities of the device initially encouraged some participants to have a less rounded workout and offering only steps as a metric altered the focus of some participants engaging in other sporting activities. These findings are to the first design requirement derived from the evaluation of *Houston*, that users should be given proper credit for their activities (Consolvo et al., 2006).

5.3.3.2 Changing activity tracker

A number of our participants moved between different activity tracking systems or devices during their self-tracking journey. Sometimes they changed to a new tracker after having a technical issue or losing their previous tracker, whereas others swapped because they wanted a different design, form-factor, or additional functionality. Of the 13 participants in our longitudinal study who were still tracking their steps at the point of the follow-up interview, two were tracking with a different Fitbit model, and four participants were tracking their steps with non-Fitbit devices or applications, including: the Nintendo 3DS, the Garmin Vivofit, Apple Health on an iPhone 6S and the smartphone app Breeze, by Runkeeper.

When a participant changed to a new tracker from the same manufacturer (e.g. moving from a Fitbit Zip to a Fitbit Flex), they could continue using the same platform and retain access to their previously tracked data, but if they swapped to a different manufacturer's tracker they could not usually move their existing data to the new system. As L32 pointed out, they could continue to access their data through the previous platform, *"I don't think that would be too much of an issue, because if I wanted it or needed to reference it, I don't know if I would need to, it would be available via the Fitbit site, so that would be perfectly possible",* but retaining access to two systems may make comparisons more difficult. We previously discussed our participants' feelings about their historically tracked data in section 4.4.3.

5.3.3.3 Tracking with other tools

Many participants reported taking up use of other self-tracking tools, including those for tracking: other physical activity, such as running or cycling; lifestyle attributes, such as food or alcohol consumption; and, personal or health data, such as weight or chronic pain symptoms. Most frequently participants supplemented their activity-tracking systems with these tools (some linked the different tracking tools together, to share or combine data), whereas in other cases the new tracking tool replaced their previous activity tracker. Oftentimes participants either supplemented their activity tracker to move beyond a limitation with their existing technology, or to better support their goals.

5.3.3.3.1 Tracking other physical activity

As discussed in section 5.3.3.1, many of our participants who were regularly doing non-NEAT physical activity had a desire for more holistic tracking of their exercise. By means of a workaround, and to track additional physical activity data, some participants took up use of additional tracking tools such as GPS tracking applications (e.g. Strava or Runkeeper) or devices (e.g. Garmin sports computers or watches). Some participants further supplemented this with physiological heart-rate data, by wearing a heart-rate strap connected to their smartphone to measure their physiological responses to exercise.

5.3.3.3.2 Sleep Tracking

Outside of physical activity, the trait that participants most frequently tracked was their sleep, closely followed by food or diet tracking. Generally, these systems claim to record the number of hours the user slept, and often provide some sort of "sleep score". Additionally, some (including the "Sleep Cycle Alarm Clock" app that many participants used) also offer a "smart alarm clock", which claims to wake the user at the most appropriate point of their sleep cycle. Some activity trackers also offer built-in sleep-tracking, though the Fitbit Zip does not include this.

A large proportion of our participants used some sort of sleep-tracker, be it functionality embedded in their activity tracker, or as a separate application. Most participants were interested in tracking sleep because they felt they had some problems with, it such as: not sleeping enough, *"I'm interested in how much I sleep, because I don't think I sleep a lot"* (P12); or, struggling to fall asleep, *"I'm a bit of an insomniac and my brain doesn't tend to switch-off"* (P43). However, except for the Sleep Cycle Alarm Clock app (which participants used as their alarm clock, rather than solely as a sleep tracker) sleep-tracking had a strong novelty effect, and participants usually only tracked for a short period of time, and rarely engaged with their tracked data. P23 felt that the data was not worth the effort of collecting it, *"the fact that you have to remember something, put the phone there, under the mattress or whatever, and then you cannot leave it charging…"*. Gaining utility from the data could also be difficult, as P6 explained: *"at first I started doing it every single night and now I very rarely do it, because there's nothing interesting in it. I know that sometimes I sleep better and sometimes I sleep worse and now I can see it on a graph, but it doesn't really give me anything"*. This raised an interesting point – without careful tracking and analysis of other factors related to sleep (the sleep environment, physical activity, diet, stress and mental health, etc.), the tracked data was difficult to interpret and action: our participants struggling to gain any meaningful insights from it. Many of these other traits could be tracked, but even so the results would be difficult to make sense of and participants might struggle to create meaningful changes.

5.3.3.3.3 Diet and weight tracking

Diet and weight tracking were also common metrics for our participants to track alongside their physical activity. As mentioned in section 4.1, many participants were motivated to track their activity because wanted to lose weight, so it was therefore not surprising that many explored food and weight tracking to help them reach their goals. However, similarly to those who were tracking sleep, very few continued to track their diet over a longer term, mostly because of the effort involved. Some participants had previously tracked their diet before getting an activity tracker, often through a weight-loss plan (such as Weight Watchers), by completing a written food diary, or with a mobile applications or websites. Diet tracking functionality was built into some of the trackers our participants used, but this was generally limited in functionality compared to the dedicated diet tracking app, MyFitnessPal, which was more popular amongst our participants. Databases of food in the activity tracking applications were far more limited in scope, and participants told us that the experience was not as slick. P45, who had tracking his diet in both the Fitbit app, and with MyFitnessPal explained that her preferred the latter: *"it helps a lot that you can scan the barcodes, so that means that I've got confidence in the fact that the input's correct* […] *you can just put in 'Pret Cheese Sandwich' and it will just know and you hope that's accurate".*

Most participants who tracked their food found it beneficial, at least over a short-term, and those who had not previously tracked their calorie intake found it particularly enlightening. For example P36, explained: *"I just think it's totally brilliant. There's hardly a food that I eat, that comes in a packet with a barcode on it, that I can't just simply scan* […] *through going to the gym, and use of the Fitbit, I'm doing enough exercise, then* [I] *note the number of calories which the Fitbit tells me I'm exerting, and then make sure that I don't eat more than that number of calories a day".* Many other participants had similar experiences, at least at first – some also tracked their weight, sometimes using Wi-Fi connected scales, to better understand how their body was changing over time. For example, P6 received a set of Fitbit Aria "smart scales" as a gift and enjoying using them together with her Fitbit and MyFitnessPal, explaining: *"in Fitbit I check how many calories I have left to eat that day and so on. It's kinda really nice because every day I know very accurately how much stuff I've already done and how much stuff I've used up and how much I'm likely to use that day so* <u>*it's made managing the process of losing weight really easy*</u> […] *It's really nice that I don't have to remember to note down my weight or anything like that - I barely have to look at it and it all works together*" (underlining our emphasis).

Making "it all work together" was often key to participants attempting to lose weight, who wanted to easily see a comparison between the number of calories they were consuming through eating and drinking, and the number they were burning through movement and exercise, to create a deficit. Most tracking systems some integration with different platforms (e.g. Fitbit shares calories burnt to MyFitnessPal), which some users took advantage of. Participant A3, who was trying to lose weight after a health-scare took advantage of this, telling us *"MyFitnessPal is where it's altogether. The weight and the food is right there and it shows the steps also so that's the main one".* However, despite the usefulness of putting their tracked data in one place, other participants had difficulties in setting up the links between different tracking systems and understanding how data moved between these different platforms.

However useful participants found tracking their food, almost all of them found the continual effort of tracking challenging, and most soon stopped. Unlike using their activity trackers, which passively recorded their step data (so long as the device was functional and attached to them), diet tracking required the users to make a conscious effort. Our participants often stated that recording their food consumption was laborious and *"too much effort"* (P30). Participants experienced various difficulties with tracking diet, including foods that were not listed; finding logging to time consuming and annoying; forgetting to log meals; and, uncertainty around portion sizes, leading to distrust of the data. Further impacting this, some participants were unconvinced to the usefulness of tracking food over a longer term, P49 explained: ***"it's useful over a short-term because it shows you how much certain food items like, cost you, as far as calories are concerned. But once you've been educated in that way you just don't need it any more".*** Many other participants agreed, telling us they had learned something during their short time tracking, taking a better understanding away. For example, P9 remained interested in her diet and the number of calories the app suggested she was burning: *"I now try to eat healthily and I don't snack, then I try to make sure I've burnt at least 2,000 calories on the* [Fitbit] *app"*.

Throughout this section we have presented a rich characterisation of the many barriers our participants faced when engaging with tracking beyond their initial uses and over a longer time-period, along with the highlighting the workarounds that some created to lessen the effect of these barriers. Unfortunately, in many cases our participants did not manage to create workarounds to circumvent barriers altogether, and instead barriers were responsible for them *lapsing* or *stopping* tracking. It is not unusual for early adopters to face challenges when using and integrating a new piece of technology into their lives (Rogers, 2003), and with tracking technologies these issues appear to be exacerbated by their close and always-worn nature. In most cases where unsurmountable barriers were responsible for a participant stopping tracking they suggested that they would return to tracking if barriers were removed, suggesting that longer-term tracking was of interest.

By understanding the workarounds that our participants created, we are better able to understand their unmet needs. From our research two key areas crucial for the design of future design to better support users' needs for long-term engagement were apparent: the ability to offer more complete, holistic, and accurate tracking, befitting each individual's needs; and, the ability to better support individual's desires around visual appearance, aesthetics and physical form of the trackers. In both areas, the allowance of easier and more flexible customisation of suites of tracking technologies could bring benefits. However, it is important to consider that the barriers identified were not solely responsible for all participants who stopped tracking, and the overall importance of sustained long-term engagement with tracking systems is not yet clear – something we explore in Chapter 6. Even so, removing barriers to engagement can only have positive effects on users' satisfaction with these devices, leading to better experiences.

5.4 Individual differences, context and situated use

The impact of context on use of technology is well recognised (e.g. Suchman, 1987), and it is not difficult to imagine the profound effect that contextual factors have on people's use of personal informatics systems, which are so closely enmeshed into users' everyday lives. For example, a retiree with physical health problems in rural England will likely interact with their Fitbit Zip quite differently to how a college sports undergraduate student living on an American university campus might use their Jawbone Up. However, despite this, surprisingly few studies in personal informatics consider the extent to which contextual factors such as a person's physical ability, schedule, where they live, and social factors, may not only affect their use of the technologies, but also any behavioural outcomes. Indeed, Lupton highlights this in her 2014 OzCHI paper, stating: *"little attention is paid either in self-tracking cultures or in the human-computer interaction literature to the ways in which such social factors as gender, place of residence, social class, race or ethnicity serve to shape people's opportunities and life chances. Instead the self is understood as an atomised individual, shaped by personal life experiences and empowered to manipulate her or his destiny by acquiring self-knowledge and acting rationally upon this knowledge"* (p.83).

Various models, such as the social ecological model (Moos, 1974), highlight the importance of considering perspectives broader than the user alone, namely the ecology of use: the individual's relationships and peers, the person's organisation, the wider community, and finally, the broader society as a whole. Further illustrating this point, a recent paper (Maharana and Nsoesie, 2018) presenting a machine learning algorithm that successfully predicted obesity levels from street imagery received attention in popular press. If an algorithm is able to successfully predict obesity levels for neighbourhood design, is likely a link between the design of urban spaces and how they are used. User studies of personal informatics technologies *have* been conducted with populations all over the world, but few compare how people make use of these technologies in different locations (one notable exception is Bentley et al., 2013) and little attention is paid to contextual factors either within, or between these studies. Given the influence of context, research findings may not be generalisable to wider populations and therefore results may not be broadly applicable.

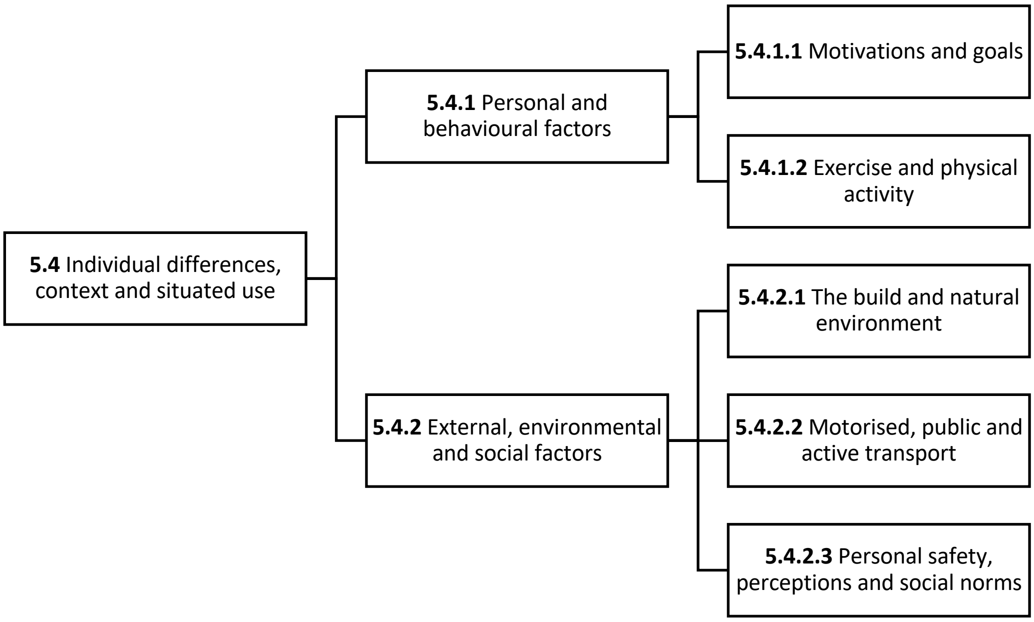

Figure 5.17 – Context of use section outline

Motivated by our lack of understanding of the impact of contextual factors on use of personal informatics systems, this section (outlined in Figure 5.17) focuses on how micro and macro-level differences in context affected use across our diverse range of participants, who: had different backgrounds, demographics and abilities; were using a variety of different systems, for different reasons; and, were located in two contrasting cities, with different social norms, weather conditions, facilities and transport solutions. From this, we present a better understanding of the influence that has context on people's use of tracking technologies, focusing on personal and behavioural factors such as motivations and capability, and external, environmental and social factors. Some differences were broadly applicable across locations, such as how participants in London most commonly changed their behaviour by walking more as part of their daily routine, whereas many of those in Atlanta instead changes their planned exercise (likely caused by a combination of social norms, weather conditions, access to different transport and leisure solutions, and the built and natural environment), whereas other differences in engagement were on a much more individual basis.

5.4.1 Personal and behavioural factors

Various personal and behavioural factors influenced our participants' ongoing use of their trackers, including: their motivations and goals for tracking; their ability, perceived ability and self-efficacy related to physical activity; and finally, their preferred sports and leisure activities. These factors not only impacted behavioural outcomes (as we further discuss in the next chapter), but also how participants used and engaged with their trackers. For example, a user looking for support in their marathon training will likely use their tracker differently to someone who is just starting out with being more active.

5.4.1.1 Motivations and goals

Participants' motivations for tracking had a large influence on their tracker use, as well as the ecologies of other tracking systems they built up. Some participants were initially uninterested in changing their behaviour, instead tracking because they were interested in the technology, or because they wanted to collect data. However, many went on to become interested in changing their behaviour in some way, such as by being more active, getting fitter, or losing weight, and used the tracker to support them in these goals.

Participants generally used the features they felt were the best fit for meeting their goals, but sometimes this resulted in them using their trackers atypically, even missing out on features which might have been useful. An illustrative example was from the considerable number of participants who were interested in losing weight, some of whom primarily engaged with calorie data, rather than steps. As a result P8 did not engage with setting step goals and, feeling that her calorie data was too sensitive to share, chose to not use any of the social functionality offered by her Fitbit – as explained in section 5.2.3 this was one of the functionalities that many participants were engaged with over a longer time period. She quickly lost interest in tracking, explaining: *"I just don't think it* [the Fitbit] *gives me the information I want. I've heard about this BASIC watch, I think that's something I'd be more interested in, because of the heart rate thing".* If she had engaged with tracking steps, she might have got more utility from her Fitbit, but instead, she believed that an alternative device with a built-in heart rate monitor would be more suitable for her, because it would give her a most accurate estimate of the calories she was burning. This could be considered a mismatch between the participants' expectation and what the device could provide (as discussed in 5.1.3.2), but illustrates the importance of considering user goals and expectations when designing and evaluating these technologies.

Though most participants began their tracking journey with steps, a small number were already tracking a different activity and subsequently took up use of an activity tracker to get a more holistic picture. These participants were often not interested in changing their NEAT behaviour, instead interested in the data for other purposes. For example, L8 was a keen cyclist and started using a Garmin activity tracker to give him additional information in his Garmin Connect profile – adding his steps and NEAT activities helped provide him with a more holistic measure of his activities, particularly helping when he was training and recovering from bicycle rides. In this case, the participant did not engage with any of the functionalities intended to encourage or support him in changing his behaviour, such as the step-goal, calories burned, or social functionalities, as he was already actively participating in another activity. Generally, a participant's preferred exercise or activity played a role in their use of their trackers, as we explore in the following section.

5.4.1.2 Exercise and physical activity

Many of our participants tracked to aid behaviour change: to be more active, to take more steps, or to lose weight. The trackers they used were designed to be enmeshed into every part of their lives and as such, their physical activity inclinations impacted use: their preferred activities and hobbies; any barriers to physical activity that they might have; their ability, or, perceived ability; and what they considered to be a "walkable distance" all had a bearing on their use of the tracker, and any changes resulting from its use.

The leisure, or exercise, activities that participants already engaged in influenced how they used their tracker, or the behavioural changes they made because of using it. For example, some participants regularly did planned exercise (such as running, or going to the gym) and increased or altered these activities to track more steps (or created "workarounds" to track steps when doing other activities, see section 5.3.3.1) after taking up tracking. For example, P49 changed her gym routine to include more steps and P9 increased the amount of netball training she was doing. Participants who did not already take part in a planned activity either took one up (such as A23 who started attending a "circus arts" class, or L4 who joined a gym), or more frequently attempted to integrate more steps into their daily routine. Interestingly, participants in Atlanta tended to increase their planned exercise after starting tracking, whereas those in London tended to increase their NEAT activities and work more steps into their day-to-day routine. Access to an environment, or facilities, where participants felt they were able to be active was key to this, particularly for those who were unable to integrate physical activity into their daily routine – we further discuss in section 5.4.2. Where barriers to this existed, use of an activity tracker did not always help participants overcome these barriers, who would instead become decreasingly engaged and often stop tracking.

Some participants struggled with health issues which moderated their behaviour change, sometimes preventing them from changing behaviours to the extent they wished. For example: P12 struggled with chronic pain which meant she needed to be careful not to do too much activity; P18 was recovering from an operation during the study and her doctor advised her to not exceed a particular number of steps; and P14 aggravated an existing injury after changing his behaviour, which resulted in him having to minimise the number of steps he was taking. In these cases, encouraging participants to do more than they are fit and healthy to do could have negative consequences, illustrating the importance of considering different use cases beyond behaviour change in the design of tracking systems.

Another more personal consideration effecting participant's use of their tracking technologies was their capability to exercise, and their existing activity levels. For example, the requirements and desires of a user who is already active (e.g. a regular runner who is training for a marathon) are different to those of someone who is just starting out on their physical activity journey (e.g. someone who finds getting off the bus a stop earlier challenging). Although a simple measure of steps can be useful for someone who starting out with being more active (see section 4.4), many of our participants who were already active found the data provided by their activity tracking technologies to be overly simplistic. These participants instead wanted more detailed information about their performance (e.g. speed, or split times) and the amount of effort they were putting in (e.g. heart rate). As we have previously mentioned (see section 5.3.2.4), many of our participants associated the appearance of their trackers with sporting activities, or those who regularly exercise. However, in reality many more active participants found their trackers to be lacking in functionality. For example, L10 felt that the physical aesthetic of his Nike Fuelband was the result of aspirational marketing, and the functionality was incongruent with his expectations. Some participants were willing to accept these devices as useful for tracking "the other 23 hours of the day" (of NEAT activity when they're not exercising – see 5.3.3.1), but those expecting them to accurately track sports-like activities considered them misleading, causing them to lose interest. More recent devices have gone some way to alleviating these problems, with built-in heart rate monitoring functionality and connected GPS, but disparity between the needs of novice and more active users might remain.

The amount that our participants considered to be a "walkable distance" also had a bearing on how they interacted with their trackers. Many participants in London considered far longer distances to be walkable (e.g. up to lengths of 40 minutes – L4), compared to those in Atlanta. For example, A13 explained that 5-minutes was *"the radius for people in Atlanta to walk* […] *I think it really comes down to ease of parking. Everyone has the mindset of 'I want to get from point A to point B as easily as possible'. For me, ultimate convenience is a 5-minute walk. There's absolutely no reason where a car would make more sense in that scenario"*. Highlighting the differences in opinion, we asked A13 if they would also consider a ten or fifteen minute walk: *"It's certainly a walkable distance, but if I was going to that place I'd look at it and I would say 'it's going to take me 15-minutes to walk there, or I could drive there in 2 minutes"'... I'm just going to drive there in two minutes"*. Whereas participants in London often increased their steps by including more NEAT activities in their daily routine, participants in Atlanta instead mostly increased the amount of planned activities they did. Multiple factors are at play here, including social norms, a lack of facilities, and the weather, as we discuss in the following section.

5.4.2 External, environmental and social factors

The effect that the broader external environment had on our participant's physical activity, and how they used their trackers, was considerable. One of the biggest factors was participants' physical situation, which influenced them on multiple levels: from social norms, to the weather, to facilities and transport options. These differences were most pronounced when contrasting participants located in London and Atlanta, but they also existed between participants located in the same city, as the more local environment also had a significant impact, with factors such as access to different transport solutions or perceptions of safety in the area.

This section starts by looking at the built and natural environment, including the effects that weather, topology, and the physical fabric of the places where our participants worked and lived, had on their tracker use. We then move on to the different transport options that are available to participants, and the effect this had. The biggest contrast here was that almost all our participants in London regularly used public transport, whereas very few in Atlanta did. Finally, we present the issues and concerns that our participants had regarding their personal safety, and the influence this had.

5.4.2.1 The built and natural environment

The built and natural environment had a considerable effect on our participants, with factors such as the weather, the physical fabric of where they lived and worked, and access to infrastructure and facilities directly impacting their physical activity and how they used their trackers. We already have an understanding of the impact that these factors can have on physical activity, transport choices and society more broadly, as architects and town planners study and leverage the design and layout of urban spaces (e.g. in space syntax). However, this impact is often little considered when evaluating personal tracking technologies and how they are used, along with evaluating the efficacy of behavioural interventions.

One of the most obvious examples of the natural environment impacting people's physical activity was through the weather, as participants explained that the weather would either dissuade, or encourage, them from doing activities outdoors. This impacted their use of the tracker by, for example, dissuading them from walking outdoors or commuting by foot, in opposition to the change encouraged by the device. This was particularly true when considering seasonal weather changes, which had a large impact on activity throughout the year. For example, many participants in Atlanta explained that the temperatures during the height of summer that were too high for them to consider exercising outside, which prevented them from walking for transport: *"it gets extremely hot. Whenever I walk, even walking on campus is annoying, because I walk from point-A to point-b, it's like a ten-minute walk. It's not a tiring walk, but by the time I get to point b I'm sweaty and I'm drenched. It's very annoying to me"* (A17). These participants would instead increase their activity by using indoors facilities such gyms or exercising in the evenings when it was cooler. Some of our participants in London would similarly complain about the hot weather - *"hot weather, not good"* – but comparatively the influence this had on their activity was much smaller: *"I do* [walk in hot weather]*, but if I lived in Atlanta perhaps I wouldn't"* (L6).

Inclement weather also had a considerable influence on activity, preventing them from being outside when they might have otherwise been. Unsurprisingly, in contrast to the hot weather that those in Atlanta complained about, this was more frequently mentioned by our London-based participants. For example P14, who because of using his Fitbit Zip had made changes to his transport habits to include more walking, explained to us, *"if I can meet the 10,000 then I'll walk home or to pick up my son, <u>so long as it's not raining</u>"*. If it *was* raining he would instead take public transport to avoid getting wet, and thus miss his step goal. However, not all our participants stopped their new walking habits when the weather was unfavourable: P28 explained that she "*was quite pleasantly surprised when it was raining, when it was cold, when there were so many reasons to get that bus I still walked"*. Similarly, P6 bought wet-weather running clothes and a bicycle to help her stay active through the winter, where she had previously moved her exercise indoors. These seasonal differences in physical activity and use of the tracker illustrate the importance of evaluating use over a longer time-frame when considering how people use these technologies in the real world: these results would not have been captured in a shorter-term study.

Another environmental factor that influenced how our participants made use of their trackers was the built environment itself. Those in Atlanta explained that the city did not support active transport, partially because of its sprawling size and layout, and partially because facilities in the built environment did not appear to have been designed with pedestrians in mind. Many felt that the low density of the city made walking for transport impractical, *"everything is so spread out, especially in the south* […] *so we just drive"* (A6). Similarly, most Londoners also had to travel long distances to get between home, work, and social occasions, but other facilities such as grocery shops or exercise facilities were often located within a "walkable distance". Additionally, whereas most of our participants in London were able to easily use a wide variety of different transport solutions (e.g. the Underground, buses, trams, taxis, hire-bicycles, etc.) and integrate walking or active transport into their journey, this was not the case in Atlanta, where transport options were much more limited and instead most travelled by car.

Other participants in Atlanta complained of more direct problems with embracing walking as a means of transport in the city: *"there aren't a great selection of sidewalks or footpaths here. It really hasn't been built for pedestrians"* (A19). The condition of pavements (sidewalks) was frequently mentioned as a barrier for utilitarian walking in Atlanta, particularly outside the centre of the city. A9 provided insight into why this was: *"the city does not do sidewalk maintenance, so the individual landowners are responsible for their own sidewalks"*. When discussing how his children got to school A8 explained how the lack of pedestrian facilities meant he was not confident in letting them walk: *"like 3/4 of it has sidewalks. The rest we have to walk through yards* […] *If I had it my way I'd make them walk to and from school as I did, but it's just not safe* […] *when they're older maybe. My eldest, yeah, but the youngest is still six and I don't feel comfortable letting my six-year-old. I'm afraid she'll step off into the street or something without paying attention because she dropped something, then – clip - and that's now I have one kid"*. In contrast, problems with pavements and general provision for pedestrians was never mentioned as a barrier to walking in London.

Despite the lack of pedestrian facilities in Atlanta, our participants did increase their steps by: going to the gym; taking part in team sports or activities; running or walking in public parks, both inside and outside of the city; and using The Beltline[20]– a repurposed railway line running around parts of the city linking various public spaces and with access similar to a bridleway in the UK. Many of our participants spoke of these spaces positively, supported initiative such as Atlanta Streets Alive[21], and some used them to walk or cycle. However, very few of our participants could easily access these facilities from their homes, so instead of walking from their front-door (as many of our participants in London might), they would instead drive to these facilities to exercise.

5.4.2.2 Motorised, public and active transport

The transport options participants were accustomed to using, and saw as socially acceptable, had a significant effect on how they changed their activity as a result of tracking. Most London-based participants used active transport for at least some of their journeys and changed their behaviour by integrating more steps into their daily routine, whereas participants in Atlanta instead tended to

[20] https://beltline.org/
[21] https://www.atlantastreetsalive.com/

mostly rely on personal motorised transport throughout. Participants in both London and Atlanta had *opportunities* to use a variety of different transport methods to get around their respective cities, including active transport (walking, cycling and running) public transport (buses, the underground network in London and MARTA in Atlanta), taxis and personal cars. However, our participants' opinions, and use, of these different transport solutions varied hugely between the two locations.

Very few participants in Atlanta regularly used public transport, with most instead using personally-owned cars. Participant A6 provided a statement that summed most participants feelings about the public transport system in Atlanta (named MARTA): *"unfortunately in Atlanta we do have, you know, the MARTA. It's the world's crappiest subway".* Only two of our 24 Atlanta-based participants regularly used MARTA, with most feeling they were dependent on driving: *"in the suburban areas you really need a car"* (A19). In contrast, just four of our London-based participants reported using, or having access to, a personal motor vehicle, and these indicated that most journeys they made using their car were outside of London, where it was more convenient. Debating the merits of car ownership in London, L5 explained: *"I don't actually think that having a car would change my life too much* […] *It might change my grocery habits, just because I would take advantage of the car and take heavy, but I think that because it has such a transport infrastructure and you can get anywhere you want with public transportation that is on time and punctual and fast, having a car would just make you waste time in traffic"*. A key factor here is convenience (both cost and time): whereas public transport in London is be more convenient for most journeys, according to our participants this could not be said for Atlanta.

Many told us that MARTA was not convenient: most said there were no stations or stops within a walkable distance of their home; that the public transit *"doesn't go anywhere"* (A20); and that it is *"great if you're going to the airport, but if you're going anywhere else it's really not"* (A15). Participant A3, who *did* live near a bus stop explained, "*There are* [bus stops]*, but they're* [buses] *so slow up here... You have to catch a bus to the train station, to another bus... It would take me two hours to get to work",* whereas driving took him less than 20 minutes. Another barrier was the social stigma attached to using transport options other than driving, A17 explained: *"I don't know a single person in the entire city who's using the buses* […] *except homeless people. Seriously. There's absolutely a social stigma tied to using buses",* and A16 indicated there was also a stigma attached to being a pedestrian in Atlanta, *"when you're walking it's almost stigmatised a little bit like, 'oh my god, what are you, poor?'"*.

Some of our Atlanta-based participants created workarounds to make more use of public, or active transport in the city. Overcoming barriers in the environment are challenging, but some went to considerable lengths to do this: three participants reported that they chose the location of their home to allow them to easily reach local amenities and walk, cycle, or use public transport, rather than relying on a car. This included A20, *"how I chose where I wanted to live was based on if I could bike in"*, and A11 who grew up in the UK, *"we bought our house in* [anon] *because I wanted it to be close to the library, and also close to public transportation"*. One major consequence of participants being reliant on their motor vehicles was that they were "tied" to them, and beyond parking further away from their destination or walking during the day, they were less able to incorporate active transport into their routine compared to those in London, for example by getting off the tube or bus a stop earlier "[I] *started getting off the tube a stop earlier when going to work, and getting on a stop later*" (L5).

Although the increased flexibility of using public transport in London allowed participants to integrate more steps into their daily routine, the public transport system also provided barriers to being more active. The speed, ease, and relatively low cost of using public transport in London, particularly when one had purchased a season ticket, resulted in some participants being reluctant to incorporate active transport. This was particularly true of those who had a pre-paid season ticket (either weekly, monthly, or annual) which allowed them to travel within a certain area completely free of charge for the duration of the ticket. For example, P10 had an annual pass so never took up active transport, explaining that as he had already paid for the ticket (so there was no cost saving) and was more interested in getting to and from work *"as quickly as possible"*, because his commute was already *"unbearably long"*. Other participants created strategies with public transport ticketing to help keep them motivated, such as L5 who took a shorter (and cheaper) journey on the underground and walked the remainder of the way, with the financial saving helping keep her motivated. Other participants indicated that they had based their mental model of the layout of London on the Underground map, which famously provides a spatially inaccurate view of the city. *"I quite like that about London- you suddenly discover how close everything is when you actually take the time to not get the tube"* (L28).

5.4.2.3 Personal safety, perceptions and social norms

Multiple participants from both London and Atlanta had concerns about their personal safety (e.g. concerns about being shot, stabbed, or mugged whilst out walking or exercising), as well as their physical safety (e.g. being hit by a car when walking or cycling), which impacted their activity. Our Atlanta-based participant's concerns about personal safety were more pronounced compared to those in London, particularly when they were walking, cycling, or using public transport. Concerns ranged from those who were worried about motorists hitting them, "*they don't think much of pedestrians because it's such a rarity… they don't think about cyclists at all*" (A9), to those who were more concerned about their personal safety, *"mugging, definitely - just being a woman in the city it's never far from the front of your mind"* (A15). Although they were more pronounced, safety concerns were not exclusive to participants located in Atlanta, and indeed many of our participants in London were also worried about walking in certain situations. However, the extent to which these concerns prevented people from doing activities were very different. For example, participants in both Atlanta and London were concerned about walking at night, but whereas most in London would still walk at night, albeit with a heightened level of awareness, few participants in Atlanta would even consider doing so. When we asked L6 if she would walk in the city at night, she told us, *"yes, when I'm given the chance, obviously it's a bit limited"*, whereas when asked the same question A1 responded saying, *"NO! Not a chance! Do I look stupid?"*. Both of these examples come from women, but male participants also responded similarly. We do not have enough data to draw any particular conclusions about gender differences in this area.

In attempts to better understand the safety concerns our participants had we asked them about specific examples of journeys they could make on foot, and what prevented them from doing so. A20 explained that she was, *"concerned about being stabbed* […] *I'd have to walk through* [location anonymised] *and.... it's just ghetto. You know, gang activities and stuff"*. Further to this, we found that many participants were most concerned about particular areas of the city, rather than the city as a whole, *"I won't walk in certain parts of Atlanta after a certain hour, that's for sure"* (A9). However, prior bad experiences, media reports, and ease of other transport options meant they would generally avoid walking at night under any circumstances. Accordingly, many of our participants in Atlanta indicated to us that the activity tracker would not change their behaviour when they perceived concerns to their safety.

This section has provided an overview of the effects that the context of use had on how people used their personal tracking technologies. There were pronounced differences when comparing those in London and Atlanta, often related to the built environment, available facilities, transport options and social norms in the two places, and resulted in a considerable difference in outcomes from tracking. There were also differences in the ways in which our participants changed their behaviours: whereas the majority of participants in London who increased their steps did so by integrating more steps into their daily routine, through activities such as walking instead of using public transport, our participants in Atlanta instead tended to do undertake more planned physical activity. There were, of course, exceptions to this – our sample from Atlanta included one participant who regularly ran to work, and another who cycled, but compared to the number of participants in London who did not make changes to their physical activity by working more NEAT activities, primarily active transport, into their routines was very low. Considering these differences, future research should consider context when evaluation similar devices and more research should specifically consider use in different contexts and with different user groups – something which is still currently understudied.

5.5 Summary and discussion

In this chapter we have presented an analysis showing the richness of our participants' interactions with their tracking technologies throughout their self-tracking journey. We started with phases of tracking over time, highlighting the temporal nature of tracking and how participants used the embedded behaviour change techniques and other functionalities of their tracker over time, before moving onto the barriers they faced to continued tracking, and the workarounds they made to overcome these barriers. Finally, we took an in-depth look at how the context of use effects participants use of their trackers, along with how this influenced their behaviour.

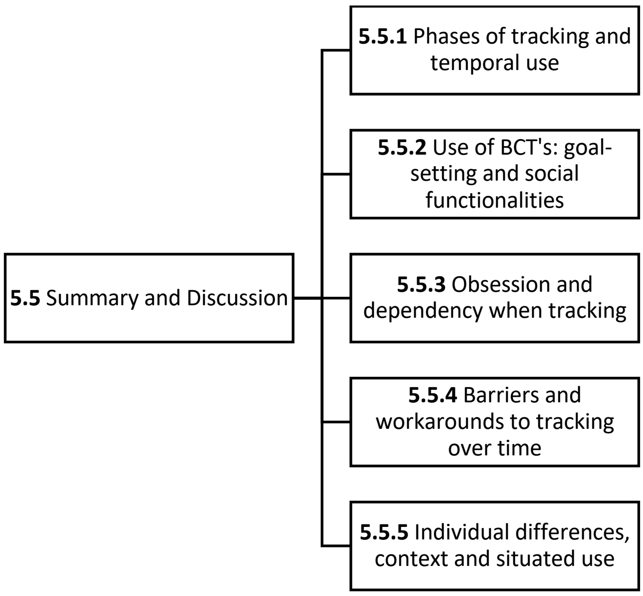

Figure 5.18 – Chapter 5 discussion outline

As a result of the findings presented in this chapter, and relating these back to the broader context of self-tracking and existing literature, we now present four contributions from this work (listed in Figure 5.18): firstly a better characterisation of the phases of tracking, not only confirming existing findings around the temporal and sporadic nature of tracking over time, but also extending existing work by reconsidering intentionality in the phases of tracking; then, we discuss participant's use of behaviour change functionalities, particularly showing how goal-setting can be useful for those with less structured days, and how the social functionality had a profound effect on some participants – but not always in a positive way; we then discuss how sometimes participants' tracker use appeared to become obsessive, and the concerns this brings; we then discuss our classification of barriers to tracking over time, along with the workarounds that some participants created to alleviate these barriers and continue tracking; finally, we begin to discuss the importance of considering the context of use when designing and evaluating tracking technologies, and the considerable effect these factors had on our participants' use of their trackers over time, which has thus far been little considered in self-tracking literature.

5.5.1 Phases of tracking and temporal use

In this chapter we have discussed how, throughout our studies, many participants did not consistently engage with tracking for a long period of time, instead often tracking on a temporal basis. Recognising this temporal nature of tracking, we characterised these different periods of engagement as "phases of tracking" (outlined in Figure 5.19). *Continued Tracking* characterises those who continued tracking over a longer term; *Lapsing Tracking*, referring to all times when one has stopped tracking for a period of less than 30-days – either intentionally, or when externally enforced; 5.1.3 *Stopping Tracking*, where one has intentionally stopped tracking, or has lapsed for a period of longer than 30-days; and, 5.1.4 *Returning to Tracking* after a lapse, temporarily, and permanently, after stopping tracking.

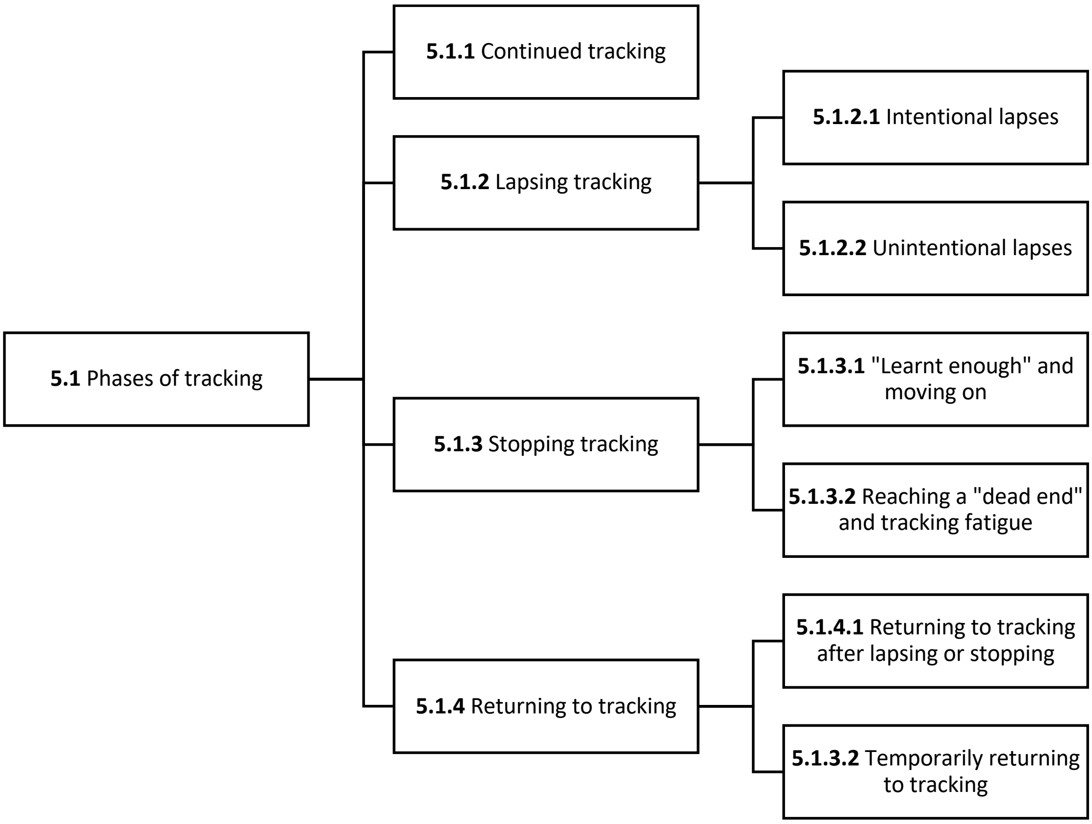

Figure 5.19 – Recap of phases of tracking over time

We are not the only researchers to recognise the temporal nature of tracking and begin to categorise these phases. In 2015 Epstein et al. published the "lived informatics model of personal informatics", which similarly focused on the temporal nature of tracking in the real world. The approach taken by ourselves and Epstein et al. are very different, whereas we studied use of trackers over time, Epstein et al. instead relied on participants' reflection on their tracking experience during a single interview. Despite our different approaches, where ours allowed us to gain a more contextualised understanding of how participants' engagement changed over time, much of Epstein's model is reflected in our own findings. We confirm Epstein's findings around the higher-level phases, both identifying lapsing, stopping and resuming tracking. However, whereas Epstein et al. categorised four different types of lapses: forgetting, upkeep, skipping and suspending, we instead focused on a participant's *intention* to lapse, or stop tracking - our findings confirming and enriching their categories. Further to this, our categorisation also shows how users may return to tracking after a change, such as or moving to a new house, or going on holiday, so they can once again gain insights into their behaviour and an understanding of the number of steps they are taking. Often participants would intentionally return temporarily, without an intention to track for a sustained period of time, similar to an intentional lapse.

The effects of both intentional and unintentional *lapses* can move beyond the lapse itself, resulting in further consequences to a person's engagement and motivation to continue tracking. Lapsing can, even if unintended, cause users to reconsider their tracking behaviours and needs, and an unintentional lapse may sometimes cause a user to stop tracking entirely, as the lapse "breaks" the habit of tracking and cause them to reconsider their use of the tracking tools. In our research we found that this was not simply the result of a "gap" in their tracking behaviour causing them to lose engagement (similar to the so called "Seinfeld method" (lifehacker.com, 2007) which advocates repeating an activity every day and not "breaking the chain"), but was instead caused by participants more consciously *reconsidering* their continued tracking. These lapses in tracking (similar to Cox et al.'s (2016) design frictions work on intentionally introducing hurdles in the interactions to make them more mindful) could actually cause some other more meaningful change – such as changing tracking, or making a behavioural change. Therefore, participants deciding to stop tracking after a *lapse* is a more complex issue than perhaps otherwise imagined.

Whereas Epstein et al.'s work focuses on various self-tracking technologies, ranging from activity trackers to social media and financial tools, and presents a picture based on individual interviews, our data is based on more in-depth longitudinal observations of temporal use of activity trackers. This results in our more nuanced understanding of how intentional and unintentional lapses occur. In particular, we provide new evidence of how people resume their tracking behaviour even after a longer period of stopping, suggesting different motivations behind short-term and longer-term interruptions in the tracking behaviour. The outcomes after use, including when it involves a period of lapsing or stopping are the focus of the next chapter.

Differently to the mostly qualitative approach taken by ourselves and Epstein et al., Meyer at al. (2017) were the first to take a purely quantitative approach to looking at phases and patterns of use over time, identifying 6 phases of use based on use and duration (from "minor use phase", where the user *"has not really used the tracker*", to "very long phase", where the user has tracked for more than 103 days) and 12-patterns of use for different phases of tracking and levels of engagement (2 of which were considerably more common than others), from a large corpus of step-data recorded across four studies. This approach is potentially useful, as use patterns may be detected in real-time, allowing tracking solutions to be personalised to better meet user needs. However, despite being based on the data of 104 participants and 14,413 days of use, as the authors state, their categories are descriptive of recorded data. Furthermore, we argue that binning categories based on quantitative data alone will likely not be fully representative of real-world use patterns, as this offers a blinkered perspective of the mechanisms of use. Using quantitative data alone fails to create a deeper understanding of the factors that resulted in particular use patterns, and therefore how users could be better supported. Instead, a mixed-method approach, including qualitative data would result in a better understanding of use over time. However, combining both quantitative and qualitative approaches in a single study represents a significant challenge, as the workload involved in including enough data points for quantitative analysis, whilst also understanding the lived experience through qualitative work, would be considerable. This is particularly difficult given the evolving use of technologies and the fast-paced nature of this field.

We found that phases of tracking were dependent on participants' motivations to track, their "style" of engagement with the tracker and, in particular, with their use of specific features, such as social functionality. Generally, more temporal tracking was more common with participants who were not engaged with other functionality such as goal setting or the social functionality, whereas those who were more highly engaged with these functionalities were more likely to consistently track over a longer period of time. For example, if a participant's motivation to track was simply to gather data and gain insight on their daily life, we found they were more likely to stop tracking sooner. However, if a participant instead engaged with social functionalities, or fell under Rooksby et al.'s (2014) "seeking rewards" style, they were more likely to track for longer. As we discuss in chapter 6, a longer term of engagement with the tracker did not necessarily result in more or less successful behaviour change, but motivations, styles of use, and engagement with tracker features (as we present in the next section) did have an impact on the length of use. Factors directly related to the tracking technologies themselves (such as form-factor and reliability of tracking) were significant, but not the only factors which affected engagement. We noted how participants regularly found that *"life got in the way"* (P9) when tracking, with events such as trips, injuries, long working hours, weather, and even uptake of other physical activities having a strong bearing on their self-tracking journey. Throughout these life events and changes participants found differing levels of utility and motivation for tracking, strongly effecting their engagement with the tracker. Unlike the other studies we have mentioned, which primarily focus on the use and non-use of specific tracking technologies and do not take into account other contextual factors, through our holistic and longitudinal approach we were able to uncover how these life events have an effect on the tracker's journey.

Our findings provide evidence that long-term use and engagement with trackers is *not* necessary to produce change. Traditionally, there has been an assumption that instead it was necessary, and that any form of stopping tracking represented failure. More recently, other research (e.g. Epstein et al. 2015, Kersten-van Dijk et al., 2017; Gorm and Shklovski, 2019) has begun to challenge the ideal of long-term engagement, but very little work has been done to demonstrate this as most research is not repeated measures, or only involves short-term follow-ups. Through our longitudinal approach we have better understood how trackers can be successful in encouraging or aiding behaviour change without sustained use. We also observed participants sometimes providing apparently contradictory reports over time, where changes in context or use caused them to alter their opinion or activity – something that may not be apparent in non-repeated measures studies. Some of our participants gained enough insights after short periods of tracker use, resulting in positive changes that persisted over time, despite stopping tracking. This was the case of P40 who gave up smoking after using the Fitbit for a short period of time. Further details about behaviour changes and responses to tracker use will be discussed in Chapter 6.

5.5.2 Behaviour change features, goal-setting and social functionality

Section 5.2 described how our participants used the various behaviour change techniques and functionalities embedded into their trackers. Amongst these features, goal-setting and social functionalities stood out as having most impact on our participants engagements with their trackers and resulting behavioural responses. Furthermore, our participants' interactions with these functionalities could sometimes have negative consequences. For example, behavioural goals sometimes discouraged participants from taking further steps, and some participants' engagement with the behavioural goals and social functionality could be considered obsessive, or harmful (even by their own peers). Additionally, loss of the social functionality often caused participants who were engaged with it to stop tracking entirely. Dependency on the scaffolding provided by technology has been studied in habit formation apps (Renfree et al., 2016), though this work did not focus on any detrimental effects to the user, and has also been seen as a potential pitfall in activity tracking research (e.g. Attig, and Franke, 2019), where participants were found to only take steps because of the encouragement provided by their trackers. In these cases, the act of being more active is strongly associated with use of the tracking technologies and stopping use of the tracking technologies resulted in the new, healthy behaviours, also stopping.

Setting behavioural goals is a commonly used behaviour change technique in self-tracking systems and is generally considered to be useful in encouraging behavioural change (Consolvo et al., 2009; Munson and Consolvo, 2012). Indeed, a proportion of our participants successfully used behavioural goal setting to increase the number of steps they were taking, and two participants who had little structure in their daily lives, engaged with goal setting over a longer time-period to encourage them to remain active. However, use of the goal-setting functionality did not always result in positive outcomes – some participants reported stopping taking further steps once they had met their step-goal, it effectively moderating any further activity. The potential negative outcomes of goal-setting have been little discussed in personal informatics literature, although a similar phenomenon was reported in the IDEA RCT (Jakicic et al. 2016), whereby participants who were far from meeting their goal appeared to "give up" and not attempt to take more steps. Whereas the problem of challenging goals being demotivating, even when users have high self-efficacy, is recognised (e.g. Locke and Latham, 2012), this could potentially be negated by encouraging participants to set more achievable goals, or dynamically changing goals to be more achievable (similar to Garmin's adaptive step goal, and in Lin et al.'s (2006) Fish 'n' Steps), the problem of participants doing less *after* their reaching their step goal is more difficult to design-out.

Our participants use of the various social functionalities embedded in their trackers was another significant theme from our findings, as many who used these functionalities reported them having a significant impact on their ongoing engagement and accordingly their behaviours. Many of the initial works in activity tracking (e.g. Consolvo et al. 2006; Lin et al. 2006) had a strong focus on these social aspects, offering social comparison, support, and competition. Often our participants initially used social comparisons to make sense of the number of steps they took, but similar to distant goals being demotivating (see above), some participants found social comparisons with those who took significantly more steps to be ineffective and demotivating, instead preferring to compete and compare more closely with similar people. A solution could be to match participants at different levels, or with different capabilities, and have only these participants compete and compare with one another – similar to sports league rankings.

Utilising the social functionalities, some of our participants tracked with others, sometimes in groups, but use of the social functionality was by no means consistent amongst all participants, or across time. Some participants did not engage with the social functionality at all, whereas others were highly engaged, and tracking socially aided their continued use of the tracker. However, some participants engaged with the social functionality to a level bordering on obsessive, making changes which were not always aligned with their general goas and desires – a potential issue which we return to discuss in the final discussion.

Research shows that extrinsic motivation is more complex than simple dual-models suggest (Ryan and Deci, 2000), but the behavioural changes that many of those who made changes as a result of their use of the social functionality did seem to be extrinsically motivated and driven by external regulation or introjection, rather than because of more internalised motivations. Aptly, because some participants only made these changes driven by their use of the social systems, their motivations and behavioural changes both disappeared if their social support or competition was removed. As an example, participants in case study 2 (section 5.2.3.2.1) made quite significant changes to their behaviour, but these seemed to be directly as a result of competition and the new social norms that had taken over the office, as they all became engaged with tracking. However, illustrating the delicate nature of these changes, after some participants stopped tracking (because of battery issues, a common barrier discussed in the next section), the entire group quickly disbanded and most participants reported to us that once the social encouragement had gone, the *changes they made did not stick*, indicating a dependency on tracking. Although this was in contrast to other participants who continued with some positive changes over time, this still indicates that loss of social functionality can result in loss of change. This is important to when we consider the fact that many workplace wellness programs are highly centred around leveraging similar functionality (Goetzel et al., 2014) and many focus on short-term events and challenges (Chung et al., 2017) meaning that changes may not last beyond the period of intervention. Supporting this, our participants who did take part in workplace wellness programs reported similarly – stopping their activity as soon as the external scaffolding was removed. We continue our discussion of the various barriers to prolonged engagement with activity tracking systems in the following section.

5.5.3 Obsession and dependency with tracking

Throughout this chapter we have highlighted how some participants were highly engaged with their tracking systems, or aspects of them. However, sometimes participants' levels of engagement moved beyond enthusiastic to obsessive, as they changed their behaviour and their tracker use took priority over other parts of their lives. These obsessions were not only our own interpretation, but were often highlighted by participants themselves: in section 5.1.2.1 P1 compared her Fitbit use to her previous "obsession" with her weight when she was younger, and multiple participants in section 5.2 described their use of the goal-setting and social functionalities as "obsessive". These interactions have the purpose of removing the user from the lived experience and enjoyment of exercise and taking steps, resulting in them experiencing steps only through their quantification. These obsessions, which although similar to conditions such as orthorexia (Sanchez and Rial, 2005) and orthosomnia (Baron et al., 2017) relate to participants' *tracking* rather than their *tracked* behaviours. Even so, they can potentially be harmful to users, particularly over a longer term, by creating unhealthy relationships with quantification and measurement of the activity. This may lead to an impact on their behaviour, similar to over-quantification of key performance indicators, as has been seen in the business world (e.g. Ridgway, 1956).

Pointing towards dependency on their trackers, some participants in section 5.1.2.2 mentioned how they felt "differently" about their physical activity when they had unintentionally lapsed tracking, and knew their steps were not being tracked. This provides real-world use confirmation of findings in more controlled studies (e.g. Jakicic et al., 2016; Attig and Franke, 2019) which have previously pointed towards the strong relationship between tracking and changes to the tracked activity itself. Dependency is important to consider when evaluating the efficacy of behaviour change technologies, as a dependency on the tracker to change their behaviour, or participants changing their activity to appease the intervention, may result in users reverting to their previous behaviours once the intervention is removed. Other work in the behaviour change literature has shown similar over-reliance and dependency on the scaffolding provided by behaviour change technology (e.g. Renfree et al., 2016; Stawarz et al., 2015). However, some of our participants continued to take steps when they had unintentionally lapsed (section 5.1.2.2), aware that "*Just because they're not being logged doesn't mean they don't count'*" (P34) – suggesting that some users are aware of this potential dependency and that it is far from universal.

5.5.4 Barriers and workarounds to continued engagement

As discussed in section 5.5.1, the temporal nature of tracking is well documented and one of the primary factors influencing people's engagement are barriers related to the tracking technologies themselves. The "abandonment" of wearable technologies has been the subject of much discussion in HCI and popular press (e.g. Arthur, 2014, in *The Guardian*). Beyond our depiction of the phases of tracking, including abandonment, in this chapter we presented a rich characterisation of barriers to continued engagement, along with the "workarounds" participants created to overcome these barriers. Understanding these workarounds, and participants reasons for making them, provided us with further insight into the problems they were experiencing, their unmet needs, and the design opportunities which could alleviate these problems. Further to previous work, we also detail the effect these barriers have on engagement and use: some barriers proved insurmountable, whereas others could be dealt with through use of workarounds. Interestingly, all participants who were *not* tracking at the time of the interview claimed that they would start again if barriers were removed, suggesting that longer-term tracking was of interest.

At the time of undertaking this research the reasons for temporal and short-term use of personal informatics systems had received little attention in academic work, something which we sought to address. Some of the findings in this chapter were published at Ubicomp (Harrison et al., 2015) and presented in a session entitled "Engagement and Disengagement" along with four other papers that looked at the use and non-use of tracking technologies. Since publishing this work, our understanding has been built-on and extended by many other researchers in the field, resulting in a more complete categorisation of barriers to engagement with tracking systems. Findings from Yang et al. (2015) confirm our findings around issues around accuracy of data tracked and how participants struggle to make sense of how steps were measured. Clawson et al. (2015) reviewed ads on Craigslist over a month of users selling their own activity trackers and found that among the various motivations for abandonment, there was also reasons for "successful abandonment" in cases where users wanted to upgrade a device or when the system had played a critical but temporal role in promoting change. Similarly, Lazar et al. (2015) collected experiences from users who were given up to $1,000 to purchase any tracking device and use them for two months. In their paper, they discuss the importance of reconceptualising abandonment as short-term use, suggesting that although these technologies are often marketed for continued use, users might still benefit in short-term engagement. There are a number of limitations in these papers that our research overcomes. Firstly, those conclusions are based on assumptions or evaluations of short-term use (up to two months). Secondly, they do not focus on the workarounds that participants created to overcome those limitations and make do with their technologies to still achieve their goals.

The importance of holistic tracking, that appropriately rewards users for their activity, has been emphasised since one of the seminal papers in activity tracking (Consolvo et al., 2006), but despite this, most current systems rely upon accelerometers to recognise and quantify activity and usually only count steps. Improvements have been made towards more holistic tracking: for example, by integrating more sensors (e.g. many commercial systems that track heart-rate and other physiological measures), or by offering a broader range of activity classifiers (e.g. Morris et al., 2014), but steps remain the most common measure for activity tracking systems. This is a difficult problem, as although using steps as a measure cannot be holistic and do not always provide an appropriate reward or representation of activity, they are also a useful measure for tracking systems, as they are non-sensitive, easy to comprehend and easily compared, whereas more holistic measures such as METS may be more tricky (Kersten-van Dijk et al. 2017). Additionally, steps work well for automated tracking systems, instead of relying on the active, or semi-active logging of non-ambulatory activities (e.g. cycling) which requires user input (Choe et al., 2017a).

To move beyond the limitations of trackers focusing on steps, our participants created workarounds by deliberately 'tricking' their tracker to count steps during non-step activities, by positioning the tracker on particular parts of their body. Users' reasons for doing this proved insightful: they wanted to be rewarded with steps for these activities because they wanted an aggregate measure of all their exercise. The *Nike Fuelband* offers a solution, with an abstract aggregate measure of activity in the form of 'fuel'. However, users may have difficulty in understanding how different activities contribute to this abstract representation and individual activities may not be tracked accurately. A different approach might be to allow users to customise their own activity classifiers, perhaps allowing them to train their tracker to record different types of exercise. This could be achieved, for example, by placing an accelerometer in an appropriate position and then providing examples of the activity. Such end-user customisation has been proven to be a successful way of increasing engagement in other fields (e.g. Johnson et al., 2013; Singh et al., 2014). An aggregate activity 'score' could be made up from different tracked activities, which could then track overall activity levels (rather than just steps), something users currently appear to be appropriating the step measure for, via various workarounds.

The appearance and form factor of physical trackers also play an important role in engagement over time, as users have different desires and there are no one- size-fits-all solutions, particularly given the highly personal and always-on nature of these devices which are usually carried in the most intimate moments. Our participants created workarounds to make the trackers better support their desires: wearing them in hidden places and wishing to customise them with aftermarket accessories. At the time of our work most wearables offered limited options for customisability, but some of these challenges have begun to be addressed in more recent devices which offer more options, along with opportunities for customisation. As designs and technologies continue to evolve, it is important to understand how barriers and other issues might be overcome or fixed in the future. For example, integrating tracking technology into wearables that offer other functionalities, such as smartwatches, might be a way to overcome the issue of 'forgetting to wear it'. For example, Cecchinato et al. (2017) found that participants who used to track their activity abandoned their device in favour of a more comprehensive smartwatch that could both track activities and deliver important notifications. However, as with any novel device, early adopters are not always the most representative users and future work will be needed when these devices become more mainstream. Moreover, removing the barriers in order to encourage longer-term use is not always necessary for a useful change to occur.

Our findings overall, provide evidence of how barriers affected use, and more importantly how barriers relate to temporal use, along with the understanding that short-term use can still lead to change. Evidence of this will be provided in the Chapter 6.

5.5.5 The impact of context on use

The context of technology of use can have a significant impact on people's interactions with them, and in the case of technologies potentially related to behaviour change, also any resulting outcomes from use. In these cases contest does not only apply to the locations where these technologies are used, but also personal and behavioural factors, as outlined in this chapter. Grudin (1988) argues for the necessity of better understanding the context of use over time to ensure the potential can be maximised, a claim recently supported by Clawson et al. (2015) who looked at how tracking technologies were being resold online as a result of abandonment. Use of tracking technologies across different user groups has been conducted (e.g. adolescents (Gaudet, Gallant and Belanger, 2017), or the elderly (Lauritzen et al., 2013)) and with users with different motivations (e.g. weight-loss (Jakicic et al., 2016), or rehabilitation (Alharbi et al., 2016)) but to date, very little work has focused on explicitly comparing use in different locations, nor the impact of the physical fabric of where people are located. As we have shown, there can be significant differences between how people in different situations use personal informatics technologies and associated behavioural effects. Many studies have focused on users in North America and the majority of manufacturers of current devices are also based in the US. However, many differences exist between North America and elsewhere in the world (and indeed, also across North America), and therefore use and engagement with technologies will likely also differ across locations. One exception is the Health Mashups study by Bentley et al. (2013) which considered the use of an activity tracking app in both Atlanta and Chicago. However, their work did little to consider the differences in engagement and use between these two cities.

To better understand the impact of context on use we studied a wide range of participants, including contrasting use in those normally located in two different cities: Atlanta, GA and London, UK. By studying similar users in two contrasting cities we could better understand some of these changes and the resulting impact on their experience of tracking. Our findings pointed towards considerable differences, not only in their use of trackers themselves, but also in behavioural outcomes. The built and natural environment had a considerable impact on our participant's NEAT and other physical activities, along with how they interacted with their trackers and their resulting changes in behaviour. For example, whereas many of our participants in London worked more steps into their everyday routine by walking for transport, many participants in Atlanta experienced barriers in the environment that prevented them from doing this. Instead, they tended to make changes to their planned exercise activities, which literature (e.g. Buchan et al. 2012) suggests may be less likely to be successful over a longer time, due to the higher chances of relapse, illustrating the importance of considering context.

Atlanta and the surrounding area offer an interesting contrast with London. A 2005 study (Conroy-Dalton and Dalton, 2005) looked at a satellite city of Atlanta and how the built environment there encouraged more social, environmentally friendly and economical solutions to transport. In their study of Peachtree city, Conroy-Dalton and Dalton found that "transit racism" (i.e., "unjust, unfair and unequal transportation policies and practices" Bullard, Johnson and Torres, 2000, p.49) resulted in inequalities between those who own a car and those who were left stranded due to lack of affordable public transport. As a result, citizens created a workaround whereby available golf carts were being repurposed as personal transport. In our research, we found how participants who lived in Atlanta had negative feelings towards public transport and because of the built environment, were limited in their options. For example, the lack of sidewalks prevented them from being able to change their commute options or integrate more physical activity into their everyday life, forcing them to either plan for it or not do it at all. In contrast, participants in London had a different perception of public transport and the urban infrastructure available allowed participants to get off the underground a stop earlier and walk the remaining distance.

While more work should be conducted to extend our comparative work and better understand the effects of situation on peoples interactions with personal-tracking technologies (and the subsequent relationship with behaviour change), our findings begin to show how these are under-studied factors in HCI that can actually have a large influence on the ways in which people use these technologies and integrate them in their lives, and should be more considered in the design and evaluation of these technologies. In line with our recommendations, Conroy-Dalton and Dalton (2005) urged for more comparative work to understand how uniqueness and commonalities of the built environment can affect people's lives. Here, we have shown how it affects participants' levels of physical activity in two culturally, socially and physically different cities. Of course, our examples do not cover other environments, such as more rural places where opportunities for public transport, active transport or even access to more organised physical activities might be even more limited, potentially resulting in quite different use of these systems amongst users in different situations.

5.5.6 Chapter summary

In this chapter we have discussed how our participants used their trackers throughout their self-tracking journey. Even though only a relatively small number of our participants consistently tracked steps over a longer time period, the majority suggested that their use of an activity tracker either had some lasting positive impact or had provided them with useful insights. This was often through an increase in the number of daily steps they took, but other changes such as taking up a non-tracked activity (activities such as cycling or swimming) or other lifestyle changes were also mentioned. In addition to the insights gained from use of the activity tracking, participants also mentioned that they had used other personal informatics tools to track other aspects of their lives, such as the food and drink they consumed, their weight and body composition, and how much they slept each night. With the ways in which our participants used their tracking technologies, in the next chapter we instead focus on behavioural and psychological outcomes of tracking, beyond initial uses. It is vital for us to better understand how people use these technologies in the real world, along with the impact that context has on their use. However, focusing on their use of the trackers alone offers us little insight into the impact that use of the trackers had on our participants: the psychological reactions and realisations they had, along with the behavioural changes they made. This is what we concentrate on in the next chapter, relating our participants wants and desires for trackers, and their use over time, with the actual outcomes.

Chapter 6. Responses to Tracker Use

The final pieces of the self-tracker's journey are the most human and behavioural aspects: a characterisation of the effects that tracking had on the users themselves. Where the previous chapter focused on participants ongoing engagements with their trackers, this chapter instead moves beyond the users' relationship with their technology and looks towards the affective and behavioural responses and outcomes that resulted from tracking. Focusing on the longer-lasting responses and outcomes that came as a result of more considered use and engagement, this chapter extends the *initial responses* to tracking in Chapter 4 by further characterising affective responses and extending behavioural responses to also include changes to behaviours beyond the tracked activity – steps – to also include *changes to other physical activity* and *lifestyle changes*. In section 4.5, we showed how our work mapped onto, and extended, the *digital epiphanies* work (Cox et al. 2013), but where this was largely based on participant's short-term interactions with a relatively small amount of tracked data, this chapter instead looks at responses over time, as a result of consideration, reflection and "slow" thinking. The responses we witnessed over a shorter-term were mostly directly related to the tracked activity (i.e. steps), whereas longer-term responses were instead related to a variety of different behaviours (including those that were not measured by their tracking systems) and were often more related to participants' ever-changing goals. Although we focus on participants' responses to, and outcomes of, tracking over time, these are intrinsically connected to their ongoing interactions with tracking technologies and the quantified data.

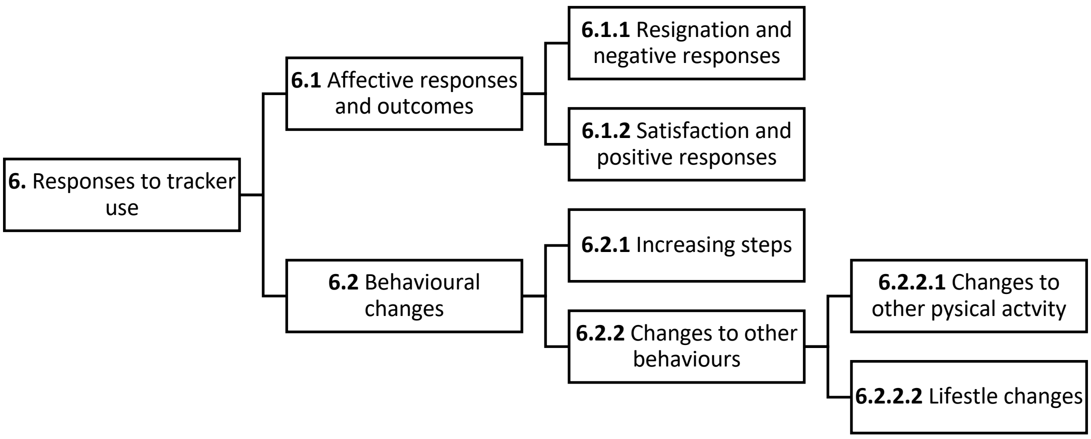

Figure 6.1 – Chapter structure

In this chapter (outlined in Figure 6.1) we further characterise the ways in which our participants responded to use of their trackers over time, detailing the processes they went through and the factors that affected their outcomes. These responses did not always happen directly as a result of tracking, as other situational factors also influenced participant behaviour, but by analysing and characterising the more, or less, positive outcomes we offer insights into the mechanisms that were most useful for positive change.

Other work relevant when considering people's use of personal informatics systems over time is the Lived Informatics Model (Epstein et al., 2015), which builds upon the Stage-Based Model of Personal Informatics Systems (Li et al., 2010), by providing a more comprehensive picture of the ways in which people track over time, and how this fits within their broader self-tracking journey. However, these existing models mostly focus on the users' relationships with the tracking technologies and their respective data, without as much of a focus on the emotional and behavioural aspects of integrating these technologies into their everyday lives over time. Additionally, the factors that influence users' responses, and their continuing journey even beyond the period of tracking, are not covered in depth, due to the research focusing on active and returning users. Instead our work takes a broader view, by not only considering tracked activity, but also considering the affective or emotional responses that participants had, the role these played in their tracking journey. Additionally, because this work was undertaken over an extended time-period, we are better able characterise the self-tracker's journey along the way, taking into account external influences and behavioural changes and responses beyond the tracked activities.

The behavioural changes that participants made were not always related to the behaviour they were tracking, and some participants stopped tracking before they made changes. However, this does not mean that subsequent changes were unrelated to their use of the tracking technology – oftentimes tracking appeared to have acted as a catalyst for these further changes, or helped participants better understand their behaviours and how they can change them to meet their goals. This was similar to work in exergaming by Schwanda et al. (2011), where the technology acting as a starting point for behavioural changes beyond those that arose during use. In our research some participants stopped tracking soon after starting, but still had a sustained change to their behaviour or attitude, whereas for other participants tracking steps represented the beginning of a longer self-tracking journey, where tracking remained, sometimes supporting their activities, throughout.

Our participants' responses changed over time and not always in a discernible order. A participant might initially respond in one way, for example taking more steps, and then revert to their previous behaviour, realising that they were satisfied with what they were already doing. Accordingly, our use of the words "response" and "outcome" in relation to the behavioural changes and affective responses does not refer to an ultimate result, but rather the consequences of use which may be in flux and liable to further change. We recognise that the self-tracker's journey is ongoing, changing over time, including beyond our interactions with participants. Ultimately, the responses and outcomes to tracking presented in this chapter are a long-term phenomenon that may change over time and as a result of tracker use and other contextual factors.

6.1 Affective responses and outcomes

Our first categorisation includes affective responses, where a participant's attitude or feelings towards a particular activity change as a result of insights they have gained through tracking, but where there is not *necessarily* any change in their actual behaviour. These responses might either happen alone, or concurrently with behavioural responses, and in many cases are not an ultimate response.

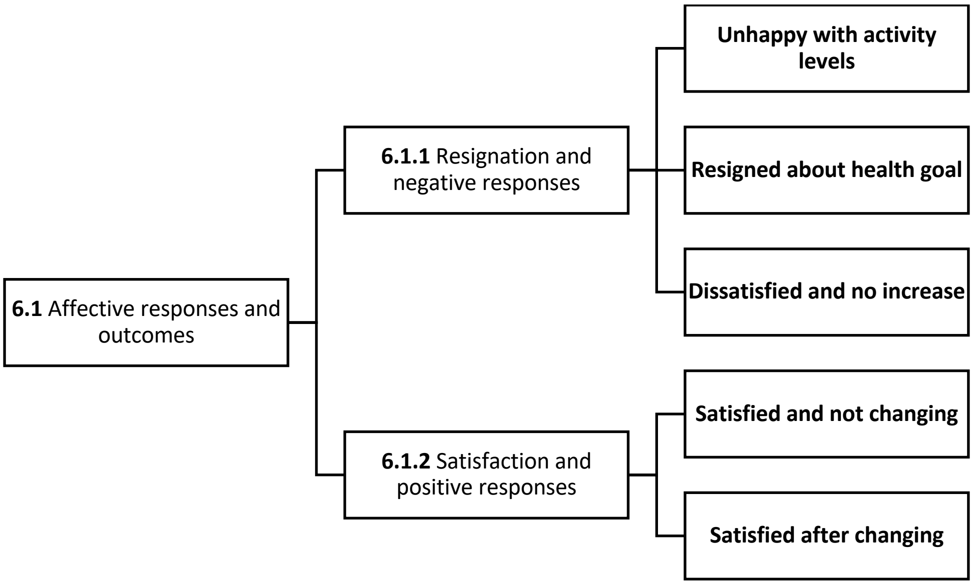

Figure 6.2 – Affective responses outline

The affective responses to tracking that participants experienced had at the beginning of their self-tracking journey (as characterised in section 4.5.1) were generally very different to the more considered outcomes they had further through their self-tracking journey. The initial responses mostly arose from a participants' *reaction* to the data and was often a direct emotional response, whereas the responses presented in this chapter came from a more reflective perspective. Appropriately, many of the responses in this section are not just related to the tracked data, but more to the entire *experience* of tracking; reflection on their initial responses and any changes they had made; on their general health and wellbeing; and, on their broader lifestyle and goals. We first consider negative affective responses and the feelings of resignation that some of our participants experienced.

6.1.1 Resignation and negative responses

After first viewing their tracked data some participants were disappointed with their existing activity levels, which often led them to change their behaviour, or feel *resigned* to continue with their existing behaviours (or both). Feelings of *resignation* arose in those who felt unhappy with their levels of tracked data, but also felt unable to make any changes. Unlike the initial feelings of dissatisfaction or disappointment with their recorded data, resignation was not an immediate response, but rather the result of some kind of engagement – reflection on their activity or the tracked data, or after an attempted behavioural change. Many of those who felt resigned were either: unhappy with their recorded activity levels (e.g. recording fewer than expected steps); unhappy with the how the technology recorded their activities (e.g. feeling they did not get enough credit for running, cycling or yoga); or, were meeting their tracked activity goals (perhaps after making a change), but were still not meeting their broader health or lifestyle goal goals (e.g. regularly completing 10,000 steps a day, but still not losing weight), and felt that they were unable to further change, despite having a desire to do so. Feelings of resignation were often transitory, as most participants who responded in this way often did so for only a limited amount of time, soon gaining further insights and inevitably moving to an *acceptance* or a *change* response. However, some participants who felt resigned (e.g. P29, P30), failed to move beyond this and gradually lost engagement with their tracker. There is potential to provide more technology support for these participants to support them in further reflecting on their activities and progressing to a more positive response.

Some participants were **unhappy with their activity levels**, believing themselves to be more active than indicated by the device. Upon seeing the number of recorded steps, these participants often felt they already took as many steps as possible as part of their routine and had no opportunity to walk any further, did other types of physical activity that were not accurately measured by the device (such as swimming), or were otherwise incapable of taking more steps (usually because of having a busy schedule). For example, P29 was already taking as many steps as she could throughout a typical day but discovered that on a routine work day she took fewer than 10,000 steps – a figure she was dissatisfied with: *"It's really upsetting, I thought I walked way more".* This initial disappointment turned into resignation, as she explained, "*it's making me think about things more – no, I've not changed… I'm already very aware of getting up and walking around* […] *I don't really have any opportunity to do more"*. She continued to track her steps for some time, as she was interested in quantifying them, especially on *"unusual"* days outside of her routine, but because of her busy routine she felt *resigned* to taking fewer steps than she wished she could. At the follow-up interview she was no longer tracking, explaining that *"the battery died, I just got a bit lazy about getting a new* *one"*. However, rather than remaining resigned about her inability to take more steps in her routine, she had realised that the measure of steps alone was limiting: *"I'm still interested in the idea of tracking, I think maybe steps felt a bit limited* […] *I'm quite happy with saying 'I did yoga and I did that last week, and this week I'm going to do this and this'. For me it's more doing activities on certain days, rather than numbers throughout the entire week".* For this, and others who partook in a wider range of activities that were not tracked by the device, a more holistic measure of activity might have been beneficial to their continued engagement.

Other participants, often those who had had health or wellness goals, felt **resigned to not meet their health goals**, despite being *satisfied* with the number of steps they were taking. For example, P23, who hoped that his Fitbit Zip would help him lose weight, was initially satisfied with the number of steps he was taking, explaining, *"it* [the Fitbit] *made me realise that I actually walk more than I thought"*. However, despite continuing to regularly meet his step-goal, he still did not lose any weight, telling us in the third interview "*I now feel unexcited by the Fitbit"*. Soon after this he became less engaged, often forgot to wear his tracker and eventually stopped replying to our invitations for interviews. One could imagine that resignation this might be a typical response in this position. However, some months later he took part in our follow-up interview and explained that he had further reflected on his behaviour and rather than focusing on steps had instead started attending the gym more regularly and had taken up swimming - claiming to see health improvements as a result. Unfortunately, as was the case with many of our participants, he explained that other events in his life had conspired to stop these changes: *"it's been really eventful in the last couple of months. I move houses, I change jobs, and then split up with my boyfriend"*. At this stage, his Fitbit had served its purpose and he no longer wished to use it, but it had provided him with insight and the short-term meaningful interaction he had appeared to inspire a positive change, albeit a temporary one.

Other participants felt **dissatisfied with their existing activity levels and resigned** to continue without showing any desire to change. For example, after approximately 4-weeks of using her device after the sticker was removed from the screen, P2 explained that she had not attempted to increase her activity, despite having a desire to do more, *"If you're supposed to do around 10,000 steps I know I wouldn't be anywhere near it, so why depress myself?"*. Then, referring to other Fitbit users in her workspace who routinely took more steps than her she said, *"I know they do it, but they're much more athletic so I don't see the point… I'd need to compare with someone like me who finds it hard to find the time or gets tired easily"*. This highlights a challenging problem, where providing an inappropriate goal, or social norm, causes a participant to feel demotivation or resigned, which can affect their behaviour. This phenomenon has been observed in other social projects, where distant competition has worked as a demotivating trigger (Massung et al., 2013). There is potential for personal informatics technologies to better supported this participant or others in a similar position: by providing a more appropriate goal or a closer social comparison their response might be different.

6.1.2 Satisfaction and positive responses

In contrast to the resignation responses above, some participants were *satisfied* with their behaviours and did not feel any desire to change. Whilst some participants initially responded positively after tracking their steps (as described in section 4.5.1.1), we found that many soon had a desire to change their behaviour, and it was only after making these behavioural changes that they returned to being satisfied. This was perhaps because a large proportion had existing goals in mind when they started tracking, and even if they initially responded positively to their tracked data, they could only meet these goals by changing their behaviour in some way. As such, the positive feelings of satisfaction with their activity levels was a fleeting response for some participants who, despite their initial satisfaction, would become dissatisfied over time. This was especially true if they were not moving towards their overall goal (e.g. to lose weight), which caused some participants to then change their behaviour, sometimes in ways unrelated to the tracked activity. For example, some participants chose to change their diet, or take up a different physical activity, after becoming dissatisfied with increasing the number of steps alone.

Some of those *satisfied* participants decided **their existing activity levels were "good enough" and decided to not make any changes**. For example, both P20 and P27 already regularly met their goal of taking 10,000 steps each day, saying *"I've not changed my behaviour* […] *already usually do enough of steps"* (P20), and *"I've not changed my activity as a result of this, it's just my routine… I think I already do enough"* (P27). However, whilst their affective responses were similar, their device use was quite different: P27 stopped tracking after a relatively short duration, whereas P20 was still tracking at our follow-up interview, explaining: *"over the weekend if I stay at home I walk nothing. I stay there and then maybe I have 2,000 or 3,000 steps* […] *sometimes instead of taking the tube I walk to go to the places*", suggesting there was some level of behaviour change as a result of his continued.

Some participants who did not regularly meet their 10,000-step goal were satisfied with their existing behaviour, despite initially wanting to do more. For example, despite usually averaging around 6-7,000 steps, P16 was satisfied, explaining, *"I think I might start caring less about my walking habits now... It just occurred to me that when I do nothing I do 3,000 steps. Just coming to campus I've crossed 6,000 steps. Now that I know I do 6,000 steps without doing much I'm pretty sure I can easily* *cross the threshold of 10,000"*. As the study progressed he told us that he had not increased his steps and continued to be satisfied with his existing behaviour, aware that when his routine called for it he would be able to easily achieve 10,000 steps. This is perhaps an area where the technology could better support users in meeting activity recommendations and their own goals, for example by explaining the benefits of being physically active or presenting suggestions on ways to change.

Other participants who were initially satisfied with their existing step-count only remained **satisfied with their behaviour after they had *changed*** in some way. Sometimes this was by increasing the number of steps they were taking, but in other cases this was by making changes to other physical activity not directly tracked (such as swimming or cycling), or even by making other lifestyle changes (such as changing diet or giving up smoking). These changes to behaviour are described in the following section.

6.2 Behavioural Changes

Most participants reported changing their behaviour in some way as a result of tracking, most commonly by increasing their steps – the behaviour directly measured by their trackers. However, many participants also made other changes, such as increasing or taking up other physical activities, or changing other aspects of their lifestyle such as their diet or attempting to give up smoking (one successfully), as outlined in Figure 6.3. This section focuses on the processes leading to behavioural change, an understanding that can help better design future technologies to support users in having more meaningful interactions.

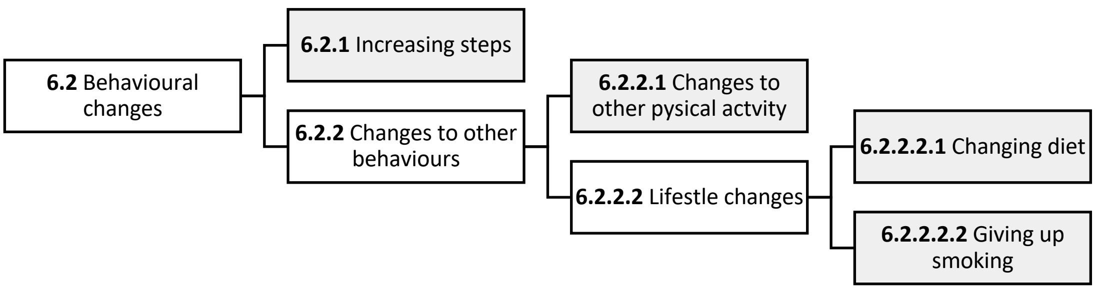

Figure 6.3 – Behavioural changes outline

Even though not all of the behavioural changes that participants made were directly linked to the activities they were tracking, participants attributed them to their use of the tracker in some way. Often, these changes were the result of participants reflecting on their existing behaviours and identifying something they wanted to change – often to meet a pre-existing goal. Various factors acted as catalysts to encourage this reflective process, including: tracker-related issues such as battery failures or technology breakdowns; situational factors such as moving to a new house or falling ill; and the affective responses in the previous section, where resignation or satisfaction sometimes led a participant to reflect on their behaviours and then change. Only a very limited number of participants made meaningful changes beyond an increase in the number of steps they were taking. However, those who did, most frequently "progressed" through the different responses outlined in this chapter, initially increasing their steps, before changing other physical activities, and then making lifestyle changes.

6.2.1 Increasing steps

By far the most common way that participants reported changing their behaviour was by increasing the number of steps they took each day. Similar to their initial responses to tracking in section 4.5.2, participants used two main strategies to increase their steps: integrating more steps into their daily routine (often by increasing active transport); and, doing planned exercise and sports. The increases that participants integrated into their daily routine were generally sustained over a longer time-period, and some participants even claimed to continue with these habits after they had stopped tracking, whereas changes to planned exercise were often less well sustained.

Many participants integrated small changes into their daily routine to increase their steps, such as using the stairs instead of the lift or walking to have face-to-face conversations to office colleagues, and *"make every step count"* (P14). Although many of these changes resulted in few extra steps, they often appeared to "stick", not only beyond participants' initial interactions but also after they had *stopped tracking*. For example, in the follow-up interview, P14 (who was no longer tracking), explained *"I'm* [still] *walking a bit more, in the sense that the minor corrections that I'd done, for example I'd always tend to walk up the escalators, I walk up the stairs, I tend to take the longer route to work, especially if I've got time... So those minor adjustments to what I was doing before the Fitbit are still there. At least for me I think these things that I adopted when I had the Fitbit I have kept"*. Similarly, P7, who had also stopped tracking said, *"I definitely always still walk up escalators now, and I didn't before... Because I know that it is just that little bit of increase in exercise that I wasn't doing, so I think actually that has stuck with me, I do that everyday*". Participants who were still tracking, such as P18, also continued with these behaviours, *"what it does help with, is things like... if I go for a pint of milk, I might walk the long way around to the shop"*. It seems prudent to expect those small type-1 changes that can be integrated into one's daily routine may be more successful over a longer term, as they may more easily become habitual, scaffolded in those other habits that happen within one's daily routine, compared to doing more planned activities which may require more of a conscious effort. However, the extent to which these small changes last over an even longer time-period remains to be seen, but they often appeared to be successful in our sample.

Other participants incorporated bigger changes into their daily routine, most frequently by making more use of active transport. This was particularly common amongst our participants in London, who had more flexible transport options than those in Atlanta. Some participants simply got off the bus, or underground, a stop or two before their destination. For example, P11 told us: *"I didn't used to walk, you remember that. I would take the tube. I would take the bus... Well, I'm still taking the tube or the bus, but what I usually do is that I walk for a specific distance and then I take the next stop, or two or three stops after"*. However, this change required participants to make a conscious decision and remember to get off, which often did not last over time. For example, L5 *"started getting off the tube a stop earlier when going to work"* when she was tracking, but then travelled the entire way to work after she stopped using her Fitbit.

Other participants told us how they would *"simplify"* (P11) their journey and maximise steps by doing part of their journey by foot, often by walking instead of taking short bus journeys between their destination and a train or underground station. For example, P28 walked between her home and her local underground station (where she would then travel to work), rather than taking the bus – which meant that she could more easily achieve her 10,000-step goal each day. She also claimed that this change provided more tangible benefits: *"by doing all of this walking I do feel better that I am doing some exercise, which is nice. Otherwise you just go from an office chair to the bus to a couch via a tube* [London Underground]" and in the follow-up interview she reported that she had since *"firmed up a lot"*. Similarly, P8 explained how she would walk instead of taking the bus, "*it's a 5-minute walk to work, but if the bus was there I'd take the bus instead - if it was there. But since wearing the Fitbit I'll always walk. I don't even take the bus anymore*". Changes such as this, where a participant integrated walking into their existing transport habits tended to continue over time, even after they stopped tracking: the battery in P11's device died and P28's device stopped working and needed replacement, but they both continued to walk as part of their transport routine. Other participants who only tracked for a short-term reported similarly, suggesting that short-term meaningful interactions with the device and the insight they gained was enough to encourage them to make a sustained change, when these activities were integrated into their existing routines.

Whilst many participants who integrated more steps into their daily routine maintained these changes over time, far fewer of those who took up, or increased, their planned exercise and sports-activities maintained this change. For example, inspired to do more activity by his Fitbit Zip, P14 started playing badminton with his wife and some friends, but despite also encouraging them to track this change did not last. In the follow-up interview he explained that although he had continued with some of the changes he made to his daily routine, he was no longer playing badminton. Participants in our comparison study told us similar stories of how they initially took up sports activities when first using their trackers, but that these would often not continue over time. These findings are in-line with existing literature, showing that new physical activity behaviours are often not maintained over time, and that integrating, or anchoring, changes into an existing habit may be more successful (e.g. Fogg, 2009).

Not all of the changes that participants made were in-line with physical activity guidelines (see section 2.1.4), which recommend a mix of cardiovascular and weight-bearing activities. At the beginning of their self-tracking journey some participants made changes that appeared to be a direct response to quantifying their steps, whereby they maximised the number of steps they were tracking at the expense of other activities: changes incongruent with activity guidelines and sometimes even the participants' own goals. However, over time most participants re-considered these changes, often after reflecting on their behaviour, and instead undertook more well-rounded physical activity. However, whilst most participants moved beyond their initial, compulsive behavioural response to tracking, others, often driven by strong engagement with the social functionality (see section 5.2.3) remained focused on tracking as many steps as possible. This focus was often at the expense of other activities, and even other aspects of their lives. For example, participants L6, L17 and L18 tracked alongside each other and made considerable changes to record more steps, both as part of their daily routines (such as walking for transport) and just for the sake of tracking steps (such as marching on the spot whilst watching TV). These participant's interview and survey responses suggested they were meeting cardio-vascular exercise guidelines, whilst doing little to no weight-bearing activities, thus failing to meet activity guidelines, potentially resulting in negative health consequences. These participants appeared to be so engaged with the social functionalities that they failed to reflect on their activities and their consequences, along with how they met, or failed to meet, their broader health goals.

Many of the participants who made large changes to the number of steps they were taking each day reported being fairly inactive before starting tracking (e.g. P6, P11, P12, P14 and P28) and enthused about the benefits that being more active had on their lives. The positive changes that some of these participants made encouraged them to continue to change their behaviour, by changing other aspects of their physical activity and lifestyle beyond the number of steps they were taking, as described in the following sections.

6.2.2 Changes to other behaviours

Some participants made changes to behaviours that were not directly recorded by their trackers, including other physical activities (such as cycling and swimming), along with lifestyle changes such as changing their diet, or stopping smoking. Generally, these changes were the result of a participant going through a process of deeper reflection with their tracked data, their experiences of tracking and their broader health or wellness goals. Many participant's initial motivations for tracking (outlined in section 4.1) were linked to goals such as "losing weight", and although their goals changed over time and as a result of tracking, they usually remained unaligned with simply taking more steps, thus causing participants to explore other behavioural changes to meet their goals.

Some participants wanted to make further behavioural changes after they had already increased their steps, whereas others instead struggled to increase their steps and changed a different behaviour as an alternative. For example, a participant might initially increase their steps, but then find that this does not help them meet their weight-loss goal, resulting in them instead starting a gym routine. Most of these changes happened as a result of deeper reflection, but this was not always the case, as some participants instead had a more sudden realisation - a "digital epiphany" of sorts (Cox, Bird and Fleck, 2013). For example, after choosing to walk home after first receiving her Fitbit Zip, P40 had a sudden realisation that she was unfit, *"I thought about my health, about the movement I get every day, and I realised that I can't breath very well…",* which started of a process of behaviour change which continued over a significant time period (we refer to P40 throughout the remainder of this chapter).

Whilst the number of participants who made meaningful changes beyond steps was relatively small, this remains an interesting finding that illustrates the potential for tracking technologies to have a broader impact on peoples' lives beyond the behavioural traits they are measuring. By understanding the processes that encouraged these changes, we can create recommendations for the design of future trackers to have more meaningful impacts on users' lives.

6.2.2.1 Changes to other physical activity

A small number of participants made changes to their physical activity in ways that that were not directly tracked by their devices, including cycling, swimming and weight-lifting, but attributed these changes to tracking their steps. Often participants changed, or took up, a different physical activity after reflecting on their self-tracking journey and the responses to tracking they had made so far, deciding that a different activity would better suit them. Some participants made these changes after having successfully *increased* their steps, building on the changes they had already made. Others instead took up a different physical activity instead of increasing steps, either because they were *resigned* to continue with their existing steps, or because they were *satisfied* with the number of steps they were taking, but still wanted to change.

Some participants first increased their steps, and then went on to make other changes to their physical activity, and sometimes other aspects of their life (see following section). Many of these participants gained something by taking more steps (e.g. fitness or enjoyment) or had a realisation (e.g. that they were unfit) which caused them to consider taking up other activities. For example, after significantly increasing her step-based activities and feeling much fitter, P40 purchased a bicycle and started cycling, having already started running, "*I bought a folding bike - that's really new!* […] *the last time I rode was when I was 21 or 22... now I'm 37"*. Similarly, as a result of getting fitter after walking more, P6 *"upgraded and I've bought an actual bike"* (she already had an indoor exercise bike) and had purchased appropriate clothes so that she could cycle in inclement weather - something which she had never before considered. Whilst P6 continued to track with her Fitbit, P40 made these changes despite her tracker not being fully functional throughout most of the study (a problem with the device meant that it worked sporadically for the first few months, then stopped working entirely when the battery ran out and she chose to not replace it), so although the process of change started because of use of their tracker it was not always a key part going forward.

Other participants made changes to untracked activities simply because they had a heightened awareness of their general activity as a result of tracking steps. For example, P32 who tracked consistently explained, *"over the course of what is now 18-months, I've definitely been more active generally than I was previously* […] *what I've found is that as soon as you start tracking one thing you become hyper-aware of how much activity you're doing more broadly, right? So if you haven't moved around all that much in a day, you will be more inclined to go out and walk a greater distance to try to cover that ground. Similarly, you'll also be aware that you haven't done any press-ups, haven't been the gym, whatever else. So it's all part of the same picture I think"*.

Other participants took up a different physical activity after realising that they were unsatisfied with simply increasing the number of steps they were taking. Often these participants made changes *after* increasing their steps, including those who decided they wished to have a *"more rounded workout"* (P49) or felt inspired to take up an additional activity, even though this would not be recorded by their tracker. P47 also fell into this group – already a regular runner, after tracking she further increased her ambulatory activity to include active transport and other NEAT activities, before deciding these changes were not improving her general health: *"I was really disappointed, because for the first time I was really healthy - not smoking much, not drinking, going to the gym every day,* *and then I get sick, so I might just as well be unhealthy. I was healthier when I was unhealthy!"*. Largely influenced by external factors (*"I had moved to* [anon]*, where you don't really walk - you need a car for everything"*), she decided to stop tracking, reduce her cardiovascular activities, and instead focus on building muscle mass, explaining, *"one of the good things about using the Fitbit, is that I did get more into fitness, and I started trying to educate myself. I released that although walking had been good for me mentally and psychologically* […] *I started learning more about fitness and things like that and I found out that it's not about cardio, it's about building muscle, and lifting heavy weights, so I started doing more of that".* Some months later, during our follow-up interview she had continued with this new regime, making significant changes to her physical activity, limiting cardiovascular activities to *"25 minutes of cardio a day"*, explaining: *"there's no way back, once you've changed your mind like that and you've learned stuff"*.

Finally, some participants who failed to increase their steps but had a continued desire to be more active, along with those who were meeting their step-goals, but not their broader health or wellness goals, also took up other physical activities. These participants either felt *resigned* to not increase their steps or were unhappy with the changes they had seen from increasing their steps. One particularly obvious example of this comes from P23, who eventually took up swimming and increased his gym attendance. Before this, he was initially *satisfied* with the number of steps he was recording, before feeling resigned because despite this he was not nearing his overall goal, which was to lose weight. In his third interview he stated, *"it made me realise that I actually walk more than I thought. I now feel unexcited by the Fitbit"*. However, the insight he gained through his step count resulted in him changing his activity in a way not tracked by the device – he took up swimming and attended the gym more often and began to see fitness improvements as a result. At this stage the Fitbit had served its purpose and he no longer wished to use it, but it had provided him with insight and the short-term meaningful interaction inspired a healthy change.

Although some of our participants made meaningful changes to their physical activity beyond steps after using their tracking technologies, this was not true for all. Some participants who responded negatively, or felt resigned, instead stopped tracking and made no changes. This is a missed opportunity for the technology to encourage further, and perhaps more appropriate, behavioural change in these participants. An alternative could be to encourage these participants, where appropriate, to consider making other changes outside of physical activity, for example to other lifestyle traits: something that some our participants attempted, as shown in the following sections.

6.2.2.2 Lifestyle changes

Beyond physical activity, many participants made other changes that were related to, but not directly linked to, activity tracking. Although these changes were not directly related to steps or physical activity, and were not recorded by their trackers, many participants attributed these changes to tracking. Most commonly participants made changes to their diet, often eating and drinking more healthily, or trying to eat less. Finally, two participants claimed to give up smoking as a result of using their tracker, although one started smoking again after she stopped tracking.

6.2.2.2.1 Changing diet

Beyond changes to their physical activity, the most common change our participants made was to their diet. A large number of participants chose to either eat more healthily, or to restrict their calorie intake to create a deficit. This is unsurprising, given that many of our participants started their tracking journey with a goal that was somehow related to weight loss. A large proportion of our participants explored food tracking, but none continued to do so over a long period. As detailed in section 5.3.3.3.3, many participants found consistently tracking their food to be too much effort, and many were unconvinced about the longer-term benefits of doing so. However, similarly to physical activity tracking, participants did not need to track over a continued period to have a meaningful interaction.

Some participants changed their diet and became more conscious about their eating and drinking choices as a result of an increased awareness when they were tracking. For example, A12 explained to us that he stopped drinking soft-drinks soon after he got his tracker, partially as a result of an increased awareness and the effort he was putting into his steps: *"I had gotten addicted to soda, now I don't touch the stuff* […] *It makes you think about it. It makes you aware of it and conscious of it* […] *with the Fitbit you've got a constant reminder and you find yourself less tolerant of your excuses.* […] *It's like 'so, I walked 18,000 steps today, I'm going to now have a fucking Pepsi' - well that would be counter-productive"*. Other participants were similarly more conscious of their food choices after learning how many calories they were burning from their steps and other physical activity. Many of the tracking systems provide an estimate of the number of calories burned – some participants were surprised to find out how few calories they were burning by being active. For example, P24 was surprised how few calories he was burning when swimming, compared to his day-to-day activities: *"the main revelation was the number of calories that swimming takes compared to just walking around"*.

Other participants changed their diet and physical activity in a more conscious and determined manner. For example, P7 explained that her main interest in using her Fitbit was to find out *"what does it mean in terms of how much more food I can eat"*. Resultingly, she combined the calorie data provided by her Fitbit with her knowledge of calories in food to help determine her diet, to maintain her weight: *"I love food and I love cooking, I love baking but I'm very restricted because that obviously means putting on weight and that's what we don't want to do - we want to have a healthy lifestyle and not be prone to getting heart disease or anything like that, so that's my ultimate goal... to make myself as healthy as possible"*. Other participants were keener to lose, rather than maintain, their weight, and attempted to create a calorie deficit by controlling portion size or eating more healthily. For example, P6 who was keen to lose weight after she met her exercise goal (to run 10km), was careful to create a calorie deficit: *"every day I know very accurately how much stuff I've already done and how much stuff I've used up and how much I'm likely to use that day so <u>it's made managing the process of losing weight really easy</u>"* (underlining our emphasis).

6.2.2.2.2 Giving up smoking

Perhaps the most significant lifestyle change we witnessed was from the two participants (P13 and P40) who gave up smoking. Both these participants related this change to use of their tracker in some way. For example, P13 claimed that she had a heightened awareness of her health as a result of regularly checking her Fitbit, which encouraged her to stop smoking: *"what happened is that I was checking my activity more often, so I was measuring that, and that* [smoking] *was in the foreground".* However, once she stopped checking her activity she returned to smoking – soon after completing the main study she stopped using the device and sold it on eBay. During the follow-up interview, she explained, *"as time went by without the Fitbit and without the conscious effort it became a... I lost the target perhaps a little bit* […] *this activity of measuring myself and measuring my effort went to the background. By just talking to you I realised that most likely this was the reason why my goals were loosened a little bit. They went to the background. One of the goals was not smoking. As it went to the background and loosened a little bit I started smoking a bit, as a social smoker"*.

Similarly P40, who made many large changes during the study but did not have any particular health or wellness goals in mind when she started tracking, also attributed her decision to stop smoking to use of the Fitbit. Soon after she started tracking she became more aware of her physical activity and started to make changes. Firstly, she began to avoid public transport for shorter journeys, choosing to walk instead. Then, after just two days of using the tracker she broke a 24-year addiction (she had been a smoker since she was 13): "*I thought about my health, about the movement I get every day, and I realised that I can't breathe very well because I was a smoker for a long time* […] *I quit smoking* *the cigarettes".* This sudden decision to stop smoking might be considered an epiphany in that it was a sudden realisation but was caused by a process of reflection on her overall health, resulting from her interaction with the activity tracker. P40's story is particularly interesting, as within two-weeks of starting the study, the battery in her tracker ran out and the device stopped working. However, despite this she continued her journey, and carrying the device, explaining: *"sometimes I keep it in my hand… instead of using the cigarette. The smoker needs to keep something in their hands, I use the Fitbit instead of the cigarette"*. In the final interview of the main part of the study she explained that she was again reflecting on her health and lifestyle, telling us: *"Fitbit helps me to really think about my health, and I realised that I don't do enough movement"*, she then explained that earlier that day she had been for a run for the first time in years, having decided she was now ready to change another aspect of her life. Over 6-months later, in the follow-up interview, she happily informed us that she had not returned to smoking, *"I didn't retake cigarettes at all - no cigarettes at all"*, that she had continued running, as well as joining a gym and purchasing a bicycle. Throughout this journey she continued to carry her non-functioning Fitbit, which she had named *"Chicco"*. Eventually, she gave *Chicco* up for *"adoption"* to a friend who she thought would benefit from it.

These sections have provided examples of the behavioural changes that our participants made to non-tracked activities, along with illustrating the processes and stages they went through during their self-tracking tracking journey to reach these responses. For the most part the outcomes presented in this section are neither a final endpoint nor a unilateral transition (i.e. our participants cycled through various responses, they are non-exclusive and not ordinal). Some of the activities or behaviours that participants reported taking up or changing, were recorded by their trackers to some extent, but perhaps of more interest are those changes that participants made which were not recorded by their tracker. Rather than encouraging participants to change a behaviour that was being directly recorded by the device, the process of tracking one part of their lives encouraged a change in a different part. Some participants reported gaining something meaningful through their interactions with the device, however long or short, and then stopped using it once it had served its purpose, whereas others continued to track for a longer duration, or adapted their tracking to the activities they were interested in.

6.3 Summary and discussion

This chapter has presented the range of responses to tracking our participants had during their self-tracking journey, including both affective and behavioural responses to tracking. Importantly, we found these responses did not only relate to the tracked activity itself (i.e. steps), but also to other health and lifestyle related behaviours, such as other physical activities, diet and even smoking.

Furthermore, responses did not always occur during the period that participants were actively tracking, instead happening after participants had *stopped* tracking, though importantly they still in some way attributed these changes to their use of the tracker. Also of note, further characterising the non-linear self-tracking journey, responses can happen concurrently and independently from one another, they are ever changing, and are often related to external and situated factors. This points towards a much more complicated model of use of personal informatics technologies than is proposed in existing models.

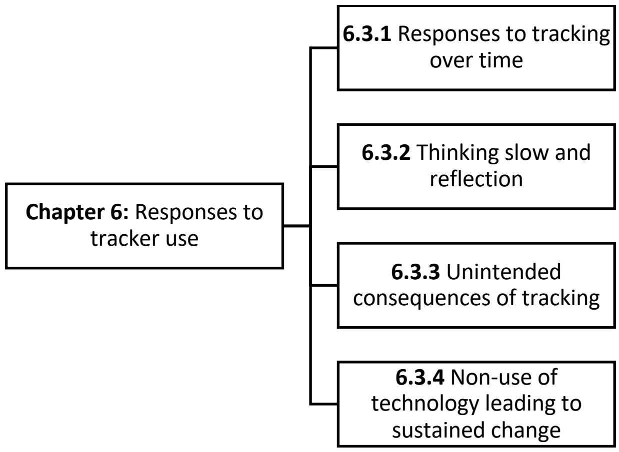

Figure 6.4 – Chapter 6 discussion outline

The primary contribution presented in this chapter discussion (outlined in Figure 6.4) is an in-depth categorisation of responses to tracking over time, including both affective and behavioural responses – extending our existing understanding of the responses to use of personal informatics systems. Chapter 4 presented a categorisation of our participants' *initial* responses to use of their tracking technologies, unsurprisingly finding that the most frequent response was to increase the number of steps they took. However, as we have described in this chapter, over time many trackers go on to change their behaviour in a range of different ways. As a result of our broad and longitudinal approach, we further define the responses from tracking personal data, providing a deeper understanding of the affective responses and behavioural changes they made, along with the journeys that our participants made along the way. The differences between the responses presented in chapter 4 and those presented in this chapter highlight the importance of undertaking longer-term research, especially with behavioural change systems, as initial responses will generally differ from those over a longer-term. Beyond our characterisation of responses over time, we: delve into the processes behind these responses, detailing how our research confirms and extends existing research into how people make sense of, reflect on, and create insights from, their tracked data; we unpack and describe unintended consequences from our participant's use of their tracking technologies, both positive and negative; and finally, challenge the assumption of the importance of longer-term use, showing that shorter-term use *can* result in sustained changes in behaviour.

6.3.1 Responses to tracking over time

The work presented in this chapter builds significantly on the initial responses to tracking described in section 4.5, which presented the behavioural (increased steps) and affective (positive or negative) responses that our participants made when first using their tracking systems. A major limitation of the work presented in Chapter 4, and the digital epiphanies work (Cox et al, 2013) this built on, is that these findings only related to participants *initial* responses over a short period of use and is thus not be representative of their responses over a longer-term. The responses presented in this chapter move beyond these limitations to present a more nuanced view of responses to tracker use over time, culminating in the categorisation presented in Figure 6.5, below.

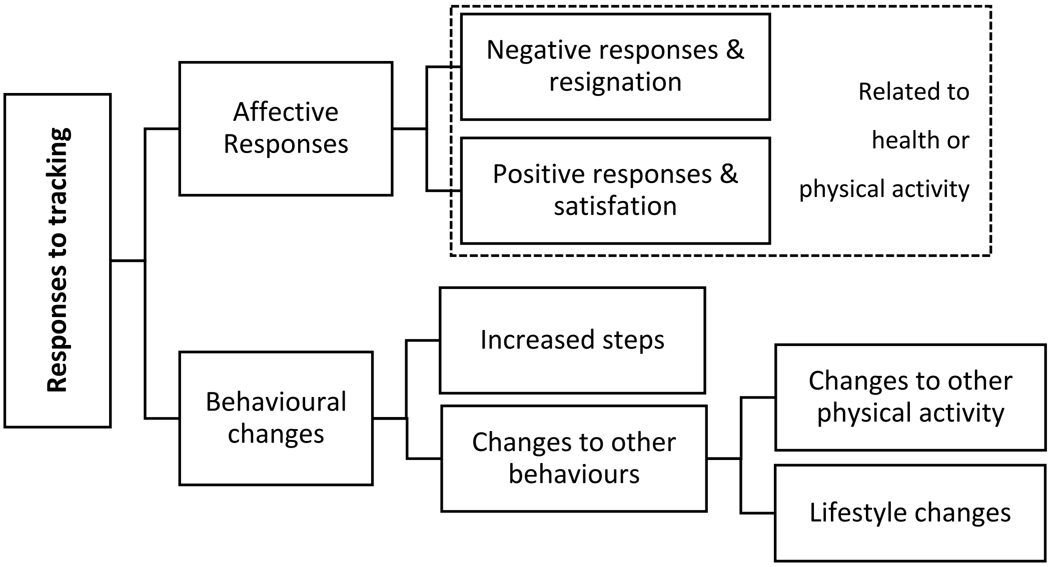

Figure 6.5 – Categorisation of responses to use

At the highest level, similarly to our categorisation in section 4.5, we present affective and behavioural responses to tracking. Similar to participants' initial responses, affective responses may be either positive or negative. However, over time negative responses may lead to resignation, and positive responses may lead to satisfaction. Participants felt *resigned* because they were dissatisfied with an existing behaviour and felt unable to change, or, less commonly, they felt *satisfied* with their existing behaviours and felt no need to change – neither response necessarily resulting in a behavioural change. Whereas when first using their trackers the most common behavioural response that participants made was to *increase steps* (in our case, the tracked behaviour), but this was not always a lasting change. Over time some participants engaged in further reflection and made changes to other physical activities (such as cycling, or swimming), many making attempts to track these other activities (either using additional tracking technologies, or workarounds as outlined in the previous chapter), and some making lasting changes. A small number of participants went further still, making changes to other aspects of their lifestyle, such as changing their diet and even giving up smoking. In terms of health outcomes, these participants made the most profound changes and appeared to benefit most after using their tacking technologies, but only a small proportion of participants achieved these outcomes. In their analysis of Fitbit use, Hermsen et al. (2017) found that having a behaviour-change goal to "stop smoking" significantly decreased a person's likelihood to sustain tracking over time, stating *"The Fitbit tracker does not in itself contribute to the attainment of these goals, which could easily have a demoralizing effect"* (no page number given). In contrast, we found that although the technology does not seem to contribute to the attainment of other goals, that it could play a supporting act.

Almost all our participants fitted into these response categories at least once during the study, and usually moved into different categories over time. This was particularly true of those participants who engaged in a longer process of reflection, who would first respond in one way before changing their responses over time, progressing through multiple categories. The main exception to these responses were those participants who did not engage with the technology, or who were uninterested in the data and appeared to (at least during the period of our studies) find no utility the technology. It is important to note that for some, insights gained from short-term use of the tracking technology were enough to inspire long-term change, whilst other participants would reassess their behaviours after a period of reflection on their collected data. Other times, situational or contextual factors external to the technology and tracked activity nudged participants to further reflect on, or otherwise change their response.

At the beginning of their self-tracking journey participants tended to focus directly on the tracked activity (making changes which were not always aligned with their broader goals). These responses changed over time to include changes to untracked behaviours, including other physical activity and lifestyle changes. The increased awareness of ambulatory activity may, after a process of reflection, encourage changes to other behaviours not recorded by their tracking system, such as strength training, swimming, diet, or giving up smoking. Importantly, these outcomes are not mutually exclusive (i.e. participants often experience psychological and behavioural outcomes simultaneously), different responses can happen concurrently, and they often change over time. For example, a participant might have a *positive affective response* to their tracked behaviour, but rather than *accepting* the behaviour, choose to make a further *change*.

Other existing work of relevance when considering people's use of a personal informatics system over time includes the Lived Informatics Model (Epstein et al., 2015), which builds upon the Stage-Based Model of Personal Informatics Systems (Li et al., 2010), which focuses on the iterative stages of collecting, integrating and reflecting on data, and making "action". Epstein's model builds upon this work by providing a more comprehensive picture of the ways in which people track over time, and how this fits within their broader self-tracking journey. However, these existing models mostly focus on the users' relationships with a single tracking technology and respective data without as much of a focus on the emotional and behavioural responses to tracking over time – reducing these to "action". Instead, we take a broader approach, by not only considering the tracked activity(s), but also considering the affective or emotional responses that participants had, the role these played in their tracking journey. Additionally, because our research was conducted over an extended period, we are better able to characterise the self-tracker's journey along the way, taking into account external influences, behavioural changes and responses beyond the tracked activities. Affective responses to personal informatics use are often little considered in evaluations and models of behaviour, but this is beginning to change as the importance of these factors becomes clearer (e.g. Etkin et al., 2016; Singh et al., 2017). We have not only, included and categorised these affective responses, but have also began to create an understanding of the flow between them and behavioural responses. Recognising and identifying these emotional responses might enable systems to better support nudging users towards more positive responses to use (e.g. Picard and Klein, 2002; Tajadura-Jiménez et al., 2015) – perhaps providing more support at opportune moments, through the use of different BCTs, or by leveraging social support to encourage users to take a different path.

6.3.2 Thinking slow and reflecting (beyond the tracked data)

Although our participants' most typical response was to increase their steps, many also made other behavioural changes – often after a period of reflection on the tracked data, their behaviours, and their goals. As we have noted, most participants had broader behavioural goals beyond "taking more steps", such as to lose weight, or to be healthier, and taking more steps was not always the most appropriate action to aid them meeting their goals. We argue that simply taking more steps as a result of tracking aligns with Kahneman's (2011) "System-1" thinking, in that it is fast and reactive to the data presented to the user, whereas engaging in more reflective practices and making other behavioural changes result in them engaging, "System-2" thinking. As such, encouraging users to be more reflective and engage in System-2 thinking may result in changes which are more befitting to their broader health or wellness goals.

Being more reflective does not only apply to participant's engagement with the tracked data, in fact reflection with the tracked data itself was rare and most participants found engaging with their historically tracked data to be difficult and not fruitful (see section 4.4). Instead, over time many of our participants also reflected on their *experience of tracking*, the *changes they had made* and their *affective responses* within the context of their lives, abilities and broader goals. Rather than engaging with the data, it was this more in-depth reflection that resulted in making changes beyond the tracked activity. For example, a participant with an overall goal to lose weight might initially just take more steps, but then after reflecting on this change instead decide to take up swimming or change their diet. Self-tracking journeys are usually much more complex than this, especially when considering the affective responses to tracking.

For most participants it took some time for them to engage in "deeper" levels of reflection (Fleck and Fitzpatrick, 2010) and type-2 thinking, and many participants did not appear to engage in any reflection, their tracking journey finishing to soon. The outcomes from deeper levels of reflection and engagement with tracking varied considerably between different participants – unsurprising when considering how enmeshed these activities are in their everyday lives and the multitude of other factors which influenced their behaviour. However, many of those who did engage in deeper reflection gained new knowledge, or perhaps even wisdom, and as a result had other responses to their tracker use. Encouraging activity tracker users to reflect on their behaviours and changes could yield positive outcomes (for example, as suggested by Slovak et al. 2017), but careful guidance could also be provided in order to encourage positive and sustainable changes.

6.3.3 Unintended negative consequences

Many of the responses our participants made as a result of engaging with their tracking technologies appeared to have not been intended by the designers or manufacturers of personal informatics systems. These unintended consequences were often positive, such as the positive changes some participants made to other aspects of their lives. Many of these positive changes also extended beyond our participant's use of their tracking technologies, though the benefits and insights that short-term use brought about for our participants was presumably not intended by the manufacturers of these devices, who presumably rely on their customers ongoing use and purchase of their technologies to survive. However, but the creation of healthier habits without reliance upon the scaffolding provided by these technologies was undoubtedly a positive outcome which has been recognised as an issue in other work (e.g. Renfree et al, 2015). However, despite the unintended benefits that some participants derived from use of their trackers, not all unintended consequences are positive. Academic research and popular media alike have recently become concerned about people's search for, and obsession with, perfection in aspects of their lives, particularly when driven by self-tracking tools. Conditions such as "orthorexia" and "orthosomnia" have been the subject of concern and discussion (e.g. Sanchez and Rial, 2005; Baron et al, 2017; Saner, 2019), suggesting the potentially harmful consequences of using these tools. We have observed similar behaviours in our participants, which have led to participants making extreme changes to their behaviour in the search of maximising the number steps they take, at the expense of other parts of their lives.

The findings presented in this chapter have been offered to us from the participants' own perspectives, after a period of their own reflection, rather than our own judgement or viewpoint. We are not health professionals and we do not claim that use of personal informatics tools has led to necessarily negative health outcomes, but we do advocate careful use and design of personal informatics systems and suggest that the potential for these systems to cause harm should be considered when designing them and prescribing or suggesting their use.

Some participants increased the number of steps they were taking at the expense of other physical activities which might be considered more beneficial to their overall health (and in line with the physical activity guidelines outlined in 2.1.4), such as weight-bearing activities. For example, P49 in section 4.5.2.4 changed her gym routine to maximise the number of steps she was tracking, but stopped doing weight-resistance activities, as these were not recorded by her Fitbit. Generally, these responses were uncommon, occurring for only a short period of time when first using the tracker. However, although use of activity-tracking systems did not appear to discourage strength-training activities, by focusing on steps alone they also do nothing to encourage these activities which are essential to everyday wellbeing - strength training activities are recommended for all to maintain physical capabilities and furthermore strength training helps to preserve bone density and reduce the risk of osteoporosis and chronic conditions such as heart disease, arthritis and type-2 diabetes (Seguin and Nelson, 2003). Despite the problems with using steps as the only measure of activity, there are also benefits: steps are generally not considered sensitive information to share with others (as calories burnt or weight might be); they are easy to understand and compare between others; and finally, 10,000 steps is an easy to remember and conceptualize goal (Sullivan and Lachman, 2016; Kersten-van Dijk et al., 2017). Additionally, from a behaviour-change point of view, the more specific goal of "reach 10,000 steps a day" is more likely to be achieved than a less well defined goal such as "be more active" (see section 2.5.4). Nonetheless, it is important that we remain aware of general physical activity recommendations and ensure that behaviour change interventions target not only cardiovascular activity, but also resistance-training activities, which may be more difficult for current technologies to reliably track.

Other participants appeared to become obsessed with the tracking technologies, in particular making attempts to record as many steps as possible at the expense of aspects of their lives. This could perhaps fuel other issues such as overtraining, compulsive exercise, or "exercise addiction" (according to the definition proposed by the US-based National Eating Disorders Association, 2018) and associated negative consequences. Some participants admitted that they had started to become obsessed with taking as many steps as possible the tracked activity would go to extreme lengths to record as many steps as possible each day. Whilst this might not immediately seem to be a negative consequence of using the technology, some participants admitted that things were beginning to 'take over' and their obsession with taking as many steps as possible was starting to affect other parts of their life in a negative way, such as causing them to lie to their colleagues and take time out of work to walk to meetings when they should have been working. Other participants stopped tracking having not changed their behaviour, but having had a negative affective response to use of their tracker – perhaps leaving them feeling more negative and demotivated than before. Future research should further consider methods of supporting users of personal informatics technologies to move beyond negative affective responses and explore other options to achieve successful behaviour change. Users who fall into this journey could be better supported to have more positive outcomes, such as suggestions for alternative healthy changes to their behaviour.

6.3.4 Non-use of technology leading to sustained change

One of the key findings from this chapter, and resulting from our longitudinal approach, is that continued long-term use of the tracking technology was not always important for a continued change in behaviour. Indeed, many participants who made significant transformative changes to their lives did so with minimal assistance or use from the technology. For example, P40 went from being fairly inactive, relying on public transport to move around London and doing no planned physical activity, to mostly using active transport, running and cycling for leisure and giving up smoking, whilst using a tracker which was not functional in terms of tracking her steps for much of her tracking journey, though she did get other utility from using the device as a symbol of her new healthy behaviours. Others also made, and maintained, significant changes after stopping tracking, providing further support to suggest that meaningful changes can continue beyond use of the tracker. One could argue that these changes happened because of observer effects, driven by the requirement to meet the researcher as part of the study. However, many participants made changes after the main part of the study, at which point observer effects should be lessened as they were not in the study at this time and were unaware that we would be contacting them for the follow-up interviews (although the consent forms did provide a statement saying that we would retain their contact details for further studies).

Popular media often characterises the “abandonment” of activity trackers after only a short period of use as a “failure”, and in the previous chapter we characterised some of the many barriers to continued engagement that our participants faced – all of which add up to an often-negative portrayal of these devices. However, as we have seen from multiple examples in this chapter, continued long-term use is not always necessary for meaningful interactions. Furthermore, a short-term but meaningful interaction can result in long-term meaningful changes in behaviour and attitude. This is not to lessen the sustainability challenges surrounding poor reliability and early abandonment of technology devices, as highlighted by P47 in section 5.1.3 and discussed by Vaajakari (2018), but instead suggests that alternate models of use and ownership could instead be explored. These findings also point towards the importance of taking a broad and longitudinal approach when evaluating health behaviour change technologies and interventions, along with the importance of continuing to follow-up with participants once they have “dropped out” of an intervention, which may still have an ongoing effect. Also of importance when evaluating these consumer technologies and interventions is to consider the unintended consequences of use – both positive and negative.

This chapter concludes our presentation of the self-trackers journey, although this of course does not signify the end of the self-trackers journey. In the discussion we bring together all aspects of the self-tracking journey. Concluding with recommendations for future research and the direction of self-tracking and health behavioural technologies.

Chapter 7. Discussion

The previous chapters have described how a self-tracker's journey unfolds over time and in different situations. These findings are based on two studies: the first, a longitudinal mixed-method study that involved 50 participants located in London who tracked their steps using a Fitbit Zip, took part in regular interviews and completed a diary over the course of 28-weeks, and then a follow-up interview at least 24-weeks later; and the second study compared 24 participants from Atlanta and 24 from London in their current and previous use and non-use of various activity tracking technologies.

At the outset of this thesis we set out to explore **how do healthy adults use and experience activity trackers over time and in different situations? (Overall Research Question).** We presented our findings to this question in a hypothetical self-tracker's journey, which started in *Chapter 4* where motivations, choice of technology and initial responses to tracking are discussed (**Research Objective 1: updating the current understanding of how healthy adults initially engage with activity-trackers**). *Chapter 5* then focuses on the relationship that participants had with their various activity tracking technologies. This ranged from the phases of tracking, to how features of the devices (e.g. sharing, goal setting, gamified elements) influenced behaviours, particularly when they created barriers and afforded workarounds, through to how individual and contextual factors affect use and non-use (**RO2: exploring how healthy adults use, and not use, trackers over time and the factors that impact this)**. Finally, *Chapter 6* discusses the behavioural and affective responses that can occur during a self-tracker's journey, both in terms of positive and negative changes. It is important to emphasise how these responses do not necessarily come at the end of a journey, but rather can occur at any point (**RO3: categorising how healthy adults change their behaviour or attitudes, as a result of using tracking technologies**). To maintain the metaphor of a self-tracker's journey, affective and behavioural responses can represent turns and paths that users can take at any point during their journey and how these make them feel. Although we have characterised these thematic findings as a journey, with responses to tracker use at the end, we note that self-trackers do not generally follow a chronological journey, and that responses to use do not come at the "end" of this journey. Indeed, responses do not necessarily even stop when they stop tracking, but instead the effects of tracking, even for a short-time, can influence a person beyond the point they have ceased tracking.

This research has provided considerable understanding regarding how healthy adults use and do not use activity trackers over time and in different situations. In some cases, participants have made significant changes to their behaviour and sustained them over time, alongside use of the technology. In other cases, participants stopped using their tracking technology shortly after starting, yet were still able to sustain longer-term changes. However, while most changes were positive and affected not just the number of steps taken but also other healthy behaviours, some changes highlighted the harmful effects that activity tracking technologies might have. Therefore, it is important to understand how such systems might be used as part of a users' identity and overall health and wellbeing. As such, our findings have important implications for how activity tracking technologies should be designed and studied.

This chapter presents our contributions in three areas: contributions to knowledge, where we discuss our empirical findings in relation to other existing work on self-tracking technologies; implications for design, where we apply our findings to reflect on the design of current personal tracking systems and present suggestions for how these systems could better support users tracking over time, while avoiding potentially negative consequences; and finally, implications for studying these systems based on our findings, which point towards the importance of considering context of use, use over time, and impacts beyond use of these technologies and engagement with data per se. Throughout, we discuss our findings and experiences in relation to the research question stated in the introduction and existing work, and also discuss the design and methodological insights gained as a result of this research.

7.1 Contributions to knowledge

At the outset of this thesis we aimed to answer the following overall research question:

> **How do healthy adults use and experience activity trackers over time and in different situations?**

To do so, we studied how a large cohort (98) of new and existing activity-trackers used these technologies in the real world, over time and in different situations. Rather than taking a focused approach, whereby we only looked at their interactions with their activity-tracking technology and the targeted behaviour (i.e. steps), we took a broader approach to understand how their use and non-use of their activity tracking technologies was enmeshed with other aspects of their lives, other technologies, and other activities. This enabled us to build up the rich-picture of personal informatics system use, non-use and resulting behavioural and affective responses that we have presented in this thesis. Within each of the previous three chapters we have discussed a number of contributions that have allowed us to build this nuanced understanding. In this section, we bring together our findings and new insights to discuss how they generate contributions to knowledge.

At the outset of this thesis (2012) there was relatively little research on the real-world use of activity-tracking personal informatics systems, with seminal works such as *Houston* and *The Ubifit Garden* (Consolvo et al. 2006, 2008) being obvious examples based on relatively short-term evaluations of prototype systems, and Li et al.'s (2010) work on a broader range of early-adopters of personal informatics systems. Rather than considering the lived experience of users integrating these technologies into their everyday lives, these works instead focused on creating and evaluating prototype systems, or focused on early adopters of a variety of different personal informatics solutions. Since 2012, being a novel and topical application of technology, there have been many publications across multiple academic fields looking towards longer-term, in the wild use of these technologies, and the lived experience of them. However, despite the considerable work undertaken over the last five years, much of it has taken a narrow and short-term approach, allowing the in-depth longitudinal approach we took to glean novel insights. Furthermore, because we took a broad and in-depth qualitative approach and where possible, continued to speak to participants even after they had stopped using their tracking technologies, we were able to produce a much richer picture of their relationship to the technology and their lifestyles.

Therefore, in this thesis we make two contribution to knowledge that extend the current understanding of people's engagement over time with personal informatics systems.

> *Firstly*, our work shows how **(a) the temporal and periodic nature of tracking over time does not go hand-in-hand with users' responses to tracking.** This comes as a result of having built in Chapters 4, 5 and 6 a more nuanced understanding of people's *engagement with personal informatics systems over time* through our classification of phases of tracking, along with a more complete understanding of user' *responses to personal informatics use*, that includes changes beyond the targeted, or tracked, activity. Situating these contributions within the context of other longitudinal research in self-tracking, we point towards ways to better support users in having meaningful interactions.
>
> *Secondly*, we recognise that not all responses to tracking are positive and discuss the **(b) unintended and potentially harmful outcomes from use of self-tracking systems,** which we characterise as *harmful informatics.* We have observed these potentially harmful consequences of self-tracking technology across our cohort of participants and present concerns in two areas: harmful interactions with the tracking systems themselves, such as

dependency and obsession, and the negative and potentially harmful behavioural changes that some users make as a result of tracking, in our examples through *too strong of a focus on steps at the expense of other physical activity* and *overtraining*. We discuss these concerns and potential negative consequences, and opportunities for self-tracking systems to better support positive outcomes.

7.1.1 Use of tracking technologies over time is not necessarily aligned with outcomes

Each self-tracking journey is unique, starting with the very first tracked step and sometimes continuing until long after the protagonist has stopped tracking. In characterising the self-tracker's journey throughout this thesis, we have presented the stages of use, detailed various factors that influence engagement, and outlined responses to use over time – not only related to the tracked activity, but also including affective responses and changes to other behaviours. Crucially, the self-tracker's journey is not limited to the period of tracking, but can instead continue long beyond this, as the user's interactions and the insights they gain may have continuing impacts. Our first contribution to knowledge shows how **the temporal and periodic nature of tracking over time does not go hand-in-hand with users' responses to tracking** and as such, opposing popular knowledge, even short-term use of activity-tracking technologies can lead to sustained changes over time. That is to say, **short-term use can still lead to sustained changes over time** and thus the technology can be considered successful in helping a user achieve their goal even if it is abandoned after a short while. We build and present this argument by combining two contributions presented earlier in the thesis: our characterisation of the *temporal nature of people's use of their tracking technologies over time*; and, our creation of *a better understanding of user's behavioural and affective responses to tracker use over time.* Bringing these contributions together and situating them within the context of other longitudinal research in self-tracking, **our work points towards alternate models of ownership and use that could better support users in having meaningful interactions while avoiding the sustainability issues surrounding abandonment and short-term use of technologies**.

Studies over the past five to ten years have focused on in the wild evaluations of self-tracking systems and as a result our knowledge of how people use these technologies temporally (Epstein et al., 2015; Gouveia et al., 2015), or episodically (Gorm and Shklovski, 2019), over time has increased, including our own phases of tracking presented and discussed in section 5.5.1. Previously, temporal and short-term use of these devices was widely criticised and characterised as a failure of the technology to sustain user's engagement over time (e.g. Arthur, 2014; Lazar et al., 2015) and the barriers to continued engagement were often examined and characterised in the literature, accompanied by design recommendations intended to aid sustained use (e.g. Clawson et al., 2015;

Yang et al., 2015), and again in our own research (Harrison et al., 2015; section 5.5.4). However, as the current understanding of real world use has progressed, some research, including our own, has begun to turn a corner whereby we have moved beyond encouraging continued use, to a situation where we are more accepting and encouraging of temporal and episodic use of these technologies (e.g. Epstein et al., 2016; Lomborg, Thylstrup and Schwartz, 2018). Thus, "short-term" use should not always be considered negatively, yet, early abandonment of these technologies might still be considered as failure from some points of view, such as when considering sustainability (e.g. Vaajakari, 2018) and likely from device manufactures who are reliant on devices sales and use for income. As such, embracing short-term or alternate models of use may be challenging from the perspective of device and service providers.

If temporal use of self-tracking technologies is normal, and does *not* represent failure, what use and benefit *do* users derive from these systems? As we have shown throughout this thesis, an "improvement" or increase in the tracked activity is not the only outcome users may see from tracking. In Chapter 6 we showed that self-trackers can derive benefit and respond to tracking in many different ways, including both positive and negative changes to the targeted behaviour, and other behaviours besides, along with affective responses to use. In section 6.3.1 we illustrated how users often transfer between different responses concurrently, and over time. Initial responses, discussed in Chapter 4, were often limited to step-based activities, but as users better aligned their behaviours with their health and wellbeing goals, other behavioural changes resulted. Users' health and wellness goals are ever-changing, and self-tracking tools have the potential to support users in having "meaningful" interactions that support these goals (Niess and Wozniak, 2018). To do so, it is essential to consider goals *within* the context of tracking over time, but the existing literature focused on temporal use and the lived experience does little to consider how tracking actually affects one's behaviour, and thus taking a limited view on what a meaningful interaction might be. When responses to use are considered, they are often either presented with an overly simplistic view (such as the "action" stage in Li et al.'s (2010) informatics model), or only consider changes to the targeted behaviour, as in the case of evaluations of efficacy and studies that mostly use quantitative data (e.g. Hermsen et al., 2017). Many of these works lack an understanding of the mechanisms behind change, changes that occur outside use of tracking systems, and finally changes beyond the tracked activity. Our classification of responses stands independently from existing models of use but enriches them by explaining how temporal use can affect behaviour, and how even if abandoned, the experience of having used a tracker can still result in a positive and sustained outcome.

Importantly, as discussed in section 6.3.4, our results show that responses to tracking do not necessarily mark the *end* of the self-tracker's journey and can occur at any point – even after a short period of use. Furthermore, people make long-term changes as a result of insights gained through shorter-term interactions with the technology and so-called "abandonment" of tracking technologies does not necessarily represent failure. By continuing to engage with our longitudinal study participants beyond the period they were tracking, we saw how the relationship between their use of the technology and changes to their attitudes and behaviours were not always directly aligned. Cox et al. (2013) began to characterise different outcomes in their study as digital epiphanies, and compared to other longitudinal approaches such as RCTs, they qualify outcomes in relation to the lived experience. However, their work is based on a short study and offers a simplistic characterisation. Bringing together our knowledge of the stages of tracking over time, with responses to tracking, we further extend our existing understanding, illustrating how **short-term use can lead to sustained changes in activity**, and moving beyond efficacy evaluations, how changes can happen beyond the targeted and tracked activity, to other behaviours, even beyond the period of use. Together, these findings point towards a much more complex model of use and outcomes of self-tracking system use than previously described, bringing behavioural outcomes together with technology engagement and illustrating how these do not go hand-in-hand, but that they do impact one another.

Many current self-tracking technologies are designed with behaviour-change in mind (e.g. Lin et al., 2006; Crane et al., 2018), along with the assumption that continuous use brings effective changes to behaviour. However, we have demonstrated in numerous instances in this thesis how these tools are not continually used, due to barriers and contextual factors. We have also shown how sustained change can occur after even a short-term use. A consequence of our first contribution to knowledge is that the design of personal informatics system should be reconsidered to act more as a "crutch" to be used when needed and then discarded when unnecessary and that this should not be seen as a limitation, but rather a strength of the technology. We further discuss how temporal use could be embraced by technology designers in section 7.2.1, as part of our implications for design. Future work should create a better understanding of how tracking technologies can be used to support users in meeting their goals, by considering how to promote meaningful interactions, the relationships between people's goals, their tracking behaviours and phases, and their behavioural outcomes. To this end, some technology companies are only very recently beginning to move away from a hardware-sales focus, to using subscription-based models providing users with additional utility. For example, in August 2019 Fitbit's CEO James Park explained they were *"transforming"* their business away from an *"episodic device sales"* model, towards paid premium services, such as coaching and in-depth analysis (dcrainmaker.com, 2019). These changes in business practice could be indicative of new models of ownership, perhaps leading to a self-tracking market where users rent, or hire, technology for a particular use, and then return it for another person to use once it has reached the end of its useful life for them.

7.1.2 Unintended and potentially harmful outcomes from use of self-tracking systems

In this thesis we have also presented the broad and eclectic engagements our participants had with their tracking systems over time, which sometimes resulted in interactions and responses that appeared to be unexpected by the device manufacturers, and even the users themselves. Some of these practices were positive, including changes to behaviours not-targeted by the tracking systems, such as those participants who took up swimming, or changed their diet in response to tracking their steps. Whilst these positive outcomes, which align with the healthy images that self-tracking companies use to promote their goods, are interesting and important to consider, **we also found unexpected engagements that were less positive**. Our second contribution to knowledge is the characterisation of these negative uses, which fall into two groups: **negative interactions with the tracker** or tracking technologies themselves; and **unintended negative behavioural outcomes to tracking**. Together, we refer to these negative, and potentially even harmful, interactions with personal-tracking systems as *harmful-informatics*.

In the first instance, negative experience can be related to people’s use of tracking technologies themselves. This means that users might develop a *dependency* or *overreliance* on trackers when attempting to change a behaviour. In turn, this may lead to an *obsession* with tracking and using the tracker. We started to unpack these negative interactions in section 5.5.3, where we discussed our participants’ dependency on their trackers. It is important to clarify that these negative characterisations have little been discussed in personal informatics literature, where most styles and types of tracking have related to those discussed by Rooksby et al. (2014) and Lupton (2016). Rooksby et al. do mention “fetished trackers” as one of the styles, which could be interpreted as someone obsessing over the device and the data, but instead takes on a positive connotation of users finding their trackers “cool”. We are not claiming that all self-trackers might experience such negative interactions, but our characterisation highlights negative implications that might derive from use. Similar findings have been found in the context of personal informatics and food tracking. For example, Jakicic et al. (2016) concluded that use of activity tracking technologies focused on weight loss could actually have an adverse effect – with users gaining more weight – because of their over-reliance on the technology. Similarly, Cordeiro et al. (2015) found that food journaling could lead to obsession, especially in relation to eating disorders, and Simpson and Mazzeo (2017) found an association between using calorie and fitness trackers and eating disorder symptomatology. However, although these negative interactions are beginning to receive more attention, discussions around harmful effects have not yet been extended to other tracked activities, beyond what we have discussed in this thesis.

Further to the negative interactions directly related to user's engagements with their trackers, and perhaps of more concern, are the potentially negative behavioural outcomes that some participants made as a result of tracking. For example, in Chapter 4 we discussed how, when first using their activity tracking systems, many participants changed their behaviour by compulsively taking more steps, sometimes at the expense of other activities which may have been more beneficial. This response to the tracked data is unsurprising, given the strong focus that most tracking systems have on using steps as a way of recording physical activity. In our sample these responses were usually short-lived, as participants aligned their behavioural changes to their broader goals and still increased their steps, but not at the expense of other physical activity, or to a level that caused them any undue harm. However, this was not always the case and some of those who were highly engaged, or perhaps *obsessed* with using their activity tracking technologies, made attempts to maximise tracked steps in their daily life to the point that other parts of their life were affected, including other physical activity and their social lives.

It is interesting to note that the *positive unintended consequences* described in the previous section, and the *negative or harmful consequences* described here, are two sides of the same coin. Whereas those who made changes beyond the targeted activity moved their focus beyond the tracked data to instead think about their broader health and wellness, perhaps owing to a general increased self-awareness because of tracking their steps, those who increased their steps at the expense of other activities instead appeared to focus too-strongly on the tracker, the tracked data, and the tracked activity. This draws parallels with recent work by Mencarini et al. (2019), who presented a comparison of elite and amateur athletes use of sports-tracking technologies, finding that elite athletes used the data to support their own experience of training, whereas amateur athletes instead tended to focus more on the data itself, so reliability of this was more of an issue. Our sample did not include any elite athletes, but many of our participants moved beyond focusing on the tracked data, which resulted in an increased self-awareness and the unintended outcomes as discussed in the previous section. In other health-related fields besides HCI, the study of harm and harmful outcomes has received much more attention, especially in psychotherapy and pharmacotherapy and we argue that unintended outcomes should also receive more attemtion in HCI. The benefits of physical exercise are well studied, as we know how exercise can reduce mortality and prevent chronic conditions (Garber et al., 2011). Yet, the role that technology plays in exacerbating negative behavioural outcomes is far less understood. Focusing on the tracked data alone can result in users not aligning their activities with their broader goals and may also be harmful. Therefore, we argue that self-tracking systems should encourage users to think more broadly, and not just focus on the tracked activity. Our work here has highlighted some of the risks and future work should continue to explore this space.

Our findings provide further evidence that encouraging *constant* use and engagement of personal informatics tools might actually be counterproductive. Our participants were all relatively healthy and did not, to the best of our knowledge, present any health conditions. Yet, by using activity tracking systems, some of them developed some borderline harmful behaviours that in the long run could be *detrimental* for their physical health, such as replacing any strength training with just cardio exercises because that is what the tracker tracks. Therefore, rather than suggesting that steps, for example, is the wrong measure and advocating for a more holistic measure (as previous research has done), we instead suggest that personal informatics systems should encourage users to reflect on their behaviours and life, and not the data alone. We provide recommendations for how this could be implemented in section 7.2.2.

7.2 Implications for design

From our understanding of people's real-world use of tracking technologies and the contributions presented in the previous section, we now present implications for the design of activity tracking, and personal informatics systems, and how these might apply to other behavioural change systems. These implications are in three main areas: **(a) embracing temporal use and ecologies of tracking systems**, whereby users can easily use and engage with different ecologies of tracking systems over time; **(b) supporting users in having meaningful interactions with their data**, by supporting the processes users go through to make sense of their data and produce insights from it, whilst avoiding adverse unintended outcomes; and **(c) considering the salience and physicality of tracking systems and data**, considering the presentation of data and form of trackers, from dedicated tracking devices to multifunction wearables (smartwatches) and smartphone applications.

We would like to point out that this section is intentionally characterised as *implications* for design, rather than *recommendations* for design. We do so because our work was not focused on understanding how activity tracking systems could be better designed, but rather focused on how users engaged with these systems and what factors affected their use. Therefore, it makes sense to talk about how our findings inform what to consider when designing these systems, as opposed to make more specific recommendations of how to, for example, visualise data or display certain features. Future work should focus on developing and evaluating designs which fit within these implications to provide more specific design recommendations.

7.2.1 Embrace temporal use and ecologies of tracking systems

Throughout our work we have illustrated how people's use of tracking systems is complex, temporal, and sometimes challenging to integrate into their daily lives. As illustrated by the phases of tracking over time presented in section 5.5.1, it is clear that users' patterns of interactions with personal informatics systems are complex and involve periods of intentional, and unintentional, non-use. Furthermore, users also swap and combine different ecologies of tracking systems, measuring different behavioural traits depending on their interests, needs, and changing goals (see section 5.4.1.1). However, **despite the considerable evidence pointing towards temporal use, current tracking systems are not designed with this in mind** and are instead tailored towards users consistently tracking with one system over time. Whereas various projects and efforts by commercial organisations aim towards encouraging more consistent adherence to tracking over time (e.g. Gulotta et al., 2016; Kang et al., 2017; Klebbe et al., 2019) we instead advocate that designers instead *embrace* temporal or *episodic* (Gorm and Shklovski, 2019) use. As we have discussed in sections 6.3.1 and 7.1.1, many users gain valuable insights from tracking temporally, or for a short amount of time, and use their tracking technologies as a "crutch", returning to use them when needed. Beyond the challenges that inconsistent tracking brings when users engage with embedded functionalities such as goal setting and social competitions (both of which typically total, or average, the number of steps a user has taken in a given time period), users also face barriers when attempting to bring data from different tracking systems together and accessing and viewing historically tracked data, both of which may be useful for supporting behavioural change.

Many systems offer ways for users to share tracked data across platforms, allowing them to bring multiple data sources together. This is useful for those who track multiple personal traits, for example enabling a *Fitbit* user to connect to their *MyFitnessPal* account in order to see the number of calories they have consumed alongside those they have burnt, to look for relationships and reflect on the data together. Although this *is* possible with many systems, as illustrated in sections 4.1.1.2 and 5.3.3.3, difficulties began to arise with systems that do not easily allow this interoperability when users attempt to link multiple platforms, or when they swap from one platform to another. Reflecting on, and attempting to make sense of, different data points when spread across different applications and platforms, with different visualisations and time-frames, results in a challenging task for users which they are unlikely to undertake. Allowing users to enmesh their own personal data, tracked from their multiple systems, allows them to better understand themselves and meet their goals, and should be easily supported by tracking systems.

Although some platforms *do* allow users to share their tracked data with other platforms, it is generally *not* possible for users to import historically tracked data from one platform into another – often this data is effectively siloed into different platforms. As we presented in section 4.4.3, it was notable that most of our participants rarely looked at their historically tracked data, instead focusing on more recent data. As such, many self-trackers have been unconcerned about maintaining a complete record of their historical data, because they see little value in it – likely driven by difficulties in making sense of it. However, there is potentially interesting or useful information embedded within this historically tracked data and as systems better support users in making sense of, and finding insights in, historically tracked data users will likely find it more valuable. More independent cross-platform tools such as *Tictrac*[22] and *Apple Health*[23] could potentially allow users to feel less tied to a single platform. These systems aggregate tracked data from multiple platforms, enabling users to bring together multiple sources of similar and different tracked data. However, they do not offer embedded behaviour change techniques and other functionalities to help engage and motivate users. Furthermore, multiple closures of such platforms cause us to question the motivations of those running these platforms, along with their sustainability. For example, Microsoft's HealthVault, which was billed as a *"trusted place for people to gather, store, use, and share health information online"*[24], failed to become the success many had imagined it might be and is set to be shuttered in November 2019. Similar work bringing disparate sources of tracked data together into an independent platform has been undertaken in academia. For example, Bentley et al.'s (2012) work on the Health Mashups system aimed to present users with insights from multiple sources of tracked personal data, but similar systems have not gained traction commercially. This is perhaps because encouraging more open platforms allowing easy transfer of personal data is incongruent with the business practices of these platforms, which benefit from data exclusivity and encouraging users to continue using the same system. One famous example of this is Fitbit's refusal to allow users to easily share their recorded data with Apple's HealthKit system – despite encouragement from users to do so. Soon after Apple removed Fitbit's products from sale in their stores.

[22] https://tictrac.com
[23] https://www.apple.com/uk/ios/health/
[24] https://international.healthvault.com/gb/en, accessed 14/08/2019

7.2.2 Support users in having meaningful interactions with their data

Even when users have access to their historically tracked data and have succeeded in bringing multiple data points together in a comprehensible manner, **they often struggle to make sense of their data, gain actionable insights from it, and make sensible changes**. As we discussed in section 7.1.2, some users even make potentially harmful changes to their behaviour as a result of engaging with their tracking systems. However, we argue that tracking platforms themselves provide an opportunity to support users in making sense of their data and create implementation intentions that support their health and wellbeing goals, all whilst steering them away from making potentially harmful changes. Rather than acting on raw data itself (for example, the number of steps taken each day, or the number of calories burnt), users instead gain greater utility from the information, knowledge, and insights created from this data. Sensemaking literature (e.g. Faisal, Blandford and Potts, 2013) and "data wisdom models" such as the DIKW pyramid (Data, Information, Knowledge, Wisdom - Ackoff, 1999) focus on the challenges with the interpretation of, and the creation of insights or wisdom from data – providing consensus on the difficulty in this process. Whereas acting on the data alone will likely result in users only changing the tracked activity, creating insights from this data will more likely support users in making more meaningful changes that support their broader health and wellness goals (as discussed in section 6.3.2). Insights could either come about from: users themselves engaging in deeper reflection and going through a sensemaking process; by the tracking systems supporting and guiding this process; through machine learning and artificial intelligence systems presenting the user with actionable insights through analysing their data; or, through more traditional methods such as coaching or teaching.

Opportunities exist for tracking systems to encourage users to make better use of their historically tracked data. Most of our participants rarely, if ever, looked at their historically tracked data, struggling to make sense of it, particularly when engaging with the visualisations presented to them on their small-screen mobile devices. Confirming the literature, this was exacerbated if they attempted to bring multiple data sources together – which they were inclined to do when targeting a particular behavioural change, for example losing weight. Supporting this, Li et al. (2010) found that self-trackers attempt to better understand themselves by tracking more personal metrics, a trend that continues today as self-trackers and wearable devices themselves track more and more physiological traits, such as heart rate, heart-rate variability, along with more ambiguous aggregate measures such as FirstBeat and Garmin's *Body Battery* metric[25]. One could imagine that more data

[25] https://www.firstbeat.com/en/news/garmin-vivosmart-4-introduces-body-battery-powered-by-firstbeat-analytics/

would result in users creating better insights, but the challenges of making sense of data only increase when considering multivariate analysis (Polack et al., 2017). Here, users can experience difficulties considering multiple independent tracked data points, the potential relationships between these and the temporal aspects of this data, resulting in incorrect interpretations.

A potential solution to the challenges of personal-data sensemaking is for tracking systems and platforms to aid users in the process, helping them discover insights from their tracked data, related to their broader situation and context, including their health or wellness goals. This could either be achieved in a light-weight way, encouraging reflection and guiding users through the process by displaying and bringing together data points into visualisations, but still relying on users creating the insights and deciding on action. Alternatively, systems could take a step further and use artificial intelligence (AI) and machine learning (ML) to suggest insights from tracked data. Either approach should encourage meaningful insights that support users' in meeting their health and wellness goals, fit within the broader context of their lives and also take physical activity recommendations into account (as presented in section 2.1.4). Some systems already offer tailored behavioural goals, but these usually focus on specific behaviours in isolation, such as steps, rather than taking a more holistic approach.

There is increasing effort and interest into the application of AI and ML to support users in finding actionable insights in their personal data, but the limited attempts so far have often created predictable "insights", which users have not found to be actionable or useful in the real world. The Health Mashups (Bentley et al. 2013) attempted to provide users with data insights by looking at statistical patterns in tracked data, and although their participants found some of these insights to be "obvious" they still claimed increased self-understanding. AI work in other areas has been more successful, and could be applied to making sense of personal health data. For example, Gasparetti et al. (2019) used ML to create personalised weight-loss strategies from activity tracking data; and, one could imagine a personal-data sensemaking "virtual coach", similar to the "Ask Babylon" Health app[26], which could have a conversation with a user, analyse their tracked data, ascertain their goals, and then provide a "prescription" of sorts, in the form of actionable insights.

However, further work needs to be done in this area to allow us to properly understand the implications of computer-delivered insights, versus insights that people have made themselves, based on a process of reflection and better understanding of themselves – the extent to which it is important for users themselves to move through the sensemaking, reflection and wisdom-creating

[26] https://www.babylonhealth.com/product/talk-to-a-doctor

processes, rather than having potential actionable insights provided to them externally is currently unknown. If users are required to engage with, and make sense of, their own data to create insights they may feel more ownership, potentially resulting in them being better sustained over time. However, what we do know is important is that users are supported in following through with their new intentions and actioning any insights that are created. Tracking systems can encourage users to create tailored, measurable and actionable "implementation intentions" (Gollwitzer, 1999) that fit within their broader health and wellness goals, and then further support user by setting reminders and tracking this over time, bringing another level to their self-tracking experience.

7.2.3 Consider the salience of data and physicality of tracking solutions

The behavioural and affective responses our participants made were not only as the result of their engagement with the tracked data, but also from many other factors, including wearing their trackers and some participants found **the device itself acted as a reminder to be active** and as such the physicality of these systems is important. The majority of our participants used dedicated devices to track their activity, most of which had a display which clearly showed the number of steps they had taken. Additionally, our findings pointed towards dedicated devices being useful: they acted as a physical reminder to be more active and the simple act of wearing them also appeared to be useful for behaviour change. However, more recently, wearable devices such as smartwatches offering multiple functionalities, as well as smartphone-based apps, are more popular (IDC, 2018), resulting in the tracked data being more hidden on devices. These multi-functional devices offer an opportunity to provide activity-tracking systems to those who may have otherwise not used them, but this also comes with challenges, as the functionality may not be used. By multifunctional devices we mean smartwatches that offer activity tracking functionalities as well as other forms of notifications, as well as smartphones which nowadays offer a vast array of apps, including ever more popular activity tracking ones. Given these changes in our everyday devices, we argue that it is important to keep data salient in the context of new physical and digital tracking solutions.

In section 5.3.2.6 we presented data from multiple participants whose physical trackers appeared to be responsible for some change in behaviour: P14 contrasted his Fitbit with articles of faith that he wore as part of his religion and P36 even went as far as to say "*I don't think the data changed my behaviour, I think the device itself did*". Dedicated physical devices acting as a visible reminder, perhaps even being symbolic of their physical activity, have not specifically been mentioned in the literature before, but draw parallels with the phenomenon of "enclothed cognition" (Adam and Galinsky, 2012), where people have been found to perform better on cognitive tests when told they are wearing clothes usually associated with a particular profession. Enclothed cognition *"describe*[s] *the influence that clothes have on the wearer's psychological processes"* (p.918), bringing together two psychological factors: the *"symbolic meaning of the clothing",* and *"the physical experience of wearing them"* (p.918). Adam and Galinsky (2012) found that wearing a white lab coat increased attention test scores, and that attention test scores were higher when the wearer was told they were wearing a doctor's coat, versus a decorator's coat. However, whilst this suggests that the "sports-like" aesthetic of wearable technologies, in some part at least, contributes to their potential success in encouraging people to be more physically active (helped by numerous marketing materials and adverts emblazoned with marketing imagery showing people participating in active and healthy activities), this aesthetic may sometimes be a concern, especially if it does not fit within the users' self-image, or with specific outfits, as described in section 5.3.2.4 and as pointed out in Pateman et al. (2018). As dedicated tracking devices become less popular, designers need to explore other ways for data to remain salient in multi-functional devices.

One potential solution for designers to make data more salient without bombarding users with inopportune notifications is using EMI (Ecological Momentary Intervention) to provide more contextually-aware notifications of their step progress to nudge them into being more active. Current systems do provide "progress notifications", but as explained in section 4.4.2, these are often not useful as they appear at the wrong moment. A notification that appears as a person is about to make a transport decision (for example, using public or active transport), would likely be more effective than one that appears after they have arrived home from work and are already wearing their pyjamas. Systems could even provide suggestions for healthier alternatives at the time the decision is being made. Another potential problem is how people's use of other functionalities in smartwaches and smartphones might impact their activity-tracking. For example, many people do not carry their smartphone with them at all times, resulting in lost steps, and similarly Cecchinato et al. (2017a, 2017b) found that people used their smartwatches as a work-home boundary device for smartphone notifications, removing it when they got home from work, again potentially resulting in missed steps.

There is ongoing debate on which form of tracking – active, passive or "semi-automated" (Choe et al., 2017a) is the most suited for particular activities and goals. Many assume that passive tracking is the best option for most behaviours as it puts the least responsibility on the user to remember to record activities. However, actively tracking behaviours can be beneficial, as the process of manually tracking ensures that the tracked behaviours remain salient and this may be leveraged to benefit the user. Further to this, one potential risk of passive tracking is that the measured behaviour is forgotten. For example, if one was to wear an activity tracker and not engage with the tracked steps they would subsequently not engage with the behaviour change techniques embodied in the system and therefore not benefit from tracking. Solutions such as EMI might help mitigate limitations of passive tracking in multi-functional devices, whilst allowing the user to semi-automate their activity tracking and make their own data more salient to them.

7.3 Research and methodological implications

The final contributions presented in this thesis are implications to research practice. As a result of our findings and the mixed-method, long-term and situated approach we took to studying people's use of personal informatics systems, we present **three methodological implications** which we posit are currently under-considered in evaluations of these systems: **(a) Consider use over time**, as people's use of tracking systems evolve over time and outcomes from use changes accordingly; **(b) consider changes beyond the tracked behaviour**, as users may have behavioural and affective outcomes unrelated to the activity they are tracking; and finally, **(c) consider the impact of context on use**, as context can have a significant effect on how people use these technologies, and the associated outcomes.

The implications presented in this section come as a result of our own reflection on the approach we took in this thesis. Our broad and explorative approach, considering use over a longer-term and in different situations, allowed us to not only consider participants' use of the technology and the effect it had on their tracked activities (i.e. steps), but also on emotions and other behaviours, along with effects of contextual factors such as their health, living and working arrangements, the weather and other commitments. Additionally, the analysis of our comparison study helped verify the understanding we had built-up from the longitudinal study data and ensure that our findings were more broadly applicable in different situations and with different technologies. However, whilst this approach brought many benefits, it was not without challenges. Studying a large cohort of participants over time is inherently challenging and costly (both in time and resources), as is considering use across different contexts. Additionally, although this approach did bring about fresh insights and new findings, our explorative approach meant that much of the data we gathered was repeated across participants and over time, resulting in a large amount of data and challenging analysis.

7.3.1 Consider use over time and the lived experience

Our first methodological implication argues that researchers should **consider use of personal informatics technologies over time**, as people's use of tracking systems evolves and outcomes from use change accordingly. However, in order to fully understand if and why personal informatics technologies are useful for behaviour change, we argue that there is *value in carrying out studies* *with a qualitative element*. Furthermore, we argue the importance of considering *non-use* and outcomes *beyond* the period of use.

Whilst long term use of personal informatics systems *is not* necessary for users to derive benefit, we argue that long-term evaluations of these systems *are* essential for a thorough understanding of the lived experience, the benefits users derive from use, their changing interactions over time, and crucially, any harmful outcomes that may arise from use. Without a long-term evaluation we would not have been able to determine with such nuance the phases of tracking, or highlight how the initial responses, discussed in Chapter 4 changed over time, as presented in Chapter 6. Indeed, this thesis is structured to follow the journey of a self-tracker and demonstrate how use over time constantly evolves. As our approach has provided new and deeper understandings of how activity tracking technologies are used, as discussed in section 7.1.1, we argue that it is important to take a longitudinal and qualitative approach when studying use of personal informatics systems. Whilst our specific approach has its own limitations, as briefly discussed in the previous section, there is still value in considering the lived experience, temporal use and behavioural outcomes from a qualitative perspective, especially in exploratory studies.

Within HCI, we frequently rely upon short-term evaluations of behaviour change technologies which may not move beyond a novelty effect (Brynjarsdottir et al., 2012). Furthermore, some researchers argue that long-term trials and evaluations of behaviour change technologies is outside of the scope of HCI research, because *"demonstrating behaviour change is often infeasible as well as unnecessary for a meaningful contribution to HCI research"* (Klasnja, Consolvo and Pratt, 2011, p.3063). Klasnja and colleagues argue that a more suitable approach for HCI could be to focus on the evaluation of specific features and functions. However, they also acknowledge the importance of understanding *why* a technology is useful in encouraging change, and the value of qualitative methods when studying users' experiences, rather than trials, such as RCTs (randomised control trial), that focus on efficacy alone. Many longer-term studies of these technologies focus on understanding *if* an intervention is effective, rather than understanding *why* it is effective. One of the challenges in understanding the *why* is that it takes considerable effort and often requires qualitative work to fully understand the lived experience, which can also have an impact on participant's behaviours. As an alternative, Rogers et al. (2017) argue that short-term evaluations can provide useful insights, but the fact remains that people's interactions change over time, and what might initially appear to be a feature fostering strong engagement, may turn into one that causes negative interactions such as obsession or dependency (as we have discussed in section 7.1.2). Only by considering both efficacy and engagement over time can we have a more complete perspective. These arguments go beyond considering efficacy of these technologies as aiding a behaviour change process alone, to considering the broader lived experience. As an alternative, we propose that evaluations should be considered over a longer term and take better advantage of inter-disciplinary teams with expertise in different areas, bringing together researchers and different approaches that focus both on efficacy along with considering the lived experience and interactions over time.

Beyond evaluating people's use of technologies over time, we also advocate for researchers to consider behavioural changes *beyond* the main period of use. We have demonstrated throughout this thesis how users track temporally, so even if one has abandoned the technology and stopped tracking, they have not necessarily given up on tracking for good. Furthermore, even after they have *stopped* tracking, they may still continue with their changed behaviour, or make further changes. Illustrating the importance of considering use over time, we point the reader towards the positive behavioural outcomes that some of our participants had *after* their period of tracking, in section 6.3.4. These findings illustrate the importance of not only considering use over time, but also non-use, as advocated, for example, by Baumer et al. (2013). Many of our participants also had longer-term responses to use as the result of short-term engagements with their trackers. By not considering outcomes beyond the period of use, or the intervention period, researchers who are looking for particular behavioural outcomes (e.g. increased physical activity) might miss out on benefits derived from use.

7.3.2 Consider changes beyond the tracked behaviour

Our second methodological implication argues that researchers of personal informatics technologies should **consider changes beyond the targeted and tracked behaviour**, as users may have behavioural and affective outcomes unrelated to the activity they are tracking. As such, researchers should take a broader and more *holistic approach* when studying these technologies, considering both positive and negative *side effects to technology use*.

As discussed in section 7.1.1, by taking a broad approach in our own research, we have illustrated how responses to tracking are not limited to changes in the tracked activity, but also include affective responses and changes to other related, and less related, behaviours. For example, we uncovered a number of examples where participants made changes to their physical activity or lifestyles in ways quite unrelated to the behaviour they were tracking (i.e. steps), deriving benefits from use of their tracker which would not be recorded if only the targeted activity was considered. The user-derived benefits of self-tracking technologies appear to go beyond simply making changes to the tracked activity, perhaps by encouraging a general increased self-awareness – therefore evaluations focusing on the tracked activity alone does not capture all the potential benefits of tracker-use. However, many studies solely focus on the tracked behaviours and do not report outcomes related to other behaviours, possibly because these were not considered in the evaluation, or possibly because other changes did not occur.

With technology having a more and more a significant role in our lives, *studying side effects to technology use*, particularly ones that involve behaviour change, should be considered more carefully within HCI. Similar approaches to our recommendation are commonly found in evaluations and trials elsewhere, for example in the medical sciences and specifically drug trials, which do not only focus on the intended outcomes, but also carefully consider side-effects in relation to the efficacy of the drug, where ultimately, the benefits have to outweigh the drawbacks. While looking for side-effects might be motivated by wanting to limit negative symptoms, side effects are not always negative and in some cases might even become the main usage of a drug. For example, diphenhydramine was originally intended to be used antihistamine to treat allergic reactions and hay fever, but more recently has been used as a sleeping aid and a solution to nausea, tremors and even the common cold, owing to its side effects (NHS.uk, 2018). Similarly, when considering self-tracking technologies, we argue that their "side effects" can be both positive and negative, providing benefits as well as drawbacks, as we saw with changes happening beyond the tracked activity, such as in one's lifestyle, but also in examples of more harmful outcomes. Given how a technology designed with improving one behaviour in mind may result in positive changes to another, changes beyond the tracked behaviour should be carefully considered.

7.3.3 Consider the impact of context on use

Our third and final methodological implication argues that researchers should **carefully consider the impact of the context** on use of behaviour-change and self-tracking technologies, as context can have a significant effect on people's use these technologies, and the associated outcomes. While context and situated use has been long studied in HCI and related fields (e.g. Dourish, 2001; Suchman, 1987), these can be overloaded terms that take different meaning for different people. Most works in behaviour change *do* consider context, in that technologies are studied in situ and in the real-world, but the *impact* of the specific context often receives little attention and is underreported. Use and engagement with self-tracking technologies, along with usefulness in encouraging behaviour change, can be affected by context at many different levels, from a user's individual situation, including their needs, desires, ability, interests and self-efficacy, to the broader situational context including their community, the specific location and the physical makeup of a space, including social norms and the built environment. As such, when studying personal informatics systems – but we argue this should apply to any form of interaction – it is important that researchers *consider and state the context of use*, so that a deeper and more nuanced understanding can be formed, and we also argue there should also be *more comparative work* to contrast different contexts and how they affect use.

We argue that it is important for researchers to explicitly situate findings within context of use, but also to *state what the context of use is*. Various health and behaviour change models (e.g. Social Cognitive Theory (Bandura, 1986), Social Ecological Models (e.g. Moos, 1974)) highlight the importance of considering perspectives broader than the user alone, namely the ecology of use: the individual's relationships and peers, the organisations they belong to, the wider community, and finally, the broader society as a whole. However, the above models focus mostly on social factors, rather than other more physical environmental factors such as the weather, access to facilities and the built environment itself, all of which also have a large influencing factor on people's behaviour. Illustrating the importance of considering context, interventions at a policy or regulation level (e.g. encouraging people to sign-up to donate organs (Halpern, 2016)) have been successful in targeting the broader population as a whole and changing people's environment to nudge them towards particular behaviours, and as such may confound results.

Moreover, we argue that *comparative work* would allow researchers to better understand the impact that context and situated use have, when evaluating self-tracking technologies in the real world. As we initially discussed in section 5.5.5, the situation and context in which our participants used their tracking technologies had a significant impact on their interactions with them. For example, from our comparison study we were able to easily identify the differences between how participants in London and participants in Atlanta made initial changes to their activity when first tracking: many of our participants in London changed their behaviour by including more steps outside, and as part of their daily routine, whereas many of those in Atlanta instead took up, or increased, their planned exercise and took more steps by going to the gym, or taking part in team sports. The context of use is not limited to location alone, other factors such as an individual's interests, their abilities, their family and their work and personal lives also has an impact on their behaviours and accordingly their use and the efficacy of tracking systems. Clearly, the context of use has a significant impact on people's use of these systems and their potential efficacy in changing people's behaviour, but despite this the context of use appears to be little considered in existing studies of the use of these systems.

As we have shown, context does not only have an impact on the efficacy of a behaviour change technology, but also on how users interact with these systems, and their use of different features. If, going forward, part of the role of HCI research is to produce a better understanding of people's use and engagement with particular functionalities, along with creating recommendations for the design of future systems, it is imperative that we consider these factors during evaluations and with any associated recommendations. Furthermore, the context should be carefully considered when designers implement systems based on others' findings, as recommendations may not be universally applicable.

Future work could, for example, extend findings from this thesis by comparing urban and rural environments. Based on our methodology, we are able to articulate the importance of repeated, long-term studies and how this has allowed us to take a more holistic approach to understanding situated use, not just limited to walking but including other forms of physical activity and healthy outcomes. By comparing different settings, urban or rural, the situated use gains a new dimension.

7.4 Future Work

Moving on from the contributions we have presented in this work, we now present ideas and opportunities for future work arising from our findings. Although researchers from various fields have made considerable efforts towards better understanding use of personal informatics systems in various areas, and providers of these systems have themselves made huge advancements in their offerings, many questions and areas of enquiry remain unanswered and should be subjected to further work.

Firstly, we call for future work to look towards alternate models of ownership and use of personal informatics technologies, embracing temporal and inconsistent use, rather than constantly chasing usability improvements to encourage sustained and longer-term use which, as we have described throughout this work, may not always be useful or necessary. Such alternate models could move beyond a hardware-sales focus, to rental or subscription-based models, whereby the hardware could be returned and reused when the user no longer interested in tracking. As we have previously discussed, some hardware manufacturers are moving towards this type of alternate model, with Fitbit's CEO James Park explaining moving from an *"episodic device sales"* model, towards paid premium services (dcrainmaker.com, 2019). However, there is space for actors beyond commercial enterprises alone to consider and research different models of use, as commercial entities may not have the users' best interests at heart.

We also suggest that future work should aim to create a better understanding of how tracking technologies can be used to support users in meeting their goals. This could be done for example by considering how to promote meaningful interactions, the relationships between people's goals, their tracking behaviours and phases, and their behavioural outcomes. The salience of tracked data is a significant component of this, and to account for it, future work could consider use of different approaches to increase the salience of this data at key moments, such as when a user is making a decision. A key consideration is the potential of leveraging more novel technologies such as machine learning (ML) and artificial intelligence (AI) to aid users in creating insights from their tracked data, along with potentially taking advantage of coaching as a means of aiding and encouraging behaviour change. However, as we have already discussed, further work should allow us to properly understand the implications of providing AI insights and the extent to which it is important for users themselves to move through the sensemaking, reflection and wisdom-creating processes themselves.

We also recommend that designers of personal informatics and healthcare technologies better consider the broader context and situation of the use of their technologies, and that more research should look at use of these technologies in different situations and contexts. Although the body of research looking at different user groups' use of personal informatics systems is growing, there is still very little work looking at how these systems are used in different physical situations. In this work we have shown how social norms, access to different transport options, the built environment, topography and weather have a considerable influence on how people use, and respond to use of, their technologies, but there is space for much more work in this area. Other work should consider different urban and rural areas, for example including comparisons with smaller towns and villages, where transport and leisure options may strongly influence people's activity and thus their use of tracking systems, and how tracking systems should be designed to support their behaviours. There is potential for interdisciplinary collaborations here, looking at the design of personal informatics systems, healthcare systems and the built environment together.

Finally, we implore researchers, designers and manufacturers of all health-related technologies to better consider the potential for unintended, potentially harmful, consequences arising from use of their technologies, what we have coined as *harmful informatics*. Throughout this work we have seen evidence of users of personal informatics systems making changes to their lives that are not necessarily for the better: from taking more steps to the harm of other, potentially healthier, activities; to becoming obsessed with tracking systems to the detriment of their social lives. Healthcare technologies have the potential to transform people's lives, but as researchers and designers the responsibility lies with us to ensure that these transformations are for good.

Chapter 8. Conclusions

Activity trackers and other personal informatics systems are seen as useful tools for self-improvement, helping people make positive behavioural changes, following Peter Drucker's famous business mantra, *"what gets measured, gets managed"*. However, in personal informatics, as with the use of famous quotes, it is crucial to recognise the bigger picture, as misunderstandings are common. The quote is often misattributed to Drucker, but its origins instead lie in a paper entitled *"Dysfunctional Consequences of Performance Measures"* (Ridgway, 1956. p.240), and the essence of the false quote can instead be summarised as *"What gets measured gets managed - <u>even when it's pointless to measure and manage it, and even if it harms the purpose of the organisation to do so</u>"* (Caulkin, 2008. via *The Guardian*). Fittingly, we found that contrary to expectations, use of activity trackers did not always result in behavioural change, and was indeed not always positive.

This thesis has explored **how healthy adults use and experience activity trackers over time and in different situations,** through two in-depth, mixed-methods studies with 98 current and previous users of activity trackers, studying their use of various tracking systems over time, and in different situations.

We primarily concentrated on users of activity tracking systems, but many of our results are potentially generalisable to other self-tracking systems. Self-tracking journeys are complicated in nature and building on existing work we have brought deeper characterisation of the temporal, and often sporadic, nature of tracking over time, including lapsing, stopping and returning to tracking. Crucially, we extend existing knowledge by characterising the various factors that influenced people's engagement in greater depth, including: their use of built-in behaviour change functionalities; barriers to use of the technologies; and, external and situational factors, such as their health, personal relationships, social norms and the physical fabric of where they lived. The context of use has so far been little considered when evaluating personal informatics systems, but we found it to be an important factor that strongly influenced people's engagements and the benefits they derived from their use, pointing towards the importance of future consideration.

Building on behaviour change evaluations, we combined our knowledge of the temporal nature of tracking with the various positive and negative, intended and unintended, consequences to activity tracker use, showing how these changed over time. As such, we presented a categorisation of responses to use of tracking systems, showing that beyond behavioural change, people also have affective responses when using tracking technologies, which could be better leveraged to support users. Furthermore, as a result of tracking some users make changes beyond tracked behaviours, including to other physical activities and even their lifestyle – changes which have not previously been discussed in the literature. We have discussed the mechanisms behind this, and made suggestions for these technologies to better support users in having meaningful interactions. Finally, we have pointed towards the unintended consequences of use – both positive and negative, particularly considering the negative unintended consequences from use, which we have characterised as *harmful informatics.* Together, these contributions characterise *The Self-Tracker's Journey*.

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Appendices

Appendix A

Longitudinal study information sheet and consent form

UCL DIVISION OF PSYCHOLOGY
AND LANGUAGE SCIENCES

UCL

Information Sheet for Participants in Research Studies

You will be given a copy of this information sheet.

Title of project: **Walkerbit: An evaluation of Fitbit on those who live or regularly travel into central London**

Daniel Harrison
UCL Interaction Centre
MPEB 8th Floor
University College London
WC1E 6BT
daniel.harrison@ucl.ac.uk

Paul Marshall
UCL Interaction Centre
MPEB 8th Floor
University College London
WC1E 6BT
paul.marshall@ucl.ac.uk

Nadia Bianchi-Berthouze
UCL Interaction Centre
MPEB 8th Floor
University College London
WC1E 6BT
n.berthouze@ucl.ac.uk

This study has been approved by the UCL Interaction Centre Research Department's Ethics Chair [Project ID No]: UCLIC/1213/011.

We invite you to participate in this research project which is being conducted by researchers at University College London. You should only participate if you want to; choosing not to take part will not disadvantage you in any way. Before you decide whether you want to take part, it is important for you to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

This study is an evaluation into how people who live or regularly travel into central London use the Fitbit Zip activity tracker, app and website. The Fitbit Zip is a small pedometer-like device that includes functionality to connect to computers and mobile devices. Combined with a mobile application and website it offers encouragement in different ways. We will provide you with the Fitbit Zip activity tracker itself, but we expect you to use your own mobile phone (only the iPhone 4S, 5 and Galaxy S3 work with the Fitbit) in the study. You will be required to download and install a free application from the app store. For this you will need to use your own Apple/ Google login credentials.

The study will last 28 weeks in total. For the first four weeks we will be measuring your baseline physical activity, without access to the Fitbit application and website. During this time we will require you to wear the pedometer each day, but you will NOT be able to view your recorded step-data. After this four-week period you will be able to view all recorded step-data. We will ask you to use the activity tracker as you wish for the remainder of the study, making use of the mobile application and other parts of the system you find useful. If you do not wear the

Longitudinal study information sheet and consent form, part 1 of 3.

device please make a note of this and let us know at the end of each week.

By participating in the study we require you to share your step data with us and the other study participants (there will be approximately 50). Your location or other personal details will not be recognisable from this data: if you wish you may choose to be recognized by an alias rather than your real name. You may choose to share your step-data with others too, for example over social media.

For the first 16 weeks of the study you will receive a short email questionnaire each week and we will arrange meetings every four weeks. To help facilitate the completion of the questionnaire we will also provide you with a diary, which we recommend you fill- out regularly and that will be collected at the end of the study. The length of each meeting will depend on the amount we have to discuss and if you have raised any issues, but we estimate that no meeting will ever last more than half an hour and they will be scheduled to be convenient to you. Interviews may be audio- recorded for later transcription. A full schedule for these meetings will be arranged with you once you have begun the study.

The regular meetings and questionnaires will stop after the 16th week. After this we will meet with you once more for a follow-up interview, after 12 weeks. After this point you are free to keep all materials we have given you, including the Fitbit itself, and you may continue use of the Fitbit device and service. There will be an opportunity to participate in a further follow-up interview if you are still using the system. If you decide to leave the study at any point before the end date (28 weeks after the start of the study) you must return all research materials given to you, including the Fitbit device.

You should consult your GP before starting any new exercise regime or increasing your levels of physical activity.

All data will be handled in accordance with the Data Protection Act 1998 and will be kept anonymous. With your permission, we may want to use information you have given to us for teaching, conferences, presentations, publications, and/or thesis work but again this will be anonymised.

It is up to you to decide whether or not to take part. If you decide to do so you will be given this information sheet to keep and will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

You may contact us at any time by emailing study@walkerbit.co.uk.

Longitudinal study information sheet and consent form, part 2 of 3.

Informed Consent Form for Participants in Research Studies

(This form is to be completed independently by the participant after reading the Information Sheet and/or having listened to an explanation about the research.)

Title of Project: **Walkerbit: An evaluation of Fitbit on those who live or regularly travel into central London**

This study has been approved by UCLIC Research Department's Ethics Chair [ID No]: UCLIC/1213/011

Participant's Statement

I ……………………………………………...................................... agree that I have:

- Read the information sheet
- Had the opportunity to ask questions and discuss the study
- Received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury
- No reason not to take part in a study relating to exercise and physical activity
- Understood that I must consult my GP before making any changes to my levels of physical activity
- Understood that if I choose to end my participation before the end of the study (28 weeks from the start date) that I must return all materials to the investigators, including the Fitbit device
- Understood that the information I have submitted will be published as an academic publication and presentation, and I will be sent a copy. Confidentiality and anonymity will be maintained, and it will not be possible to identify me from any publications
- Understood that to participate in the study I must share my recorded Fitbit data with the investigators and other participants in the study
- Understood that I must meet with the investigators, as set out above, to discuss my usage of the device and these interviews may be recorded

I understand that I am free to withdraw from the study without penalty if I so wish. I understand that I consent to the processing of my personal information for the purposes of this study only. I understand that any such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

Signed: Date:

Investigator's Statement

I ……………………………………………………………………

confirm that I have carefully explained the purpose of the study to the participant and outlined any reasonably foreseeable risks or benefits (where applicable).

Signed: Date:

Longitudinal study information sheet and consent form, part 3 of 3.

Diary cover and example workbook pages

UCL

Walkerbit Study

Workbook

workbookbook.indb 1 19/05/2013 14:12

UCL

If lost please return to:
Daniel Harrison
UCL Interaction Centre,
8th Floor Malet Place Engineering Building,
University College London,
Gower Street,
London,
WC1E 6BT

workbookbook.indb 48 19/05/2013 14:15

Week 0/28 Study Part 1	This week: Interview 1 Date: __/__/____
Mon	
Tue	
Wed	
Thu	
Fri	
Sat	
Sun	

workbookbook.indb 17 19/05/2013 14:12

Example Diary Entry

Week X/28	Date: xx / xx / xxxx You don't need to complete the diary in this way. Do whatever feels best for you! Remember we're collecting the diaries back at the end of the study so please look after it.
Mon	Forgot to wear the Fitbit in the morning, must remember to take it off and put it on my phone at night to help me remember.
Tue	Loads of steps today! Although I suspect a lot of them came from wearing the Fitbit when I played football in the evening!
Wed	Very busy day- completely forgot to wear the Fitbit. Whoops.
Thu	Horrible weather today, took the bus to work. Had to go out in the afternoon, was a bit drier so walked to my meeting & then back home afterwards.
Fri	Woke up late for work today, so didn't have time to walk in- took the bus again.
Sat	Nice sunny day so I decided to go for a walk.
Sun	Spent the entire day at home working on my computer.

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Appendix B

Comparison study combined information sheet, consent form and survey (online)

London Activity Trackers

Pre-Interview Questionnaire

Thank you for agreeing to participate in my study, I'm looking forward to speaking to you.

I'd like you to complete this survey before the interview. It will take **5-10 minutes**.

The survey is divided into 6 sections:

- Physical activity for work purposes
- Physical activity for transportation
- Physical activity at home
- Physical activity for leisure/ sport
- Time spent sitting
- Barriers to being active

If you wish, you may bring your activity tracker(s) to the interview and it would be very helpful if you could share recorded data with us (your activity tracker may give the option to export data, otherwise we would be pleased to receive screenshots of your activity data - if you would like to ask questions about this before the interview please do get in touch).

Information from interviews will be used for the purpose of academic research and may be presented in an academic publication and/or conferences, workshops and/or teaching material. Confidentiality and anonymity will be maintained, and it will not be possible to identify you from any publications. During the interview an audio recording will be made for later transcription.

You will receive your **£10 Amazon voucher** via email after you have completed the interview (this may take up to 7 days).

There are no right or wrong answers, we are just looking for some background information about your physical activity before the interview. If we have not yet arranged a time and a date for the interview we will do so shortly.

If you have any questions or encounter problems at any stage you may contact us at: daniel.harrison@ucl.ac.uk.

Before you start the survey please read the following statements:

- I have read the information above.
- I had the opportunity to ask questions and discuss the study.
- I received satisfactory answers to all my questions or have been advised of an individual to contact for answers to pertinent questions about the research and my rights as a participant and whom to contact in the event of a research-related injury.
- I understood that the information I have submitted will be published as an academic publication and presentation, and I will be sent a copy. Confidentiality and anonymity will be maintained, and it will not be possible to identify me from any publications.
- I understand that I am free to withdraw from the study without penalty if I so wish.
- I understand that I consent to the processing of my personal information for the purposes of this study only.
- I understand that any such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.

● **I agree with the above statements and consent to take part in this study.**

○ I do not agree with the above. I understand this means that I will not be able to take part in the study.

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Please enter your name and email address to start the survey.

Your name:

Your email (this address will be used to send your Amazon voucher):

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Physical Activity Questionnaire

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** and **moderate** activities that you did in the **last 7 days**:

- **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.
- **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

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London Activity Trackers

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home.

Do **NOT** include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family.

Do you currently have a job or do any unpaid work outside your home?

- (●) Yes
- ( ) No

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During the last 7 days, on how many days did you do vigorous physical activities for at least 10 minutes at a time as part of your work?

e.g. *heavy lifting, digging, heavy construction, or climbing up stairs*

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How much time per day did you usually spend on one of those days doing vigorous physical activities as part of your work?

0 hours per day

0 minutes per day

<<

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During the last 7 days, on how many days did you do moderate physical activities for at least 10 minutes at a time as part of your work?

e.g. *carrying light loads*

Please do NOT include walking.

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How much time per day did you usually spend on one of those days doing moderate physical activities as part of your work?

0 hours per day

0 minutes per day

<<

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During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work?

Please do NOT count any walking you did to travel to or from work.

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How much time did you usually spend on one of those days walking as part of your work?

0 hours per day

0 minutes per day

<<

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PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

During the last 7 days, on how many days did you travel in a motor vehicle?

e.g. *a train, bus, car, or tram*

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How much time did you usually spend on one of those days traveling in a train, bus, car, tram, or other kind of motor vehicle?

0 hours per day

0 minutes per day

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London Activity Trackers

Now think only about the **bicycling** and **walking** you might have done to travel to and from work, to do errands, or to go from place to place

During the last 7 days, on how many days did you bicycle for at least 10 minutes at a time to go from place to place?

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How much time did you usually spend on one of those days to bicycle from place to place?

0 hours per day

0 minutes per day

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During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place?

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How much time did you usually spend on one of those days walking from place to place?

0 hours per day

0 minutes per day

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London Activity Trackers

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the **last 7 days for at least 10 minutes** in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

Remember:

- **VIGOROUS** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.
- **MODERATE** physical activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

Think about only those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do vigorous physical activities in the garden or yard?

e.g. *heavy lifting, chopping wood, shoveling snow, or digging*

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How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?

0 hours per day

0 minutes per day

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Again, think about only those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do moderate physical activities for at least 10 minutes at a time in the garden or yard?

e.g. *carrying light loads, sweeping, washing windows, and raking*

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How much time did you usually spend on one of those days doing moderate physical activities in the garden or yard?

0 hours per day

0 minutes per day

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London Activity Trackers

Once again, think about only those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do moderate activities for at least 10 minutes inside your home?

e.g. *carrying light loads, washing windows, scrubbing floors and sweeping*

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How much time did you usually spend on one of those days doing moderate physical activities inside your home?

0 hours per day

0 minutes per day

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PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the **last 7 days for at least 10 minutes at a time** solely for recreation, sport, exercise or leisure. Please do not include any activities you have already mentioned.

Remember:

- **VIGOROUS** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal.
- **MODERATE** physical activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?

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How much time did you usually spend on one of those days walking in your leisure time?

0 hours per day

0 minutes per day

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Think about only those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do vigorous physical activities in your leisure time?

e.g. *aerobics, running, fast bicycling, or fast swimming*

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How much time did you usually spend on one of those days doing vigorous physical activities in your leisure time?

0 hours per day

0 minutes per day

<< >>

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Again, think about only those physical activities that you did for at least 10 minutes at a time.

During the last 7 days, on how many days did you do moderate physical activities in your leisure time?

e.g. *bicycling at a regular pace, swimming at a regular pace, and doubles tennis*

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How much time did you usually spend on one of those days doing moderate physical activities in your leisure time?

0 hours per day

0 minutes per day

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PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

During the last 7 days, how much time did you usually spend sitting on a weekday?

0 hours per day

0 minutes per day

During the last 7 days, how much time did you usually spend sitting on a weekend day?

0 hours per day

0 minutes per day

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London Activity Trackers

Barriers to Being Active

Listed below are reasons people do not get enough physical activity. Read each statement and mark how that fits you.

How likely are you to say?

	Very unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely
1. My day is so busy now, I just don't think I can make the time to include physical activity in my regular schedule.	○	○	○	○
2. None of my family members or friends like to do anything active, so I don't have a chance to exercise.	○	○	○	○
3. I'm just too tired after work to get any exercise.	○	○	○	○
4. I've been thinking about getting more exercise, but I just can't seem to get started.	○	○	○	○
5. I'm getting older so exercise can be risky.	○	○	○	○
6. I don't get enough exercise because I have never learned the skills for any sport.	○	○	○	○
7. I don't have access to jogging trails, swimming pools, bike paths, etc.	○	○	○	○
8. Physical activity takes too much time away from other commitments - time, work, family,etc.	○	○	○	○
9. I'm embarrassed about how I will look when I exercise with others.	○	○	○	○
10. I don't get enough sleep as it is. I just couldn't get up early or stay up late to get some exercise.	○	○	○	○
11. It's easier for me to find excuses not to exercise than to go out to do something.	○	○	○	○
12. I know of too many people who have hurt themselves by overdoing it with exercise.	○	○	○	○

	Very unlikely	Somewhat Unlikely	Somewhat Likely	Very Likely
13. I really can't see learning a new sport at my age.	○	○	○	○
14. It's just too expensive. You have to take a class or join a club or buy the right equipment.	○	○	○	○
15. My free times during the day are too short to include exercise.	○	○	○	○
16. My usual social activities with family or friends do not include physical activity.	○	○	○	○
17. I'm too tired during the week and I need the weekend to catchup on my rest.	○	○	○	○
18. I want to get more exercise, but I just can't seem to make myself stick to anything.	○	○	○	○
19. I'm afraid I might injure myself or have a heart attack.	○	○	○	○
20. I'm not good enough at any physical activity to make it fun.	○	○	○	○
21. If we had exercise facilities and showers at work, then I would be more likely to exercise.	○	○	○	○

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London Activity Trackers

Thank you for completing this survey, we're looking forward to seeing you in the interview!

If you know anybody else who might be willing to participate please do pass on our recruitment survey link: www.doitforscience.com/london. Don't forget that everybody who's chosen to participate in an interview will receive a £10 Amazon voucher!

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