Application of the Behaviour Change Wheel Framework to the development of interventions within the City4Age project

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***Abstract*—The probability of an intervention being effective is likely increased if it is designed following a behavioural analysis and with the aid of evidence-based intervention frameworks. For example, the Behaviour Change Wheel (BCW) framework and its associated COM-B model of behaviour have been used successfully as a starting point for designing behaviour change interventions. However, the BCW framework can also be applied at a later stage in the design process, such as when an intervention has been designed but before it is deployed. Here we describe the application of the BCW framework and COM-B model to evaluate and refine already designed interventions. We use a multidisciplinary multi-site project ('City4Age') as a case study. The project aims to promote independent living of older adults through the deployment of interventions using wearable and environment-based technology. We conducted face-to-face interviews with site representatives to identify the target behaviours, perceived barriers and facilitators, intervention functions, and modes of delivery for each planned intervention. Additionally, literature reviews were conducted to identify evidence-based facilitators and barriers for each targeted behaviour. Subsequently, we 1) compared the intervention functions proposed by the project-sites with those most likely to be effective according to the BCW; and 2) assessed the congruency of the barriers and facilitators identified by the pilot-sites with those identified in the literature. For five planned interventions across two project-sites (Birmingham and Singapore), two had intervention functions unlikely to be effective according to the BCW. The two planned interventions to promote social engagement did not address barriers or facilitators evident in the literature, indicating they required refinement. Applying the BCW framework allowed to identify which interventions needed refining. It also helped in providing specific guidance in our recommendations for improvements prior to deployment.**

Keywords—digital interventions, Behaviour Change Wheel, older adults, COM-B model, intervention design

I. BACKGROUND

Today's aging population is putting an increased strain on health services, in part due to rising incidence rates of age-related conditions such as dementia and frailty [1]. For many older adults, maintaining a healthy lifestyle including physical activity, social interaction and good nutrition can go some way to reduce the risk of developing more serious health conditions. Therefore, identifying ways in which older adults can be encouraged to increase healthy behaviours (e.g. being more active), and reduce unhealthy behaviours (e.g. remaining sedentary for long periods of time) may be beneficial on both an individual and a societal level.

Behaviour change interventions aiming to support older adults in improving their health have demonstrated some success. Previous interventions involving older adults have increased physical activity [2–13], improved nutrition [10,14–16] and increased general well-being [17]. The rise in ownership, affordability and functionality of mobile devices has created further opportunities for interventions that can be applied to older adults [18]. For example, existing interventions have used mobile phones and wearables such as smartwatches to deliver reminders and provide suggestions for activities, and to measure and provide feedback on physical activity [19–22].

Whilst these technological advancements have made delivering interventions and measuring outcomes much easier, it remains important to design interventions in line with existing evidence and theoretical frameworks. One such framework is the Behaviour Change Wheel (BCW) based on the COM-B model of behaviour [23], and incorporating the Theoretical Domains Framework (TDF) [24]. The BCW is a summary of key intervention functions (i.e. what the intervention actually does) and policy categories for implementing interventions, derived from synthesising 19 frameworks of behaviour change across a range of domains, including health [24–27]. It represents a concise way of linking a model of behaviour to a range of intervention functions to change behaviour, linking, in turn, these intervention functions to policy categories that can facilitate each intervention function.

There is evidence that theory based interventions are more effective than non-theory based interventions [28,29]. Therefore, incorporating evidence-based theoretical frameworks may be integral in designing successful interventions. This is normally achieved by consulting the BCW during the design of the intervention [30]. Conversely, the BCW has been used to retrospectively categorise interventions [31] in order to assess which are in line with existing theory. However, there are situations in which one may wish to use the BCW after the interventions have been designed but before they are deployed. For example, in large interdisciplinary projects, behavioural

scientists may be called upon to provide feedback on interventions designed by those developing the technology behind the intervention. In such circumstances, the BCW will not have been used to design the intervention, but could be used to refine interventions, ensuring they target relevant facilitators (i.e. what makes easier to perform a behaviour) and barriers (i.e. influences preventing the performance of a behaviour) through appropriate intervention functions. To our knowledge, the use of the BCW at this stage of intervention design has not previously been evaluated. An opportunity to do so was afforded within a multidisciplinary project investigating digital support for older adults: 'City4Age'.

A. City4Age

The case study for the present paper is City4Age [32], an international, interdisciplinary collaboration aiming to enable ambient, age-friendly cities through the adoption of wearable and environment-based sensors. The project aims to use this sensed behavioural data to enhance early detection of risk factors associated with MCI and frailty, as well as reduce the risk of these conditions by providing behaviour change interventions. The project is ongoing. At the time of writing, the test-beds had selected the behaviours of interest for the interventions but had not yet deployed the interventions. The interventions have been designed by those leading each of the test-beds, without initial input from behavioural scientists. City4Age consequently afforded an opportunity to evaluate whether the BCW framework and COM-B model can also be used to refine already planned interventions.

B. Aims of the paper

Using the case study of the behavioural interventions planned as part of City4Age, this paper evaluates the application of the Behaviour Change Wheel (BCW) framework and COM-B model to refining already planned digital health interventions for older adults. To this end, we use the BCW and COM-B model to assess:

i. whether the selected intervention functions are appropriate considering the nature of the suggested facilitators and barriers

ii. the appropriateness of the suggested facilitators and barriers, according to existing literature.

II. Methodology

A. Classification of planned interventions

We conducted face-to-face interviews with representatives from each test-bed. On this paper we focus on information from two test-beds, Birmingham and Singapore. From these interviews, we collected information on the number of interventions being proposed by the test-bests, as well as the following information for each of the proposed interventions: target behaviour (i.e. the behaviour that an intervention is aiming to change), barriers and facilitators of that behaviour known to and targeted by the test-bed, what the intervention is proposing to do (e.g. provide reminders) and mode of delivery (e.g. mobile phone, face-to-face). Next, two coders independently categorised the facilitators and barriers named by the test-beds according to the most appropriate COM-B component (physical or psychological capability, physical or social opportunity, or reflective or automatic motivation). Categorisations were then verified and refined by a third coder. In case of disagreement, decisions were reached through discussions between the coders and refinement of the coding scheme.

Following the mapping of the COM-B component(s), the intervention function as planned by the test beds was coded by two independent coders. As the BCW proposes that specific intervention functions are appropriate for each COM-B component, we next coded whether test-bed proposed intervention functions were appropriate for the COM-B component identified when mapping barriers and facilitators. If the intervention function chosen by the test-bed did not relate to the COM-B component for an intervention, the BCW was used to identify alternative intervention functions.

B. Behavioural analysis

1) Topic of the behavioural analysis. Behavioural analyses are a vital part of the process for theoretically driven intervention design [18] as they identify the facilitators and barriers of the behaviour of interest. We conducted a behavioural analysis on social and community engagement and increasing physical activity, two themes of intervention for the test-beds, to assess whether the facilitators and barriers targeted by the test-beds were appropriate for each target behaviour. Here we focus on the behavioural analysis on social and community engagement.

2) Conducting the behavioural analyses. We undertook a scoping review of the literature. Web of Science, PubMed and Google Scholar were searched between 10th September and 25th October 2016, with no time period restrictions. Only published studies in the English language were included. Literature was included if it involved a target population of older adults (over 65 years of age).

3) Mapping the facilitators and barriers to COM-B and BCW. Once relevant literature was identified, the facilitators and barriers were extracted from the papers by examining the results and discussion sections of the papers. Each facilitator and barrier was mapped onto the most relevant COM-B component, and then onto the TDF framework by one researcher. The coding was completed by assessing which COM-B and TDF component best represented the facilitator or barrier, as described in the literature. Coding the facilitators and barriers onto the COM-B and TDF components facilitates the selection of the most effective intervention function for each identified barrier, as this decision is made based on the COM-B sub-component.

III. RESULTS

A. Classification of planned interventions

TABLE I. THE PROPOSED CITY4AGE INTERVENTIONS FOR THE BIRMINGHAM AND SINGAPORE TEST-BEDS ALONGSIDE RELEVANT COM-B COMPONENTS AND INTERVENTION FUNCTIONS

Site	The intervention	Target behaviour	Current facilitators & barriers	What the intervention will do	COM-B component	Intervention function	Appropriate intervention function?
Birmingham	"connect to the local area groups (reduce social isolation)"	Increase event attendance	Elderly people do not know what events are happening, or who else is going	Reminders, suggestions	Physical Opportunity	Enablement	Yes
Birmingham	"Improve individual mobility"	Increasing walking (number of steps, speed of pace) to reduce risk of frailty	Elderly people do not have a reason to walk, anyone to walk with, or they do not know the benefits of walking	Reminders, suggestions, information	Social Opportunity / Psychological Capability	Enablement / Education	Yes
Singapore	"attend social events and engage in community centre activities"	Increase attendance of social events to prevent loneliness and increase sense of community	Not knowing when events are held, forgetting when they are	Phone reminders	Psychological Capability	Enablement	Yes
Singapore	"Invitation to walk in the neighbourhood and visit social places"	Increase walking to encourage them to leave the home, preventing loneliness and physical inactivity, and increasing socialisation	Elderly people lack encouragement to walk	Phone reminders	Social Opportunity / Reflective Motivation	Enablement	Yes/No
Singapore	"invitation to engage in physical activities at the SAC (Senior activity centre)"	Increase physical activity	Elderly people lack encouragement to take part in physical activity, and lack motivation	Phone reminders, caregivers visits	Social Opportunity / Reflective Motivation	Enablement	Yes/No

Table I shows the proposed interventions for the Birmingham and Singapore test-beds. Out of the 5 interventions, two were found to have an intervention function that did not correspond to those recommended for the relevant COM-B category. The remaining 3 interventions were using appropriate intervention functions for the facilitators and barriers identified by the test-beds.

For the interventions that did not include a recommended intervention function, two COM-B components had been coded due to multiple facilitators or barriers having been suggested. In each case, only one intervention function was proposed by the test-bed. While the proposed intervention function matched one of the identified COM-B components, it was not appropriate for the other COM-B component. One intervention proposed by the Singapore test-bed aimed to increase attendance at physical activity events at the senior centre. The Singapore test-bed specified as barriers that the elderly people lacked encouragement, and were unmotivated. A lack of encouragement relates to the COM-B component of Social Opportunity, and a lack of motivation to Reflective Motivation. We identified that the proposed intervention of providing phone reminders was best mapped onto to the intervention function of Enablement. Enablement is an appropriate intervention function for Social Opportunity, but not for Reflective Motivation. As a consequence, the intervention in its current form is unlikely to adequately target the barrier of a lack of motivation and is therefore less likely to succeed in its aim of increasing attendance at physical activity events, as the intervention is unlikely to influence motivation.

Consequently, to ensure all barriers and facilitators specified by the test-beds are being effectively targeted, we recommended including the additional intervention functions outlined in Table II. The additional suggested intervention functions were selected by consulting the BCW and identifying what intervention functions are appropriate for the additional barrier's COM-B component.

TABLE II. SUGGESTED INTERVENTION FUNCTIONS TO BE ADDED TO THOSE INTERVENTIONS REQUIRING IMPROVEMENT

Site	Intervention	Target behaviour	Facilitators & barriers	Mode of delivery	COM-B component	Intervention function	Suggested additional intervention function
Singapore	Invitation to walk in the neighbourhood and visit social places	Increase walking to encourage them to leave the home, preventing loneliness and physical inactivity, and increasing socialisation	Elderly people lack encouragement to walk	Phone reminders	Social Opportunity / Reflective Motivation	Enablement	Persuasion
Singapore	invitation to engage in physical activities at the SAC (Senior activity centre)	Increase physical activity	Elderly people lack encouragement to take part in physical activity, and lack motivation	Phone reminders, caregivers visits	Social Opportunity / Reflective Motivation	Enablement	Persuasion

B. *Behavioural analysis*

1) Social and community engagement. The behavioural analysis can be found in Table III. A total of 15 unique papers were identified that met the criteria outlined in the Methods section. Some of these papers identified multiple facilitators or barriers and are therefore listed in the table more than once. The behavioural analysis indicated that the main facilitators to and barriers of social and community engagement are factors relating to transport (e.g. access to public or private transport from the home to the centre), health complaints, self-perceptions and a lack of identification with the identities associated with senior centres (e.g. not feeling "old" enough for senior centres, or seeing attendance as a reminder of aging), and the kinds of activities on offer. These relate to the intervention functions of environmental restructuring (e.g. providing transport to senior centres or improving accessibility or providing additional support for those in ill-health) and modelling (e.g. demonstrating that activities or social events are for people like the recipients). Therefore, based on this behavioural analysis, we suggest that interventions aiming to improve social and community engagement would be the most likely to succeed when providing environmental restructuring and modelling, with a focus on the identified facilitators and barriers.

TABLE III. BEHAVIOURAL ANALYSIS FOR SOCIAL AND COMMUNITY ENGAGEMENT IN OLDER ADULTS AND SUGGESTED INTERVENTION FUNCTIONS

COM-B Component	Domain (TDF)	Literature findings of barriers to and facilitators of the behaviour	Suggested intervention function
Capability, Psychological	Memory, Attention and Decision Processes	Attendance reminding them that they are aging [33]	Education
Capability, Physical	Skills	Inability to follow conversations/sensory deficits [34–37], poor health [38]	Environmental restructuring
Opportunity, Social	Social influences	Participation of friends/partner [39]	Enablement
		Lack of local social support [37], unsupportive community/perceived lack of acceptance [40]	Modelling
		Opportunity to contribute skills/knowledge [41]	Enablement
Opportunity, Physical	Environmental Context and Resources	Lack of appealing activities/social opportunities [40,42,43], A choice of activities [41]	Environmental restructuring
		Availability of private car [44] Traffic/poor driving conditions [45]	Environmental restructuring
		Access to public transport [43,44,46], Cost of public transport [44]	Environmental restructuring
		Lack of money [46]	Environmental restructuring
Motivation, Reflective	Social/Professional Role and Identity	Perception that activities are for much older people [33], not self-identifying as "old" [40]	Modelling
		Perception that activities/senior centres are gendered [47]	Modelling
	Beliefs about capabilities	Self-perceived health [48]	Education
	Beliefs about consequences	Perception that engagement and socialising will be beneficial/desirable[33,41,43]	Persuasion
		Fear of social rejection [40]	Education
		Desire to benefit from socialising [43]	Persuasion
Motivation, Automatic	Social/Professional Role and identify	Attendance as a reminder of aging [33]	Persuasion
		Activities not catering to preferred social identities [40]	Persuasion

The proposed interventions in the area of social and community engagement for the City4Age Birmingham and Singapore test-beds are summarised in Table IV.

TABLE IV. OUTLINE OF THE PROPOSED INTERVENTIONS IN THE AREA OF SOCIAL AND COMMUNITY ENGAGEMENT WITH RELEVANT COM-B COMPONENTS AND INTERVENTION FUNCTIONS

Test-bed	Intended outcome	Relevant facilitators & barriers	Proposed intervention	COM-B component	Intervention function
Singapore	Increased attendance of social events at community centre	Not knowing when events are held, forgetting when they are	Reminders on mobile phone	Capability (Psychological)	Enablement
Birmingham	Increase event attendance - connect to the local area groups (reduce social isolation)	Elderly people do not know what events are happening, or who else is going	Reminders, suggestions	Physical Opportunity/ Social Opportunity	Enablement

The barriers suggested by the test-beds included not knowing what events were being organised, or forgetting when the events were, or not being in the mood for the behaviour. The evidence located in our scoping literature search did not identify a lack of awareness or forgetfulness as main barriers to social or community engagement. However, we did locate literature that suggested the activities being organised were important motivators. Existing evidence suggests that providing more varied and interesting activities operates as a facilitator for social and community engagement. The identified importance of the activities themselves as a facilitator consequently support the suggestion that a lack of interest may be a barrier. Accordingly, if individuals have incorrect or negative perceptions of the kinds of events being organised, communicating the types of events that are occurring may be beneficial to some degree. This intervention will, however, be unlikely to impact those individuals that are genuinely disinterested in the activities. Moreover, as it is not addressing an identified barrier or facilitator directly (as outlined in the literature), it is less likely that the proposed interventions would succeed in the aim of increasing attendance at social events.

IV. DISCUSSION

The aim of this paper was to evaluate the application of the BCW framework to refine already planned digital health interventions for older adults, using the interventions planned as part of the City4Age project as a case study. We assessed (i) whether the selected intervention functions were appropriate considering the nature of the suggested facilitators and barriers, and (ii) the appropriateness of the suggested facilitators and barriers. This paper demonstrates that the BCW can be used to refine interventions that have been planned but not yet deployed. Using the BCW allowed making recommendations for refinement, and provide feedback to the intervention designers. Importantly, the finding that the majority of interventions proposed were based on facilitators and barriers that were not evident in the literature further demonstrate the need for behavioural analyses being conducted prior to the design of the interventions. If the main facilitators and barriers are ignored by the interventions, they may not be able to successfully change the target behaviour.

A limitation of the present paper is that the interventions have not yet been deployed, and therefore have not been evaluated in terms of their effectiveness. Consequently, it remains unclear whether our recommendations will have resulted in more effective interventions. Existing evidence suggests that ensuring interventions are aligned with evidence-based theoretical frameworks increases the likelihood of the intervention successfully changing behaviour [28,29]. Therefore, adapting interventions to better align with the BCW will strengthen the interventions.

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