Running App 'Zombies, Run!' Users' Engagement With Physical Activity: A Qualitative Study

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Abstract

Introduction: Sufficient physical activity is important for all aspects of health. Smartphone apps and the use of gamification, such as narrative-based augmented reality (AR) have a great potential to engage a variety of people in more PA. Zombies, Run! (ZR) is the world's most popular running exergame app and therefore a suitable model to understand what users find engaging.

Objective: To understand people's motivation and experience of using a narrative-based AR exergame app ZR for physical activity.

Method: ZR users were randomly selected for interview from a quantitative ZR users survey. Interviews which were guided by a semistructured topic guide were audio-recorded, transcribed, and analysed using inductive and deductive thematic analysis.

Results: Participants were 15 males and 15 females aged 16-53 years (Mean=36, SD=10), from 13 countries, with the largest proportions from the USA (30%) and UK (23%). The majority (73 %) used ZR while running, followed by cycling and walking. Five overarching themes that emerged were: 'Reasons for starting and staying with ZR', 'Preferred features', 'Perceived effects of ZR', 'Pros and cons of the app'. 16 subthemes included the attraction of gamification and narrative appeal, desire to add something fun to physical activity or to distract from the negative physiological effects of physical activity. Users' favourite features were the feelings of immersion and presence through narrative, storyline and characters. The narrative motivated participants to engage in PA for longer sessions and encouraged long-term use.

Conclusions: This study identified a number of factors that users found attractive in an AR running exergame, particularly narrative. Our findings suggest that ZR may engage people with exercise by modifying their perception of physical activity through a storyline or narrative, dissociating the players from the effort of exertion. AR narrative-based apps may be an effective way of engaging people with health-related behaviours or habit-forming activities.

Keywords

Introduction

Regular participation in physical activity (PA) reduces the risk of multiple conditions, including cardiovascular disease, diabetes, obesity, some cancers, poor sleep, stress, depression and cognitive decline (Whelton et al., 2002; Kredlow et al., 2015; Baillot et al., 2015; Arem et al., 2015; Reiner et al., 2013; WHO, 2014; Hamer et al., 2012; Warburton et al., 2006; Fox, 1999). However, population levels of physical activity are too low worldwide with an estimated 80% of adults classified as innactive (WHO, 2020). Interventions that can engage larger numbers of the population with physical activity are required. Smartphones represent a potential avenue to reach a large proportion of people. 3.5 billion people (45%) worldwide own a smartphone and this figure is continually increasing (Statista, 2021). Mobile games contribute to the growing usage of smartphones with the revenue for smartphone games in 2020 estimated at over $63 billion worldwide, with this number estimated to reach $100 billion by 2023 (Statista 2021b). Smartphones can promote physical activity by allowing people to access a variety of tools, such as reminders, platforms or even exergames.

Exergames for Physical Activity

Exergames are able to exploit the mobility and technical abilities (Wifi, GPS, audio and camera) of a smartphone to create a personalized and highly responsive experience for the user, without being constrained to a console and usually at much lower costs than gyms, exercise classes or virtual reality (VR) technology (Barnett et al., 2013; Robertson, 2020). However, previous studies on the use of narratives in active video game play have found that interest in the game play of exergames can decline quickly (Haichun, 2013; Lu et al., 2016) and there is need to understand the factors that might facilitate sustained engagement. The use of a narrative has been shown to significantly influence physical activity behaviour and might encourage long-term use because it maintains novelty and surprise (Lu et al., 2016). One smartphone exergame that uses narrative as a central feature is Zombies, Run! (ZR).

Zombies, Run! Smartphone Exergame App

Zombies, Run! (Six to Start, London) is a popular running app available on the Apple (Apple Inc., California, U.S.) and Google Play Store (Google, California, U.S.) stores. Released in 2012, it was co-created with a novelist, Naomi Alderman (Martin, 2017). Zombies, Run! is an "ultra- immersive post-apocalyptic audio augmented reality (AR) story" (Apple Inc, 2021), where the user is one of the few remaining survivors in a zombie-infested world. The user is given a nickname "Runner 5", and needs to collect supplies to build back a base called "Abel Township" for remaining survivors. Zombies, Run! uses narrative-based AR, also termed augmented narrative (AN) or 'reactive storytelling'. The

users can leave the game running in the background when performing any form of physical activity and link the app to the popular music libraries such as Spotify (Spotify Technology S.A., Sweden) to add their own music. Since its release, Zombies, Run! has accrued 8.5 million downloads, with 2 million alone during the COVID-19 pandemic, with approximately 200,000 monthly active users (Six to Start data). Users can choose from a number of in-app purchase options ranging from £5.49 - £87.99 per year, some with monthly or unlimited or access (Apple, 2020). Zombies, Run! was evaluated in two pilot studies in adolescents (<51 participants) which found no significant differences when compared to other narrative apps or forms of exercise (Direito et al., 2015) and N=40 (Cowdery et al., 2015)

Much can be learned from interviewing long-term users of a technology to understand which features appeal to Zombies, Run! users and this information can be used to optimize future exergaming apps. The value of qualitative research is to learn about people's experiences and use to inform the future development, engagement, tailoring and improvements. This study was part of a larger project vEngage (Farič et al., 2021). We followed the Medical Research Council's (MRC) framework for developing and evaluating complex interventions (Craig et al., 2008). The MRC framework consists of five steps, the third and fourth steps being 'evaluation' and 'reporting' which this study falls under. Therefore, the aim of this study was to explore Zombies, Run! users' experience of the narrative-based AR app, and the impact on the physical activity performance, as well as their views on physical activity and gaming.

Method

Participants

Participants were recruited via a quantitative survey of Zombies, Run! users designed to explore interest in physical activity, exergaming and specific app features. The survey was sent to all Zombies, Run! users (those trying the app for free and those with a subscription) in an in-app notification, via an email newsletter, and on the Zombies, Run! Twitter account. Participants could complete the survey anonymously, or provide their email address if they were willing to be interviewed. We randomly selected from among survey respondents who were willing to be interviewed, contacting them by email. The response rate to the interview email invitation was approximately 10%; we repeated this process until we reached a desired number of interviewees, Fugard and Potts (2015). The randomization was stratified by gender in order to get equal numbers of men and women. In the survey, participants provided their age, gender (male/female/other),

ethnicity, country of residence, their reported physical activity levels (minutes of moderate to vigorous physical activity (MVPA) per week) and whether they perceived their activity levels had changed as a result of using Zombies, Run!.

Interviews were carried out from September to November 2019. Eligibility criteria to participate in interviews included age of 16 years or older and fluent in English. Participants could enter a prize draw for a £50 Amazon voucher and Zombies, Run! T-shirt. The study was approved by the UCL ethics committee (Project ID 3777/004), and all participants provided informed written consent before the interview. Methods and results are presented in line with the COREQ checklist (Tong et al., 2007).

Interviews were carried out by NF, a female Health Psychology researcher with experience in qualitative interviewing. Interviews were carried out by telephone or video call depending on participant preference. NF had no prior relationship with any study participants before approaching them to participate. They were guided by a semi-structured topic guide developed by NF, AF and HP designed to understand users' personal characteristics, considering factors like their motivations for using a physical activity app, which game features were appealing and why, and which behaviour change techniques they engaged with (Michie et al., 2011; Michie et al., 2013). Although the topic guide did not have a specific theoretical basis, it formed part of a larger intervention development study (Farič et al., 2021) conducted within the MRC framework for developing complex interventions (MRC, 2019). The full topic guide is presented as supplementary material. All interviews were audio-recorded with the permission of the participant.

Data Analysis

Audio-recorded interviews were transcribed verbatim by an external transcription company and verified against the actual recordings by NF and TB. Qualitative analyses were conducted using NVivo software. The first stage included familiarization with the data. Two researchers (NF and TB) coded each of the 30 transcripts separately. Initial codes were identified, noted, edited, and grouped into emerging themes to ensure theoretical connectedness in an inductive manner (Gale et al., 2013; Lorelli et al., 2017). Transcripts were further analysed by NF and TB using inductive and deductive framework analysis methodology (Braun and Clarke, 2013). The themes were mapped according to the framework of the interview topic guide initially (Multimedia Appendix 1), but themes also emerged from the data. Any comparison and adjustment to the coding was made (Braun and Clarke, 2013). The final coding framework is presented in Table 2. The study team adopted reflexivity and a

collaborative approach, where each stage of the analysis process was discussed to ensure correctness of the themes and their supporting data, as well as any possible reflections and projections due to personal experience or background of the researchers (Griffiths et al., 2019). Interrater agreement in consistency of themes, constant data comparison, and proper audit trail of material and processes were used as validation strategies.

Results

2274/5342 (43%) of those who completed the quantitative survey indicated that they would be willing to be interviewed. Of these, 250 were randomly selected and sent study information sheets and consent forms. 30 participants consented and their demographics are presented in **Table 1**. Interviews lasted between 12 to 37 minutes (mean=25). 28/30 (93%) reported that their levels of physical activity had increased since using Zombies, Run!.

Table 1. Demographic characteristics of interviewed ZR users

Variable	Frequency N (%)
Gender	
Male	15 (50)
Female	15 (50)
Ethnic background	
White	28 (93)
Asian	1 (3)
Other	1 (3)
Age (band)	
16-20	2 (7)
21-30	7 (23)
31-40	10 (33)
41-50	10 (33)
51-60	1 (3)
Country of Residence	
US	9 (30)
UK	7 (23)
Netherlands	3 (10)
Each: Austria, Canada, China, Germany, Italy, Norway, Russia, Slovakia, Sweden, Vietnam	1 (3)
Highest Level of Education	
Primary/Elementary school	1 (3)
Secondary school/High school	3 (10)
Bachelor's University degree (e.g. BA, BSc, associate degrees)	13 (43)
Vocational qualifications (e.g. NVQ, BTECs)	1 (3)
Master's University degree (e.g. MA, MSc)	8 (27)
Professional (e.g. MD, DDS) or Doctoral degree (e.g. Ph.D, Ed.D)	3 (19)
Other	1 (3)
Disability or illness affecting ability to perform PA	
Yes	5 (17)

No	25 (83)
Do you think your physical activity/exercise levels have changed because of using ZR?	
Yes, they increased	28 (93)
No, they didn't change	1 (3)[a]
The mean length of PA in mins/week of MVPA before using ZR?	77.3 (range 0-450)
The mean length of PA in mins/week of MVPA after using ZR?	175.6 (range 60-300)

[a] where numbers do not add up to N=30 it means the remaining responses are missing

Themes

Themes and subthemes are shown in Table 2. Four overarching themes were identified and these were 'The primary reasons for using the app'; 'Features'; 'The effect of Zombies, Run!' and 'The pros and cons of the app'. Themes and subthemes are presented with illustrative quotes (with participant age and gender).

Table 2. Themes and subthemes of the interviews

Themes	**Sub-Themes**
Reasons for starting and staying with ZR	• Storyline, gamification of physical activity or adding fun to physical activity • Need for long-term physical activity
Preferred ZR features	• Immersion achieved via narrative and storyline and users' responses • Immersion distracts from the intensity of physical activity • Workout options for anyone
Perceived effect of ZR	• Motivation • Feeling rewarded when using the app • Feeling of achievement • Positive health effects • Positive mental health benefits • Identity shift
Pros and cons of the app	• Tracking (pro) • Characters (pro) • Cost (con) • Personalization (con) • Technical improvements (con)

Reasons for starting and staying with ZR

Storyline, gamification of physical activity or adding fun to physical activity

Participants talked about reasons they were first attracted to the app. Half of participants were drawn to the zombie or apocalyptic stories and themes. Those that were not were attracted by the concept of gamifying their physical activity. Participants initially discovered Zombies, Run! either by

chance, word-of-mouth, specialist fitness or gaming magazines, articles and shows online and the app store when browsing for fitness or running apps.

Need for long-term physical activity

Participants reported using the app from a few months to 8 years (since the app's inception). Many recognized themselves as users who wanted to increase their physical activity levels, such as to start running or maintain running over longer periods of time, and for different reasons such as wanting to perform physical activity with a different experience. Many participants felt that Zombies, Run! was appealing because it was something unusual or different and more motivating because it had a potential to distract from discomfort of when performing physical activity:

> *Oh wow, it was a long time ago. […] I've always liked running, I haven't done it a great deal and back then I would have had young children so I think I was probably looking to try to get back into doing a bit of exercise. Erm, it was mostly driven by, it looks like a really fun thing. […] I just enjoyed it. I like the fact that it takes the edge off the pain of running. So, when you kind of get back into something and you're trying to get fit, well, most of the time, you know, you're pushing yourself anyway, and it's quite difficult and then getting the motivation to get out again. […] It helped to kind of continue that because you know, good story. (M,42)*

Preferred ZR features

Immersion achieved via narrative, storyline and users' responses

The simulation and role-play were the most attractive features of Zombies, Run! app which helped users in starting as well as continue performing physical activity. For a few users, the storyline was not the most appealing part. For those, the immersion element and personal response to the storyline, is what appealed to them:

> *Largely actually, it's the storyline, it keeps me engaged. Yeah, that's the… I attribute, fully, both when I was running before and then I quit for a while and then again now. Because I did Couch to 5K [another running app] again this past fall and both times I attribute Zombies, Run! to keeping me running after finishing Couch to 5K. (M,41)*

Immersion distracts from the intensity of physical activity

The storyline and immersion made physical activity more enjoyable and sometimes made people forget that they were performing it. This also resulted in people wanting to come back to it, because the focus wasn't on the discomfort but on factors such as continuing the storyline, gathering supplies, looking forward to building the base Abel Township in the app, etc:

> *The story then fits into reality, I suppose. It is that little bit of escapism, and it has made me, in combination with a few other things that have made me from someone who would not really exercise at all, to be someone who actually, running is my primary method of exercise,*

and I like doing it, and it is partly down to things like that app just making it a little bit more of an escapism, and a little bit more fun just to take your mind off it. (M,50)

Workout options for anyone

The users valued different story missions and app features. All participants enjoyed music and narrative blending together which motivated many people to return to the app and use it. About half the sample said that music alone, or discovering new music tracks was boring and repetitive, and that the appeal of Zombies, Run! was that it was always something new and unexpected:

Zombies, Run! is the one app that actually has character and is actively in development, so I know I have something to look forward to, for example, in the new seasons and so forth. But, well, I don't really listen to audiobooks or anything else. I prefer music, but Zombies, Run! is the perfect filler to all the music I listen to. M, 16

The Zombies, Run! app options appealed to different users in different ways which suited their personal physical or mental health needs. The options, such as zombie chases, interval training, radio mode, etc. are designed to get engaged people with no or little physical activity, all the way to those training in professional environments (such as running marathons, part of physical rehabilitation therapy or for obstacle course racing or in the military to take a few examples from the users in this study). One participant explained his favourite features, and how the narrative of the app impacted on his running:

The random zombie chases. Even though I love them I hate them at the same time. Extremely helpful. Because when you have a random hey, you better start hauling tail, for 60 seconds or whatever, that. That is a good break because it breaks the monotony even in a different way. It causes me to brush the plateaus that I may be sitting in. And I don't know when they are coming. So, it'd not something I can plan, you know. Maybe the uphill part. And my goodness. I hate when that happens. It happened this morning as a matter of fact. But it's good. Because now I need to speed it up, even though these hills would kill me most of the time. It's not like a boundary that I know I am about to push. Like when I start out, I don't know if I am going to get zero of those, or if I am going to get four of those. (M,46)

Perceived Effect of ZR

Motivation

The main effect of Zombies, Run! was that the features in the app increased people's motivation and return to Zombies, Run! and physical activity more frequently, pushing their boundaries and giving users a new experience of physical activity (as not boring). Some people claimed it made them feel like they were on a mission, which would tie in with the high score for role-play feature:

I'm really loving it. I love the fact that when it's a rainy day, it gives me that extra impetus to actually go and run, because it's a story, and I want to find out what happens next. Um, and I don't let myself play it when I am walking, so I have to go running. And it's nice to have to break up your run a little bit, and not just have the music, but to have narrative as well. (F,38)

Feeling rewarded when using the app

More frequent engagement in physical activity helped people feel better on many levels. Some people explained that they felt rewarded and which made them feel better about themselves:

I grew up fat, and I was constantly told, you can't do physical activity because you're just not capable, you're not fit. I kind of internalized that message, that I just wasn't capable of running. I still struggle with finding anything positive about myself. So, running was part of being able to do that, and there's a quote that I read the other day, I don't know who said it, but it was something like, "running isn't a punishment for eating, it's a celebration of what your body can do". Um, and I'm trying to internalize that kind of message. Because when I run it's, it feels like actually I'm doing things that people told me I couldn't do, that I didn't believe I could do because I'm a fat person. And I can also help to improve my mental health, and to keep my mood up by engaging in exercise. (F,38)

Feeling of achievement

The feeling of reward was tied to achievement. Some participants felt more strongly that they had overcome particular metal or physical blocks, and therefore have achieved new goals. The feeling of achievement in performing more physical activity were very closely linked to being motivated to listen to the story:

I really enjoy it. It really helps me motivated. It keeps workouts from getting boring. It's really got a lot for me. And then sometimes I go back and I'm like, wow I walked that much. So, it kind of helps, uh, keep you going with it. (F,50)

The storyline and narrative is something I want to follow and keep up with. Um, but also on the runs, it's quite motivating with the in-run talk it gives you. And even the little starting bit you know, it feels like, you know, you're going to achieve something. (M,31)

Positive health effects

All users claimed that physical activity makes them feel better. However, some had more specific and drastic changes to both their physical or mental health. The improvement in their physical health was due to the increased motivation that Zombies, Run! gave them to perform physical activity which helped them change their health outcomes over time:

[running] It's just part of one of a number of things that I have incorporated back into just part of who I am. You know, I am no longer a smoker, I don't, that's not a thing I do anymore. Um, I am a runner, it's part of what I do three days a week, um. Yes, I don't eat the fast food that I used to eat, it's just not something that now me does. (M,41)

Positive mental health benefits

Half of the sample explicitly stated that Zombies, Run! has had a positive impact on their mental health, whether it was just feeling better after a long, stressful day, or much more significant mental health changes, such as managing mental health conditions ranging from post-traumatic stress disorder (PTSD), borderline personality disorder (BPD), agoraphobia, eating disorders, anxiety and depression. For some people, Zombies, Run! alone did not seem to impact on their mental health, but they said that being more physically active helped their mental health and wellbeing:

> *And the second major point is I think, for me, is more geared toward my social anxiety, maybe shyness. Because when I am listening to such a story, I am thinking about the story itself. I do not think about like, people that surround me. So, when I listen to Zombies, Run!, it is easier for me to just generally exist in such an environment as the, compared to the gym that is full of people I don't extraordinarily know. In a way it helps with confidence, it relieves some workout anxiety. (F,26)*

Identity shift

Some people indicated that they did not initially identify themselves as gamers or runners, but that the app had changed this identity to become either or both of these, while others never really thought much about these identities. Only five users identified themselves exclusively as 'a runner' before using Zombies, Run! in comparison to 12 after using the app. Additionally, only four users identified as 'both' (a gamer and a runner) before using the app, while 13 identified as 'both' after using the app.

Pros and Cons of the App

Tracking

Some users specifically mentioned how much they valued the statistics and logs, but for others the stats were either no longer important, or less important. The tracking options in Zombies, Run! helped some users run longer distances in shorter time or increase their running speeds at particular points. In Zombies, Run!, the tracking does not work by GPS and it is not related to actual physical distances. The app only tracks the speed and duration of movement. For some users this was a shortcoming but for others, they preferred that the app did not track their location as it preserved their privacy:

> *When I first started running I was really excited about the stats and seeing my kilometre times go down and seeing my run times get shorter. And now I'm just addicted to knowing what's going to keep happening, finding out about the project that you're part of, that you don't know anything about. (F,28)*

Characters

As mentioned before, one of the most appealing features of Zombies, Run! was the story which included different characters (acted by professional actors). Many people formed connections with characters and felt upset when something happened to them or if they got killed. Other people also enjoyed playing a character themselves and liked how everyone was the same character:

> It's an amazing storyline I that that's the one thing that keeps me with it. The characters are believable. So, erm, I also find that when I do run, at times I forget that I am running. Which is really good because sometimes I really don't want to run, so yeah, no it's good. And I have actually been known to laugh out loud, loud occasionally as I am running. […]. I've been running with Sam Yao which is the main character for four years. And it's bizarre, they almost become like family. I absolutely love hearing his voice when I do run. (F,37)

Cost

The accessibility of the app was another appeal. For some people, the purchase of particular membership may have been a barrier initially but after trying the free version all users purchased different options:

> I had a gym membership that I hardly used. I was just getting fed up and thinking, do you know what, I can just save some money and just go running and when I saw this app, I thought that sounds like my sort of thing, since it is. (M,50)

Personalization

One of the major feedbacks regarding the features of the app was that it offered less personalization options than the users expected. Despite many app choices, there were comments about preference for more narratives (not an apocalyptic storyline), app personalization such as colour and music. In this study, only one user stopped using Zombies, Run! for good because the storyline didn't fit their running settings (see more below), while others dipped in and out of the use, some even repeating many seasons, returning to it to keep them motivated with physical activity.

Technical improvements

The users offered additional feedback for the app developers, which they believed would enhance Zombies, Run! app and the game element of the app. The base-building feature in the Zombies, Run! game was most criticized, particularly by those who had used the supplies to build it and could no longer expand it or do anything with the base despite still gathering supplies. Two participants claimed they had trouble connecting Zombies, Run! to Apple Watch (Apple Inc.) which frustrated them. Only one user had stopped using the app after many years of usage due to the setting in

which they ran (treadmill) and one user mentioned their feeling of saturation with the storyline which no longer felt believable:

> *The feature where like an attack comes and you have to speed up to run faster, that never really works well for me on a treadmill. (M,32).*

Discussion

Principal Findings

This study found five overarching themes and 16 subthemes that provided a greater insight into the experience of Zombies, Run! smartphone app. Users' favourite features of Zombies, Run! were the perceived feeling of immersion and presence that was achieved through narrative (storyline), the characters, and music which was linked into the game via their music libraries. The narrative/storyline allowed participants to engage in physical activity for much longer periods of time, not only within one physical activity session, but over longer periods of time, leading to long-term engagement. The exergame increased people's presence which is congruent with a number of other studies (Slater and Wilbur, 1997). The narrative also allowed participants to forget about the negative aspects of physical exertion which has been confirmed in another randomised study, which compared Zombies, Run! to another popular running app Nike Run Club (Gillman and Bryan, 2016). In a 2014 review of 27 studies it was confirmed that a strong correlation exists between exergaming and increased energy expenditure (up to 300% higher than during resting) (Sween et al., 2014).

Some participants valued the tracking options for greater overview and statistics of their physical activity, which is in line with an expert panel analysis of the important features for the effectiveness of physical activity (Dallinga et al., 2018). However, other users called for more personalisation features, lower cost of subscription(s) and to increase the game-play component in the app. In addition to the app's positive influence on people's physical health and strength due to the increased motivation and enjoyment with engaging in more physical activity, half of the participants also reported that the exergame also positively impacted on their mental health, mostly by reducing stress, decreasing anxiety and negative self-talk and giving them a mental break.

Motivation and Perception of Physical Activity

Although Zombies, Run! was designed to engage people with running, participants in this interview study used the app for other types of physical activity such as walking and cycling. Zombies, Run! helped people change their experience of physical activity, via a story that acted as a filler, entertainment and a distraction, especially from limiting thoughts and pain during physical exertion. Zombies, Run! also helped people push their boundaries, achieve new goals, feel rewarded and create ways for them to engage in physical activity frequently (like a routine or a habit). These new experiences were reported as a natural result of immersion in the Zombies, Run! storyline and were not forced or imposed by the app. Similar effects on physical activity have been found in other

virtual environments such as VR cycling where VR conditions increased situational motivation, intrinsic motivation, internal and external regulation and lower amotivation (Liu et al., 2019).

The appeal of the Zombies, Run! app was the story itself and the way the story was executed, rather than the actual game play, which was very minimal. Participants valued that the app was supportive, but that didn't require them to look at the screen while performing physical activity. The feedback was that in comparison to other PA apps, ZR app was very different. Although not all participants were fond of zombie or apocalyptic stories, the app was described as unique, quirky, fun and engaging, with more than a half of the sample recommending the app to their friends or family.

The users reported a shift in their perception of how it feels to engage with physical activity when using Zombies, Run!. This study suggests that Zombies, Run! can potentially create behaviour change, such as seen in the Theory of Planned Behaviour (TBP) (Ajzen, 1985) in a few ways: One, by modifying people's perception of physical activity by distraction (narrative /story-line); two, by modifying people's perception of physical activity through the actual experience of it (when physical activity is no longer just physical activity, but a role-play); three, by making physical activity more enjoyable via an association with the story or narrative in the exergame (gamification or audio-AR aspect); and four, the feeling of euphoria after vigorous physical activity which has been demonstrated in several studies (Sonnenblich et al., 2018; Prabakan et al., 2015). All of these links could be explored in future studies. A study with 30 participants assessing mobile running apps (Nike Run Club and Zombies, Run!) demonstrated no differences on primary motivational state outcome between the apps, however, games-based app Zombies, Run! showed greater dissociation from physical activity and increased enjoyment (Gillman and Bryan, 2016).

A Unique Style of Augmentation and Reactive Behaviours

The popularity and satisfaction with Zombies, Run! were apparent. Zombies, Run! is not a conventional smartphone game or conventional running app. It does not fully fit the category of horror games because it is not focused on the elements to do with horror or dread, but instead focuses on the player and their effort to sustain the base and keep alive in the game (as a 'Runner 5'). The game also doesn't fully fit the category of AR because there is very little visual element to participating in the game (apart from choosing the run/chase and deciding to pause or stop the run). It instead relies on the player's imagination to fill the gaps. The players, in a sense, become responsible for their own projection of the story which has also been shown in other audio augmented games (e.g. sound packman – Chatzidimitris et al., 2016). The audio element and

immersion are heightened by the use of headphones which create a feeling of being in the story (Stobbart, 2019).

When it comes to the narrative utilization in games, only in cases when Interactive Narrative (IN) and the Emergent Narrative (EN) are applied can players to some extent modify the storyline by the interaction with the game. In this respect, the narrative of Zombies, Run! is not a case of IN or EN because the storyline is more rigid and does not allow the users to modify any aspect of the narrative or the game. So, Zombies, Run! follows a conventional narrative structure, but, it is the integration of the game into a player's real-world environment (e.g. running outside, or on the treadmill, or cycling, or in other activities) that allows users to have freedom over real-world decisions and movements (Louchart et al., 2008).

It is plausible that this freedom of choice that provides people with a feeling of complete autonomy, a known factor to increase engagement with physical activity (Sanders et al., 2016), which is also part of a health behaviour theory, Self-Determination Theory (SDT) (Ryan and Deci, 2000). Zombies, Run! can therefore be classified as AN game or reactive storytelling according to Stobbart (2019). This definition is consistent with our results showing users enjoyed the interlace of music, the storyline and the real-world setting. This created the feeling of immersion and role-play, which were the two most popular features of the app, however, the immersion was distinct from the immersion in head-mounted display (HMD) VR, which is achieved through a full visual field. This is another point in which future researchers could discern the precise mechanisms in which the audio narrative games drive physical activity. Other location-based games such as Pokémon Go also used AR to create immersion to activate physical activity in the real-world (Baranowski and Lyons, 2020). For Pokémon Go a large number of factors predicted engagement and game-play. A scoping review of the studies points that the reasons for initiation are similar to the reasons in our study (Baranowski and Lyons, 2020). These include fun, immersion (escapism), nostalgia, social ties and a desire for physical activity. Fun is also a predictor of a longer gameplay (Baranowski and Lyons, 2020). The preferences for these features are therefore universally important in apps to sustain physical activity, but are not limited to one demographic group. Instead, they appeal to a wide variety of people and populations with diverse characteristics, in the same way as smartphones or the use of the internet on a smartphone are not limited to one demographic group (Statista, 2021c). It is likely that older age groups (55-64 years, 65-74 years and 75+ years) would be least likely to use AR smartphone exergames because they are groups that are least likely to ever play games at home or elsewhere on a mobile phone (Statista, 2021d).

Strengths and Limitations

In this study we have presented the qualitative experiences with the Zombies, Run! app. This type of evaluation is a crucial component in addressing the development of smartphone AR apps for physical activity. Qualitative data provide more detailed evaluation of the engagement patterns and preferences of use of smartphone app Zombies, Run!. We obtained a reasonable sample size with diverse participants (Fugard and Potts, 2015). However, due to the cross-sectional qualitative design of the study, the users are likely not representative of the overall Zombies, Run! population or a general population. The number of people participating in this study is still likely to be indicative of some patterns of experience with Zombies, Run! app, as well as the effects of narrative-based AR exergames, but a larger sample or repeated studies would have to be carried out to learn more about the diverse experiences of people using Zombies, Run! app for physical activity.

When asked why they had agreed to the interview, some participants said they believed it was the right thing to help researchers or developers for altruistic reasons, while others said it was because they were fans of the game and wanted to invest in it and help support it in some way. No participants in this study exclusively reported negative experiences, with only one participant stopping the subscription as they *"no longer felt connected to it [the app]".* This may have led to bias in our results as participants who did not find the app engaging or motivating for physical activity may have been less inclined to agree to be contacted for interview and will have been less likely to have seen to initial survey.

Implications

The Zombies, Run! app showed a difference in the uptake and duration of engagement in physical activity among our participants. The app also helped people achieve significant physical and mental health benefits. Due to the large number of people reporting mental health benefits, a future survey could expand the categories and ask participants more about the mental health history and to what extent did the decision to continue to use Zombies, Run! depend on the mental health benefits.

Zombies, Run! app may be particularly useful for engaging people in physical activity under the current Covid-19 pandemic, where many people have lost access to or are reluctant to visit health and fitness clubs, or engaging in physical activity with larger groups. Sharp declines in exercising have been noted during lockdowns (McCarthy et al., 2021). There is a potential to develop narrative based AR apps to target behaviour change in other health-related areas e.g. pain management, depression, etc.

It may be that the aesthetics and design of Zombies, Run! mean that it works well for a niche audience, but not more broadly, and the interviewees in this study are necessarily drawn from those who like the game. Nonetheless, we suggest that the broader features enjoyed by Zombies, Run! users may be applicable to other interventions to increase physical activity. One such feature was is the narrative or story-line which was reported as the most significant factor in engagement (also long-term engagement). The mental health benefits were most likely as a result of the increased levels of physical activity, with known mental health benefits, but several people expressed their mental well-being improved due to the narrative, characters and the game which also helped in a sense of achievement and progress which is essential for successful public health interventions.

Conclusions

This is the first study to describe how narrative-based AR, AN, or reactive storytelling app can influence people's motivation and experiences with physical activity. Due to the interest and success of this study, and the current global health crisis with COVID-19, it is likely that the expansion of narrative-based AR will increase, especially in helping people form new health-related habits and behaviours.

Acknowledgments

Conflicts of Interest

This research is sponsored by the Medical Research Council industry partnership grant in support of the development of a VR game licensed by Six to Start. There is no legal, financial, or commercial conflict with our industry partner company, Six to Start.

Multimedia Appendix 1

Interview Schedule.

Abbreviations

AR: Augmented reality
AN: Augmented narrative
BPD: Borderline personality disorder
EN: Emergent narrative
GPS: Global positioning system
HMD: Head-mounted display
IN: Interactive narrative
MRC: Medical Research Council
NCDs: Non-communicable diseases
PA: Physical activity
PTSD: Post-traumatic stress disorder
RCT: Randomized controlled trial
SDT: Self-determination theory
TPB: Theory of planned behaviour
UK: United Kingdom
US: United States
VR: Virtual reality
ZR: Zombies, Run!

References

Ajzen, I. 1985. From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckmann (Eds.), Action-control: From cognition to behavior (pp. 1 l-39). Heidelberg: Springer.

Apple (Inc). 2021. App Store: Zombies, Run! [online]. Available at: https://apps.apple.com/gb/app/zombies-run/id503519713 (Accessed: 20 Mar 2021)

Arem H, Moore SC, Patel A, Hartge P, Berrington de Gonzales A, Visvanathan K, Campbell PT, Freedman M, Weiderpass E, Adami HO, Linet MS, Lee IM and Mathews CE. Leisure time physical activity and mortality: a detailed pooled analysis of the dose-response relationship. JAMA Intern Med, 2015,175(6): pp. 959-967. doi: 10.1001/jamainternmed.2015.0533

Baillot A, Romain AJ, Boisvert-Vigneault K, Audet M, Baillargeon JP, Dionne IJ, Valiquette L, Chakra CNA, Avignon A, Langlois M-F. Effects of lifestyle interventions that include a physical activity component in class II and III obese individuals: a systematic review and meta-analysis. Plos one. 2015;10(4):e0119017. DOI: 10.1371/journal.pone.0119017.

Baranowski T, and Lyons EJ. Scoping Review of Pokémon Go: Comprehensive Assessment of Augmented Reality for Physical Activity Change. Games for health journal 2020, 9(2), 71–84. doi: 10.1089/g4h.2019.0034

Barnett LM, Bangay S, McKenzie S and Ridgers ND. Active gaming as a mechanism to promote physical activity and fundamental movement skill in children. Frontiers in public health 2013,1, p. 74. doi: 10.3389/fpubh.2013.00074

Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol 2006,3(2):77-101.

Chatzidimitris T, Gavalas D, Michael D. SoundPacman: Audio augmented reality in location-based games. 18th Mediterranean Electrotechnical Conference (MELECON), Lemesos, Cyprus, 2016, pp. 1-6, doi: 10.1109/MELCON.2016.7495414.

Cowdery J, Majeske P, Frank R, Brown D. Exergame Apps and Physical Activity: The Results of the ZOMBIE Trial, American Journal of Health Education 2015,46:4, 216-222, DOI: 10.1080/19325037.2015.1043063

Craig P, Dieppe P, Macintyre S, Michie S, Nazareth I, Petticrew M, Medical Research Council Guidance. Developing and evaluating complex interventions: the new Medical Research Council guidance. BMJ 2008 Sep 29;337(sep29 1):a1655-a1655 doi:10.1136/bmj.a1655

Dallinga J, Janssen M, van der Werf J, Walravens R, Vos S, Deutekom M. Analysis of the Features Important for the Effectiveness of Physical Activity–Related Apps for Recreational Sports: Expert Panel Approach. JMIR Mhealth Uhealth 2018,6(6):e143

Direito A, Jiang Y, Whittaker R, Maddison R. Apps for IMproving FITness and Increasing Physical Activity Among Young People: The AIMFIT Pragmatic Randomized Controlled Trial. J Med Internet Res. 2015,17(8):e210. Published 2015 Aug 27. doi: 10.2196/jmir.4568

Farič N, Smith L, Hon A, Potts HWW, Newby K, Steptoe A, Fisher A. A Virtual Reality Exergame to Engage Adolescents in Physical Activity: Mixed Methods Study Describing the Formative Intervention Development Process. J Med Internet Res 2021,23(2):e18161. doi: 10.2196/18161

Fox KR. The influence of physical activity on mental well-being. Public Health Nutrition 1999,2(3),pp. 411-8. doi: 10.1017/s1368980099000567

Fugard AJ, Potts HW. Supporting thinking on sample sizes for thematic analyses: a quantitative tool. Int J Soc Res Methodol. 2015,18(6): pp. 669-684. doi: 10.1080/13645579.2015.1005453

Gale NK, Heath G, Cameron E. et al. Using the framework method for the analysis of qualitative data in multi-disciplinary health research. BMC Med Res Methodol 2013,13(117). doi:10.1186/1471-2288-13-117

Gillman AS, Bryan AD. Effects of Performance Versus Game-Based Mobile Applications on Response to Exercise. Ann Behav Med. 2016,50(1):157-162. doi:10.1007/s12160-015-9730-3

Griffiths J, Lever Taylor B, Morant N, et al. A qualitative comparison of experiences of specialist mother and baby units versus general psychiatric wards. BMC Psychiatry. 2019,19(1):401. Published 2019 Dec 16. doi: 10.1186/s12888-019-2389-8

Haichun S. Impact of exergames on physical activity and motivation in elementary school students: A follow-up study. Journal of Sport and Health Science 2013,2, 138–145. doi: 10.1016/j.jshs.2013.02.003.

Hamer M, Sabia S, Batty GD, Shipley MJ, Tabak AG, Singh-Manoux, Kivimaki M. Physical activity and inflammatory markers over 10 years: follow-up in men and women from the Whitehall II cohort study. Circulation 2012,126(8), pp.928-33. doi: 10.1161/CIRCULATIONAHA.112.103879.

Kredlow, M.A., Capazzoli, M.C., Hearon, B.A, Calkins, A.W., and Otto, M.W. (2015). The effects of physical activity on sleep: a meta-analytic review. Journal of Behavioural Medicine, 38(3), pp. 427-49. doi: 10.1007/s10865-015-9617-6.

Liu W, Zeng N, Pope ZC, McDonough DJ, Gao Z. Acute Effects of Immersive Virtual Reality Exercise on Young Adults' Situational Motivation. Journal of clinical medicine 2019, 8(11),1947. doi: 10.3390/jcm8111947

Lorelli LS, Norris DE, White DE, Moules NJ. Thematic Analysis: Striving to Meet the Trustworthiness Criteria. International Journal of Qualitative Methods 2017,16(1): doi: 10.1177/1609406917733847

Louchart S, Swartjes I, Kriegel M, Aylett R. Purposeful Authoring for Emergent Narrative. In: Spierling U., Szilas N. (eds) Interactive Storytelling. ICIDS 2008. Lecture Notes in Computer Science, vol 5334. Springer, Berlin, Heidelberg. doi: 10.1007/978-3-540-89454-4_35

Lu AS, Baranowski T, Hong SL, Buday R, Thompson D, Beltran A, Dadabhoy HR, Chen TA. The Narrative Impact of Active Video Games on Physical Activity Among Children: A Feasibility Study. J Med Internet Res 2016,18(10):e272. PMID: 27742605

Martin A. Getting Fit With The Undead: The Zombies, Run Story. [online] Alphr 15 May 2017. [online] Available at: https://www.alphr.com/business/1005907/getting-fit-with-the-undead-the-zombies-run-story/ (Accessed: 09 April 2021)

McCarthy H, Potts HWW, Fisher A. Physical Activity Behavior Before, During, and After COVID-19 Restrictions: Longitudinal Smartphone-Tracking Study of Adults in the United Kingdom. J Med Internet Res. 2021,3;23(2):e23701. doi: 10.2196/23701

Medical Research Council (MRC). 2019. Developing and evaluating complex interventions. 2019. [online] MRC.UKRI.ORG. Available at: https://mrc.ukri.org/documents/pdf/complex-interventions-guidance/ (Accessed 20 Mar 2021).

Michie S, Richardson M, Johnston M, Abraham C, Francis J, Hardeman W, Eccles MP, Cane J, Wood CE. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann Behav Med 2013,46(1): pp. 81-95. doi: 10.1007/s12160-013-9486-6.

Michie S, van Stralen MM, West R. The behaviour change wheel: A new method for characterising and designing behaviour change interventions. Implementation Science 2011,6:42. doi: 10.1186/1748-5908-6-42

Prabakaran S. Endocannabinoids mediate runner's high. Science Signaling, 2015,8(401), ec322. doi: 10.1126/scisignal.aad7694

Reiner M, Niermann C, Jekauc D, Woll, A. Long-term health benefits of physical activity-a systematic review of longitudinal studies. BMC Public Health 2013,13:813. doi: 10.1186/1471-2458-13-813.

Robertson, A. (2020). The Ultimate VR Headset Buyer's Guide. [online] The Verge. Available at: https://www.theverge.com/a/best-vr-headset-oculus-rift-samsung-gear-htc-vive-virtual-reality (Accessed: 09 April 2021)

Ryan RM, Deci EL. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being". American Psychologist 2000,55(1):68–78. doi: 10.1037/0003-

Sanders GJ, Juvancic-Heltzel J, Williamson ML, Roemmich JN, Feda DM, Barkley JE. The Effect of Increasing Autonomy Through Choice on Young Children's Physical Activity Behavior. J Phys Act Health 2016,(4):428-32. doi: 10.1123/jpah.2015-0171.

Slater M, Wilbur S. A Framework for Immersive Virtual Environments (FIVE): speculations on the role of presence in virtual environments. Presence: Teleoperators & Virtual Environments 1997, 6(6):603-616. doi: 10.1162/pres.1997.6.6.603

Sonnenblick Y, Taler M, Bachner YG, Strous RD. Exercise, Dehydroepiandrosterone (DHEA), and Mood Change: A Rationale for the "Runners High"? Isr Med Assoc J. 2018 ,20(6):335-339. PMID: 29911751.

Statista. 2021. Number of smartphone users worldwide from 2016 to 2023 (in billions). 31 March 2021 [online]. Available at: https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (Accessed 09 April 2021)

Statista. 2021b. Mobile gaming market in the U.S. – statistics and facts. 06 April 2021 [online] Available at: https://www.statista.com/topics/1906/mobile-gaming/ (Accessed 09 April 2021)

Statista. 2021c. Share of individuals who accessed the internet via a mobile phone in Great Britain in 2019 by age and gender. [online]. Available at: https://www.statista.com/statistics/275985/mobile-internet-penetration-in-great-britain-by-age-and-gender/#:~:text=As%20of%202018%2C%2095%20percent,own%20a%20smartphone%20is%20growing. (Accessed: 7 July 2021)

Statista. 2021d. Do you ever play games at home or elsewhere on a mobile phone? [online]. Available at: https://www.statista.com/statistics/300522/mobile-gaming-in-the-uk-by-age/ (Accessed: 7 July 2021)

Stobbart D. 2019. Videogames and horror. From amnesia to Zombies, Run!. University of Wales Press; 1st edition. ISBN: 978-1-78683-436-2

Sween J, Wallington SF, Sheppard V, Taylor T, Llanos AA, Adams-Campbell LL. The role of exergaming in improving physical activity: a review. Journal of Physical Activity and Health 2014,11(4), pp. 864-870. doi: 10.1123/jpah.2011-0425.

Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups, International Journal for Quality in Health Care, 2007,19(6), pp. 349–357. doi: 10.1093/intqhc/mzm042

Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. CMAJ 2006; 14,174(6): pp. 801-809. doi: 10.1503/cmaj.051351

Whelton SP, Chin A, Xin X, He, J. Effect of aerobic exercise on blood pressure: a meta-analysis of randomized, controlled trials. Annals of Internal Medicine 2002,136(7), pp. 493-503. doi: 10.7326/0003-4819-136-7-200204020-00006

World Health Organisation (WHO). 2014. Global status reports on noncommunicable diseases. 2014 [online]. Available at: https://www.who.int/nmh/publications/ncd-status-report-2014/en/ (Accessed 22 Jan 2021)

World Health Organisation (WHO). 2020. Physical activity. 26 November 2020 [online]. Available at: https://www.who.int/news-room/fact-sheets/detail/physical-activity (Accessed 22 Jan 2021)

Multimedia Appendix 1

Interview Schedule

Mention that the interview is being recorded but will be completely anonymous and confidential.

Give participant briefing on the overall project:

"Thank you for your interest in this study. UCL have been funded by the Medical Research Council (MRC) to develop a virtual reality (VR) fitness game which aims to increase physical activity in teenagers. We're exploring ways to make the intervention as effective as possible, which includes understanding how people engage with virtual and augmented reality (AR) exergames. It doesn't matter what you say, simply interested in what you think and what your experiences are. You also do not need to know anything about VR or AR in terms of technology, but since you have been using Zombies Run! exergame, we would like to hear your experiences with the app.

So that you have an idea about what we are referring to when we mention the intervention; we are working with game designers to develop a game that aims to engage teenagers with exercise. We don't know exactly what this will look like yet as we are still in the early stages of research. But we do expect the VR game/intervention to be based at home."

Section 1: Informed consent and demographics (5 mins)

- Have you seen the information sheet? Do you understand it? Any questions?

Are you happy I go ahead and start the interview?

- **Read information sheet, check they understand, respond to any questions, and seek consent**
- **Check eligibility**
  - Zombies, Run! user (previously or currently)
- **Record demographics (on Data Collection Sheet)**
  - Age
  - Ethnicity
  - Gender
  - Country of residence

Section 2: Physical activity before and after Zombies, Run! (10 minutes)

The purpose of this section is to understand ZR users opinions about the importance of physical activity, specifically relating to the physical activity levels before and after using the app. It is also an opportunity to build rapport.

- When did you start using ZR?
- What drew you to the app?
- What were your PA levels like at the time? *PROBE:* was this the motivation for start using the app?

- I see that you indicated that you liked/disliked PE in school… do you still have the same experiences regarding physical activity?

Section 3: Zombies, Run! features (15 minutes)

- How often do you use ZR? *PROBE:* Did your ZR use increase over time?
- Which are your favourite ZR features and why?
- I can see you listed X features as most preferred features and X as least preferred, can you please tell me more about that?
- What about the ZR storyline is so appealing to you?

ZR in relation to physical activity

- Do these features make you perform more physical activity and if so, in what way exactly?
- How has your running/walking changed as a result of using ZR/or as a result of these favourite features?

Section 4: Issues with the ZR app (5 minutes)

- Would you change the app (e.g. features, layout, subscription) in any way?
- Are there any issues that you have been experiencing?
- Do you have any feedback for ZR developers?
- To those who indicated that they no longer use ZR: why did you stop using ZR?
-

Section 5: Physical and mental health benefits (5 minutes)

- You mentioned/indicated that you experienced [physical/mental] changes as a result of ZR use. Can you please tell me more about that?
- How did these changes impact your health and well-being?

Section 6: Debriefing and answer any questions (5 minutes)

- Is there anything else about the app or ZR experience that you would like to share?
- Would you recommend the app to your friends/family?

Explain about the right to request a transcript, withdrawal and publication of the findings in a journal.