

Physical activity, gaming and virtual reality: the views of parents of adolescents

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Abstract

Background: Virtual reality (VR) exergaming may be a promising avenue to engage adolescents with physical activity (PA). Since parental support is a consistent determinant of adolescent PA, it is crucial to gather the views of parents of adolescents about this type of intervention.

Objective: The aim of this study was to interview parents of younger adolescents (13-17 year old) about PA, gaming and VR as part of a larger study vEngage.

Methods: Semi-structured interviews were conducted with 18 parents of adolescents. Data was synthesized using Framework Analysis.

Results: Parents believed encouraging PA in adolescents was important, particularly for mental health benefits. Most parents felt that their children were not active enough. Parents reported their adolescents gamed regularly, with perceptions of gaming mostly negative due to violent content and becoming hooked or addicted to games. There was a dilemma between screen times versus fitness time not just for their adolescent children but for parents themselves. Parents discussed an inability to relate to gaming due to 'generational differences' but an exception was exergaming, which they had played with their children in the past (eg, Wii Fit). Specific recommendations for promoting a VR exergaming intervention were provided, but ultimately parents strongly supported harnessing gaming for any positive purpose.

Conclusions: The current study suggests promise for a VR exergaming intervention, but this must be framed in a way that it addresses parental concerns, particularly around addiction, violence and safety, without actively involving them participating. While parents would rather their children

performed 'real world' PA, they believed the key to engaging them was through technology. Overall, there was the perception that harnessing gaming and sedentary screen-time for a positive purpose would be strongly supported.

Keywords: exercise, obesity, video games, adolescent, adolescence, sports, health, leisure activities, virtual reality

Introduction

Sufficient physical activity (PA) protects against non-communicable disease [1] and is associated with better mental health [2]. The detrimental health outcomes associated with low population levels of PA place significant strain on the economy and health services [3]. Adolescence, proposed to span age 10-24 years, encompasses important phase of social and biological development, and has been suggested as the stage where individuals acquire the skills that contribute to future health and wellbeing [4]. This suggests adolescence is an opportune time to encourage engagement with PA [5]. Early adolescence is particularly important in this context because levels of PA substantially decline from childhood through adolescence, and PA is increasingly displaced by sedentary behavior, particularly screen time [6,7]. UK, US and international data show that less than 20% of adolescents meet the recommended 60 minutes per day of moderate-to-vigorous PA (MVPA) [8-11]. Active adolescents are also more likely to become active adults and lead healthier lifestyles, gaining benefits both in the short-term (eg, bone health, mental health) and long-term (eg, sedentary behaviors, breast cancer, asthma, self-esteem) [13,14]. A 2018 prospective cohort which included 1826 UK adolescents (followed at 13, 14 and 15 years) found beneficial associations between device-based measures of MVPA and systemic metabolism (metabolic markers such as triglycerides, fatty acids and systolic and diastolic blood pressure). Associations were more dependent on most recent engagement, suggesting that regular PA sustains beneficial metabolic health and helps prevent disease [15].

Challenges in changing PA in adolescents

Despite the important of promoting PA in adolescents, it is not yet clear what works. A recent meta-analysis including 17 cluster randomised trials of school-based

interventions including children and adolescents up to 18 years found these had no effect on accelerometer-measured MVPA [16]. Multidimensional interventions targeting PA across a number of settings including school/home environments, policy and parents could be the promising avenue for promoting, or at least preventing decline, in PA in younger adolescents [16,17,18]. Despite the potential importance of parental support or involvement in multicomponent interventions [18] few studies have explored parental views. In addition, the possibility of wide-scale implementation of such interventions is unclear. Digital interventions have been proposed as solution that might offer wide-reach and accessibility, but the majority of trials have been small, with mixed findings and web-based [19] which is not necessarily reflective of adolescent digital behavior.

Gaming interventions to change PA in adolescents

Gaming constitutes a significant part of adolescent's voluntary leisure time behavior, with some estimates of more than 90% playing for at least an hour per day [20]. Gaming is usually sedentary, but those requiring bodily movement ie, 'exergames' have proved popular [21,22]. A 2015 meta-analysis of 35 trials showed that exergames, like Nintendo Wii, increased PA and improved physiological parameters as effectively as field-based PA, and significantly enhanced enjoyment, self-efficacy and intrinsic motivation for PA [23]. Although these small comparative trials were promising, no studies have explored exergaming interventions as a population health intervention, which is likely to involve embedding exergaming in a larger multicomponent intervention that targets social and environmental determinants; including parental support [24,25,26].

Earlier generations of exergames such as Dance Dance Revolution released in 1998 and Nintendo's Wii Fit (2007), which sold over 22 million copies worldwide, and more recently, Pokémon Go, downloaded over 800 million times, are examples that have had

huge commercial success [21,22]. Research studies on these earlier exergames have shown that playing exergames can increase energy expenditure up to 300% above resting levels and achieve PA of at least moderate intensity [23]. Randomized controlled trials in children [26,27], pre-adolescents [25], adolescents [28,29,30] and adults [31] found that exergames supported weight loss and increased fitness. However, trials have not been able to confirm exactly which psychological or social factors might lead to long-term engagement [32,33,34].

VR's potential to increase PA levels in adolescents

Virtual reality has the potential to enhance the impact of exergaming by allowing the user to feel present and immersed in the virtual environment [35]. VR ownership is predicted to rise and estimated to be owned by most homes by 2022 [36]. With the possibility that VR will reach a wider population in the following years, VR hardware and software markets are reported to be increasing to 16 billion U.S. dollars in 2022 from 6.2 billion in 2019 [37].

Small laboratory-based studies in adults have found that VR exergaming increases enjoyment and levels of PA but with lower perceived exertion than standard exercise conditions [38,39,40]. For example, one study involving 88 university staff and students found that although the heart rate was higher in VR than a standard exercise condition, participants reported feeling less tired and had higher ratings of enjoyment when VR was paired with exercise [41]. These results were echoed in an exploratory pre-post study, 12 children played a VR-based biking session (VirZoom) and traditional stationary exercise bike session for 20 minutes per session. The results showed no significant differences between the groups in the measures of heart rate, but perceived exertion during the VR-based exercise was significantly lower, with participants also reporting significantly higher self-efficacy and enjoyment during the VR-based exercise

compared to the traditional biking exercise session [39]. Another study of 30 people (between ages of 6 to 50) playing VR exergame for 15 minutes showed how perceived workout intensity correlated positively with the level of motivation, and significant increase in heart rate after gameplay [40]. These results were similar in another study involving 60 females (18-30 years) which tested the rowing-task performance, motivational and affective impact during an aerobic exercise using VR and non VR environments. VR groups rated PA tasks as more enjoyable, had improved performance (rowing longer distances, particularly the VR group which had a companion avatar) and did not perceive themselves to be exerting more physical effort when they did [38]. This suggested that playing VR exergame with companions (having presence), rather than alone raises and enhances PA levels even further. These psychological results however should be interpreted with caution due to a small sample size which cannot be generalised and lack of evaluation of the effects of long-term PA effects.

As highlighted parental involvement is likely an important factor in the uptake of PA in younger adolescents [19]. We qualitatively interviewed 31 younger adolescents and identified that they were very interested in the concept of VR exergaming intervention, but highlighted that parental approval would be important for implementation [42]. To the best of our knowledge, no studies have explored the wider determinants, such as parental support that would be required to implement a VR intervention.

The aim of this study, therefore, was to interview parents of adolescents (13-17 year olds) to understand their views of PA, gaming and head-mounted VR in order to gather evidence and build more understanding around this, in line with the MRC Framework for developing complex interventions [43]. MRC Framework is a board framework which includes several general stages; a plan; a pilot; an evaluation stage; reporting; and an implementation stage [43].

Method

This study formed part of the development work for the vEngage project [44]. Parents or primary caregivers with an adolescent child aged between 13 and 17 years were eligible to participate and recruited through social media, local secondary schools in London (UK) and the University College London (UCL) network and facilities (such as notice boards and online subject pool/study participation announcements) via emails and posters. The aim was to recruit up to 20 participants according to the recommended 10-20 interviews for a medium project using thematic analysis [45]. The study was approved by the UCL ethics committee (Project ID 12669/001) and all participants provided informed written consent prior to interview.

Materials and procedure

A semi-structured interview schedule was developed to guide interviews (Appendix A). According to recommendations from Lewis and Ritchie (2003) [46], the schedule was designed to gather rich data on select topics including PA, gaming, VR, and the potential for using VR in a PA intervention. The schedule included open questions and specific probes to use if required. Interviews were conducted via telephone in June/July 2018 by one researcher (LM). The interviews were recorded and transcribed verbatim before analysis. With regards to obtaining the information on disabilities, no standardized questionnaire was used, because disabilities were not the focus of our investigation. LM asked participants if their child(ren) had any disabilities and they were allowed disclose more information in accordance with their will and the general Data Protection Regulation (GDPR).

Analysis

Framework analysis (a form of thematic analysis) was used to synthesize the data. Framework analysis has been shown to be a systematic and effective approach for analyzing qualitative data in health research [46]. It is a recommended method for data that has been collected in semi-structured interviews. Additionally, the Framework analysis has been recommended for use when the data relates to a small number of topics [46] and is appropriate for a sample of 10-20 participants [47].

Two researchers (LM and NF) independently analyzed 3 transcripts and generated a set of codes each. The researchers then met to discuss, compare and adjust the codes in order to develop the final analytical framework. The final framework was used to code all 18 transcripts by one researcher (LM). No particular software was used in coding the transcripts, however, the final set of themes and subthemes were collected with supportive quotes in the Excel spreadsheet. The data were then analyzed to explore emerging themes and identify the common themes. Analyses were conducted with guidance from an experienced qualitative researcher (KN). Study principal investigator (AF) independently reviewed the Framework Matrix and themes before final interpretation.

Results

Participants were recruited through two local secondary schools in South London, UK (n=6) the University College London (UCL) network (n=8) and social media (n=4). Thirteen participants were mothers (age range 48-58; mean age = 53; SD= 3.4 years) and five were fathers (age range 48-58; mean age = 52; SD 2.1 years). Six had sons, two had daughters and 10 had both. The mean age of all adolescents was 14 years (range 13-

17, SD 1.4 years). Interviews lasted on average 50 minutes (range 30 minutes – 70 minutes). Only one adolescent had a disability (high functioning autism spectrum disorder (ASD)- Asperger’s Syndrome), but this did not impact on their ability to perform PA as reported by their parent. This was important to consider when analyzing our results because of literature on children and adolescents with ASD showing difficulties in development of coordination and movement [48]. However, the parent in question reported no issues in the coordination or movement for their child. The final interpretation of the data is summarized in Table 2 below with illustrative quotes in the text. Information in parentheses are the child’s age and gender.

Table 1. Demographic characteristics of parents and their adolescent children

	Participants (n)	Mean age of parents (years)	Mean age of adolescents (years)
Mothers	13	53 (SD 3.4)	14.8 (SD 1.5)
Fathers	5	52 (SD 2.1)	14.6 (SD 1.4)
Total (N)	18	-	-

Table 2. Main themes and subthemes

Main Theme	Subthemes
General views on adolescent PA	Strong belief in the importance of encouraging PA in adolescents
Views on gaming	Adolescents game too often and this can be a dilemma; Addiction and violent content were major concerns; Accepting technology and gaming as facts of life and embracing potential; Peer influence and social pressure are strongest influences
General views on VR	Limited experience; VR gaming concerns; Concerns would be overcome if health benefits existed
VR exergaming	Concern that a VR fitness game will be a fad; Regulations of use
Preference for real world PA	VR exergaming better than nothing; Obvious parental support may be off-putting; Harnessing screen time for a positive purpose strongly welcomed

General views of adolescent PA

Strong belief in the importance of encouraging PA in adolescents

Awareness of PA guidelines for adolescents was low. Only one participant knew that the adolescent PA guidelines were 60 minutes of MVPA per day. 17/18 (94%) did not know the guidelines and most were unaware that the guidelines existed. Some participants made accurate guesses.

Parents emphasized the importance of engaging adolescents in PA because of the lifetime health benefits. However, most specifically linked the importance of PA to their child's immediate mental health: *"I think it is very [important], because I'm very, very active and I know how good it is for your mind"* (16F)

"I think anything that will get her moving more and doing more exercise will be good" (13F)

Only two participants (11%) felt their child was doing enough PA. Most believed their child 'should be doing more' (16F). All strongly believed that it was extremely important to encourage PA in adolescents: *"Oh, it's massively important. I would put it one of the highest things, that and eating correctly"* (13M)

Views of gaming

Adolescents game too often and this can be a dilemma

All parents (100%) reported their child did some kind of gaming most days of the week, usually reflecting that they felt this was too often and this was associated with a level of guilt: *"Probably six out of seven days a week"* (16M) and *"Every day and far too long. I feel guilty as a parent"* (13M)

Addiction, violent content and time spent gaming were major concerns

17/18 (94%) participants had negative opinions towards their child's gaming. All

(100%) participants were concerned about gaming being violent in nature. 14/18

(78%) participants reported trying to limit gaming. This was generally raised by parents of younger adolescents:

"Oh, absolutely hate it" (14M)

"I do think they're incredibly addictive and then you get issues with trying to manage the time" (13M)

"I don't like the bloody, shooting kinds of things, I think some of it is a little too realistic" (16F)

"I wouldn't be letting him just have it in his bedroom overnight and that kind of thing" (M13)

Participants did perceive some benefits to gaming including skill development, such as becoming adept at using computers, developing visuospatial skills and improving cognitive functioning. Another particularly common perceived benefit of gaming was social interaction:

"A social aspect to it as well and even though it's not physical and in-person there definitely is a lot of banter and a lot of chat and they're very much in touch. I find that hugely beneficial" (13M)

Accepting technology and gaming as facts of life and embracing potential

Participants felt that due to generational differences they were unable to relate to gaming. However, 12/18 (67%) participants acknowledged that, when played in moderation, gaming could be fun:

"I think it's just I find it hard to relate to because it's not something that I do"

(13M)

"I think in moderation it is a source of enjoyment" (13M)

Unlike sedentary games, participants shared experiences of taking part in exergames with their children. 2/18 (11%) participants reported positive experiences of using exergames such as the Wii Fit (Nintendo, 2006), but these were always referred to as something done in the past. In spite of concerns around gaming participants accepted that gaming and technology were parts of life and could be used as a force for good. Participants felt that they could not fight against technology, that it was a reality of modern life:

"It feels like an ancient device now, but at the time it was one of those things that came along and everybody was really excited about it" (13M)

"Technology is here, it's not going away and that's fine, if it has benefits for his health, then, yes I'd always be up for that" (14M)

Perception that peer influence and social pressure are strongest influences in adolescence

10/18 (55%) participants highlighted the social pressure on adolescent gaming, particularly in terms of owning certain consoles and games. There was a general view that in relation to gaming, adolescents were influenced by peer and social pressure, then, they persuaded parents, rather than the reverse. 17/18 (95%) participants underlined the role that the peer group plays in adolescent interests:

“So that’s the thing is to try and get something that becomes the really cool thing to do” (14M)

General views of VR

Limited experience

15/18 (83%) participants had only a limited understanding of VR and most hadn’t tried it. A few had tried phone-based headsets. The same number of participants expressed an interest in VR and some said that it seemed exciting. Others recognized it had potential:

“It seems like you’re actually in there and you’re moving within that space. And it’s a whole lot more realistic, you’re actually in the game rather than watching” (13M)

“I think it opens possibilities, definitely that’s something I think that’s really the future” (17F)

VR gaming concerns

13/18 (72%) participants were more concerned about violent games in VR than in regular gaming:

"Involving killing people and that would not be appropriate in a virtual reality kind of scenario" (13M)

"It's quite a weird idea that you then have no idea what it is they're experiencing" (13M)

Linked to that participants expressed safety concerns around multiplayer VR games as they may be unaware of who their child is interacting with:

"That she might be playing or getting in contact with people who she doesn't actually know" (13F)

Further health and safety issues that participants mentioned concerned the space that VR would require: 'Linked to this were practical concerns about the space that might be required. *"I wouldn't want it taking over the sitting room" (16M)*

Whilst participants suggested that gaming could be a social activity, they were concerned that VR gaming could be isolating: *"It seems solitary, another solitary thing that, she'll be up in her room on her own" (13F)*

All parents cited cost as a barrier: *"Obviously there's the cost of it" (13M)*

Concerns would be overcome if health benefits existed

6/18 (33%) suggested they would overcome their concerns if VR presented a tangible health benefit. Participants recognized that outside of gaming VR could have potential for being educational, and this was viewed as a positive thing:

"If they (parents) can see the benefits of technology, then they're quite happy to invest in it" (13M)

"I'm sure there'll be some educational aspects to it that it could be used for as well" (13M)

VR exergaming

Concern that a VR fitness game will be a fad

However, 7/18 (39%) participants expressed concern that a VR fitness game could be a fad or novelty that comes and goes. Yet, participants suggested that if the game could maintain their child's interest they would be more likely to invest:

"It might be one of those fad things they use it all the time for the first month and then it'll die off slightly" (16F)

"Providing that it has some kind of stickiness in terms of it wasn't just a five-minute thing" (13M)

Regulation of use

3/18 (17%) participants expressed that it would be important to regulate and manage the usage of the intervention. 13/18 (72%) parents expressed that they use technology and did not want to appear hypocritical:

"It would need to be regulated really, so that it's not just taking over" (16M)

"I think it's fine. I mean, we use technology for everything now, don't we? So it's an inevitable march. I've got no problem with it. I'd be a bit of a hypocrite if I did, considering I work in technology." (F14)

Preference for real world PA

VR exergaming better than nothing

9/18 (50%) of participants felt strongly that PA in the real world would provide greater benefits. Participants showed a preference for outdoor activities and team sports. 17/18 (94%) participants thought their child would be excited to try a VR fitness game, that they would embrace it:

"I would see it as inferior to physical activity in the real world" (13M) and "I feel they're sitting indoors, on the computer, when they could be outside doing other things" (14M)

"They love new things, they love the next step up technology-wise. He would love it I'm sure" (13M)

Obvious parental support may be off-putting

However, 5/18 (28%) participants perceived that adolescents may be less keen to engage in something that their parents were actively encouraging it. Participants also expressed that view there may be gender differences relating to a VR fitness game, such that boys may be more engaged than girls. In relation to gaming it was suggested that girls may engage differently.

"I think that all teenagers and young people are developing a separation from their parents, and not necessarily wanting to do what their parents say" (13M)

"Maybe girls wouldn't be as into it as boys or maybe the time you have to give, you know, different challenges, different games" (14M)

Participants also had ideas as to what may make the game appealing. These included levels, competition, a social element and a challenge that requires skill:

"I suppose some kind of score, so you could either beat people or beat your own score" (16F)

Participants also reflected on the fact that adolescents expect the best in terms of quality and graphics:

"They are tough consumers. If it's not on-brand, if it's not hitting their buttons then they will just drop it and say, or won't even pick it up" (13M)

Harnessing screen time for a positive purpose strongly welcomed

All participants welcomed the potential of gaming with a positive purpose, particularly mentioning being active during screen time:

"If somebody has already lost them to screen time, having part of their screen time as exercise could be fantastic couldn't it?" (13M)

Discussion

Principal findings

All participants in our study strongly believed that encouraging PA in adolescents was important. Most participants felt their children were not active enough. National datasets in adolescents using objectively measured PA suggest this perception is likely correct, with less than 15% meeting minimum guidelines [49]. Awareness of the recommended PA levels for adolescents was very low in our sample. This mirrors the findings of our qualitative study in 31 adolescents [42] and a quantitative survey by our group in >1000 families showing that less than 20% of parents knew the recommended PA guidelines for their preschool children [50]. Parents who were aware of PA guidelines for their children were more likely to be supportive of PA [50] suggesting parental education to be incorporated in an intervention. Knowing targets for health would also assist with goal setting, a behavior change technique consistently associated with successful PA change [51].

Parents tended to have negative perceptions of gaming, particularly expressing concerns about addiction. Reflecting and perhaps exacerbating parents' concerns, 'gaming disorder' recognized in the International Classification of Diseases (ICD-11) [52]. This highlights the scale and seriousness of addiction and may put further pressure on parents to be alert to their children's gaming habits. The participants reported trying to monitor their children's gaming and any digital intervention involving gaming would have to address this conflict. Using gaming time in a positive way would be welcomed, so a possibility is that the games designed in the future, used as PA intervention, could include materials and messages around replacing sedentary screen time with active gaming. In addition, a future game could encourage breaks, and include some 'real world' elements (such as trying various sports or visiting clubs, e.g. climbing wall,

boxing, trampoline park, etc). Parents in our study suggested that in an ideal world their child would be encouraged to be active outdoors, but acknowledged that the gaming element would engage their child.

Parents reported they managed their child's gaming to some extent (usually with time limits), but acknowledged that adolescents should be allowed some autonomy, particularly as they approach young adulthood. This is supported by study of 500 families using latent growth curve monitoring to demonstrate that parental media restriction decreases throughout adolescence [53]. With the exception of exergames, parents felt unable to relate to gaming attributing this to a generational gap. The same effect was reported in a study of 80 16-18 year olds and their parents exploring mediation of mobile phone and internet use [54]. Exergaming was an exception in our study in terms of parental involvement. Almost half of participants had used exergames such as the Wii Fit in the past. Gamification of PA has been proposed as a way to encourage integration of PA into their daily lives [55]. Those parents who tried exergames reported playing exergames with their children, and reported enjoying it (but recognizing that the technology was now outdated and was viewed as "past activity"). Playing with others was an important driver, including peer and social influence, and whether the game was believed to be 'cool' [56].

Parents had limited knowledge about VR

Harnessing novel technology, such as mobile app game Pokemon GO, social media interventions and immersive VR game have been identified as an effective way of increasing PA in adolescents [55,57,58]. Therefore, the intervention should attempt to alleviate the discomfort that some experience when faced with new technology. For

example, an informative leaflet for parents enclosed in the intervention may help reduce parental concern.

Parents identified several benefits to gaming. These included socializing, becoming skilled at using technology, moving, or utilizing screen time for health benefits, the development of visuospatial skills and strategy. Participants were aware of VR but had limited understanding of its use. Perceptions of VR were generally positive, with many participants describing it as 'interesting', 'intriguing' and as having potential. However, there was uncertainty around VR and its applications, and participants expressed concern about their child using violent games would be used in VR and have damaging psychological effects. Therefore, when developing the intervention these factors should be considered, with violence avoided and for example, providing guidance to help protect from addiction.

Parents reported they managed their child's gaming to some extent (usually with time limits), but acknowledged that adolescents should be allowed some autonomy. This is supported by study of 500 families using latent growth curve monitoring to demonstrate that parental media restriction decreases throughout adolescence [59]. Participants raised health and safety concerns, particularly around multiplayer games, with the belief that they may cause adolescents to interact with people they do not know. There was also concern about using a VR headset causing injury or isolation for their child. Cost was a barrier reported by all participants. Many were not aware of the cost but believed it to be prohibitively expensive. The concern is not surprising given that VR is not yet mainstream technology, despite the predicted increase in household ownership by 2022 [37]. It is important that in the intervention development concerns are recognized and addressed by ensuring appropriate protective measures are taken, such as education around VR and safety.

Health benefits of using head-mounted VR for PA changed parent's attitude toward gaming

In spite of concerns which also included 'novelty wearing off in 5 minutes', participants said they would support their children's use of VR if they knew there was a health benefit or educational element. This indicates that despite reservations around VR, parents see the potential of the technology and would be open to it should it present a tangible health benefit. Whilst some participants seemed to embrace technology and its potential for promoting health and fitness, others appeared merely accepting of technology and surrendering to its applications. These responses show that, whilst in different ways, all parents were open to using technology to improve the health of adolescents [59]. With the studies mentioned in the introduction, there is a potential risk of publication bias because studies showing positive or negative results are more likely to be published than those that show no results [19].

Parents reported a strong preference for the 'real world' PA and felt that exercising using VR would be 'better than nothing'. There was a strong message for VR having the potential for adolescents who do little or no PA, which is the majority [60]. Therefore, an effective intervention is required, and based on the results, a home-based PA intervention could particularly appeal to adolescents [6]. The intervention itself could also come with direction that it is to be used in combination with the exercise outdoors, which adolescents have previously suggested would be effective and appealing [42].

It may be important that the game is marketed directly to adolescents rather than to their parents, since adolescents strive for independence [57]. Parents also suggested features they thought their children would find appealing in a game. Competition, levels,

a challenge and a social element were the aspects that came up most often and reflects findings from previous gaming research [61,62].

Only one adolescent child had a known disability, Asperger's Syndrome. It was interesting to see that the mother of this child stated that she believed that gaming and head-mounted VR would help her child because: "it takes away the pressure of having to interact with other people" (M, 13). This was interesting but due to the aims of this study, we did not explore this further. Whilst we recognize the potential for benefit of exergames in children with disabilities, we felt that any disability that impacted movement might impact parent's perceptions of PA and exergaming, would be therefore better to exclude for the purposes of our study.

Strengths and limitations of the study

The sample size was sufficient according to Clarke and Braun's [42] recommendation of between 10 and 20 participants. It is not possible to say if the theoretical saturation was reached because we cannot be sure that the views of parents would differ in other populations [63,64]. Themes that reached saturation included all major themes, especially lack of experience with VR, general views on PA, worries around violent content, spending too much time online or gaming and preferences for real world PA. Our sample comprised of more mothers than fathers and more parents of boys than girls, despite there being low levels of PA in both adolescent girls and boys. It would be useful to further investigate whether parental concerns differ depending on the child's gender. Further research should also explore ways to equally engage boys and girls with the intervention. It is possible that social desirability bias affected participants' answers since parenting methods can be a sensitive topic, but participants were open about how they knew their child should be doing more PA.

Conclusions

Adolescents have previously raised parental support as being an important factor in the intervention's success [42]. This is in line with findings from a meta-analysis that found parental support was correlated with adolescent PA [65].

The results of this study provide support for developing a head-mounted VR intervention to promote PA in adolescents. The findings provide a useful insight for intervention development. Parents had negative associations with gaming but are accepting of it and embracing of its potential. It is important that concerns are considered in the intervention development and negated, where possible, to maximize adoption and ultimately the efficacy of the intervention. Overall, parents believe encouraging PA in adolescents to be of importance. Therefore, whilst parents have reservations, it seems they would welcome anything that may improve their children's health, including if it involves harnessing a behavior like gaming and using it as a force for good. Recommendations for the next stage of intervention development would be to further research how best to educate and inform parents to reduce uncertainty around VR and the intervention. Additionally, shaping the game with an adolescent steering committee is recommended in order to ensure it is enjoyable and has longevity.

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Conflicts of Interest

This research is sponsored by the Medical Research Council industry partnership grant and leads to 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.

Abbreviations

ASD: Autism spectrum disorder

MVPA: Moderate-to-vigorous physical activity

MRC: Medical Research Council

PA: Physical activity

VR: Virtual reality

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