GetAMoveOn Network

Leveraging Technology to Enable Mobility and Transform Health

# A Scoping Review of Exertion Game Research in 2017

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## Background: the GetAMoveOn Network+

The GetAMoveOn Network is an interdisciplinary UK community that is addressing the EPSRC Grand Challenge of transforming community health and care through the delivery of tested technologies that promote wellbeing by providing timely, individualised feedback that encourage appropriate activities. We are focusing on movement as a locus for health: it is our test case as it drives so many other benefits that are of value: economically, socially and culturally.

When we move more, we become smarter; as we become stronger, chronic pain decreases. Greater movement, especially in social contexts, improves collaboration. As we move, not only do we reduce stress: we improve our capacity to handle stressful situations and to see more options for creative new solutions. Movement enhances both strength and stamina, improves bone mineral density and balance, reducing incidence of falling and associated hip injuries (causes of death in the elderly). Movement complements other functions, from assisting with sleep and therefore memory and cognition, to helping with diet and associated hormones - improving insulin sensitivity and balancing cortisol. There are recent studies showing benefits of movement related to dementia. And yet, physical inactivity is the fourth leading cause of death worldwide; sedentarism has been called the "new smoking". Meanwhile costs to UK GDP from sedentarism and associated disease are increasing - from sick days lost to work, to elders losing mobility and having to move into care homes.

We have designed ourselves into our sedentarism: sitting during our commute, at desks while we work, and at home on the sofa. There is a critical need to design ourselves back into the natural effects of health accrued simply by moving more. We need solutions that will help build both the evidence and the experience that movement can enhance and benefit people's lives.

New technologies are transforming our ability to capture lifestyle data on individuals in real time. Consumer technologies such as step counters and wifi scales are the tip of an iceberg - research programmes worldwide are proposing lifestyle data capture from devices ranging from video cameras to electricity meters to wearables. Meanwhile pervasive connectivity allows that data to be transmitted, processed through powerful machine learning tools and provided back to people in a heartbeat. While we understand the potential technologies, we do not yet know how to leverage the technology effectively to support transformative health.

Current approaches in ehealth generally only reach a small part of the population that is already interested in fitness, personal data capture, or both. Their uptake is, furthermore, of dubious effect as two recent medical reviews have shown. To have a national impact on health and wellbeing, to reduce the crippling burden of long term health conditions and to move healthcare from the clinic to the community, we need to reach everyone, across a range of abilities and aspirations. We need to connect the potential of the technology with the potential of people and realise the benefits of a healthy, brilliant, population.

Realising this potential requires research on novel technical solutions, supported by theories from sports and health sciences on blending appropriate movement strategies for particular performance aspirations to behavioural and cognitive sciences on ways to engage people to make effective and meaningful progress. We need to understand what measures are appropriate not just to evaluate progress, but to guide it and adapt to it. To have meaningful impact across these dimensions we need to combine a range of expertise including sensor networks, data analytics, interactive visualisation, human computer interaction, online citizen engagement, behaviour change, sports, exercise. The GetAMoveOn Network is a response to this research challenge.


# Abstract

This report describes and reviews existing research on one specific type of activity intervention, exertion games, in order to understand the state of the art in this field. Exertion games, also known as exergames, or active video games, are computer games in which the player must exercise in order to play. Exertion games are developed for a variety of reasons; to motivate or encourage movement, to increase overall energy expenditure, to support rehabilitation or physical therapy, to improve cognitive processes and to slow physical and cognitive decline associated with aging. In addition, many outcome measures are used to assess the success of these games, such as player engagement, self-reports of player experience, short term biometric measurement and longer term patterns of behaviour. Due to the wide variety of motivations, intervention types, and outcome measures in the literature to date, it is difficult to assess under which circumstances exertion games are likely to function as useful and successful movement interventions, and when an alternative approach may be more beneficial. This report begins to answer that question through a scoping review of empirical work on exertion games. Our review suggests that there is huge variation in game technology, study designs, outcome measures used to date in studies on exertion games, and relatively few studies including either valid non-game exercise control conditions or long term outcome measurement.

In the studies reviewed, there is some evidence that individual sessions of exertion games can encourage movement and exertion comparable to other forms of exercise. However, even the results of these short-term evaluations is mixed, with many studies failing to demonstrate those effects. Longer term studies also have very mixed results; a few studies demonstrate positive results, but primarily only when used as part of a structured intervention with regular researcher facilitation; many studies also use no-exercise control conditions, or poorly designed controls – there is some evidence that when a more realistic control condition is used, such results may be reduced or even reversed.


# Introduction

Exertion games are games which the player must do exercise in order to play. There has been an academic interest in such games since researchers became aware of the amount of exercise done by players of the arcade game Dance Dance Revolution (Konami, 1998), in which players must do dance steps in time to music. (Tan et al., 2002). Both academics and commercial game developers have since built a wide range of games deliberately designed to encourage participants to exercise, with some, such as the Wii Fit (Nintendo, 2007) being extremely commercially successful.

Exertion games are widely presented as having the potential to be health interventions, with a particular focus on childhood sedentary behaviour and obesity (Marshall & Linehan, 2017). However, the evidence for this is unclear – it is difficult to understand whether and how exertion games actually have any meaningful effect on health. In this review, we first identify 5 key questions which underlie the health benefits explored in previous work:

1) In the short term, during gameplay, are exertion games equivalent to other forms of exercise effect (e.g. raised heart rate, breathing rate increases)?
2) In the long term, can exertion games provide sustainable exercise, or motivate people to change their overall exercise behaviours?
3) Can exertion games have an effect on health related body metrics, such as targeting weight loss in obesity, improvements in blood pressure, circulation, or improve player fitness?

4) Can exertion games have short or long term effects on cognition?

5) Can exertion games be used to improve bodily control, visual-motor coordination in the elderly, physiotherapy for people with disabilities, or as part of rehabilitation programs after injuries, strokes and other debilitating medical conditions?

Due to the focus of the GetAMoveOn project, we focus purely on the evidence for the first three of these questions in this scoping review, addressing the short and long term exercise effects of exertion gaming through a structured literature search and detailed analysis of the empirical evidence for exertion gaming.

In this article, we focus purely on health - we note that exertion games may have a positive role in society as games in their own right, allowing new forms of physical play, and point the reader to Mueller et al (2016) for a wider discussion of such games.

# Method

## Scoping Review

In this paper, we present a scoping review, defined by Arksey & O'Malley (2005), as a broad but shallow review of research into a field. In contrast to a full systematic review, which would typically limit exclusion criteria to only focus on particular types of evidence such as randomised controlled trials with consistent intervention types, we review here a wide range of empirical research evidence into exertion gaming, in order to assess the variety of different approaches to designing and studying exergames.

Exertion gaming has been studied in a wide range of fields, including fields such as computer science which are not indexed in medical databases such as PubMed, and often publish in peer reviewed conferences not covered by Scopus. Due to this diversity of work, we used the Google Scholar search aggregator to identify work of interest. We note that this engine applies a slightly opaque search algorithm – in particular small numbers of articles towards the end of results are excluded from more general search terms, for example when we searched for "health game" (phrase) in article titles, we found 6 items that were not covered by a title search on health AND game (both words). Whilst this search process may miss some relevant articles, it does however give us a broad overview of the research in this area.

## Paper Search and Exclusion Process

We first searched for a broad range of search terms related to the subject of exertion games. We limited searches to title only, aiming to collect only work whose main focus was on exertion gaming. See Table 1 for search terms and result counts.

*Table 1.* Search terms used (all search terms were in title only, search date 04/04/2017)

| Search terms (in title) | Search Results | Total Unique Results |
|---|---|---|
| Active AND video AND game | 59 | 52 |
| Exercise AND game | 209 | 256 |
| exergame | 199 | 454 |
| Exertion AND game | 19 | 470 |
| Fitness AND game | 89 | 553 |
| "Games for health" | 159 | 712 |
| Health AND game | 597 | 1267 |
| "health game" | 66 | 1273 |

| | | |
|---|---|---|
| TOTAL | | 1273 |

From this initial dataset of 1273 articles, we followed an independent exclusion process between two raters. Each rater first excluded papers that were clearly irrelevant from the title or abstract. We also excluded articles where we did not have access to the source material (for rater 1, this meant 16 articles that are potentially relevant were excluded). Next, we removed any obvious duplicates, articles that were not peer reviewed, or articles simply describing systems with no empirical study of their effects. We then combined results and compared articles where we differed to make a final inclusion/exclusion decision, leaving us with 132 papers in our final dataset, which we then read in detail and summarised. A descriptive analysis and discussion of these results are presented below. The full data set is published as supplementary material to this report.

*Table 2.* Article exclusion process

| **Step** | **Reason** | **Number Left after step** | |
|---|---|---|---|
| Initial search results: | Gather all possible results | 1273 | |
| | | **Rater 1** | **Rater 2** |
| Exclude as irrelevant from title/abstract or inaccessible to us | Identifying relevant research | 305 | 213 |
| Exclude duplicates | Ignoring multiple copies of same paper. | 297 | 212 |
| Exclude non peer reviewed | Conference abstracts, PhD theses etc. | 272 | 184 |
| Exclude no study | Work contains no empirical study of effects of an exertion game | 146 | 129 |
| Articles after rater combination and detailed reading | Final choice of articles. | 132 | |

# Results

## Descriptive Analysis

For each study, we categorised the motivation described for doing the work. The motivations we identified are shown in Table 3. A sizable minority (25, 19%) are simply aiming to work out how to create enjoyable exertion games, work which we previously argued is a vital prerequisite for the success of any exertion game (Marshall et al. 2016). The vast majority however are focusing on health in some way, with 26% motivated primarily by a desire to increase activity levels, and 21% aiming specifically to target obesity by increasing activity levels.

In contrast to the motivations, which mostly relate to inherently long term outcomes, such as increased physical activity in people’s lifestyles, reduced weight or other lifestyle changes, the majority (57%) of articles describe short term studies that last for less than 1 week. This suggests that there is a disconnect in the literature between the overall long term goals of exergames research, and the study methodologies that have been applied thus far. Most of these early studies are simply not capable of evaluating the effects of exergames on activity levels or other measures of health and wellbeing.

*Table 3.* Why are people doing the research?

| Motivation of research | Number of studies |
|---|---|
| Increase overall activity | 34 |
| Obesity prevention | 28 |
| Rehab / physio | 26 |
| Fun / designing good games | 25 |
| Other public health concern | 19 |

*Table 4.* Time duration of selected studies

| Duration | Number of studies |
|---|---|
| Short term (<1 week) | 75 |
| 1 -5 weeks | 13 |
| 6-11 weeks | 20 |
| 12-25 weeks | 19 |
| 26-51 weeks | 4 |
| 2 years (exactly) | 1 |

We analysed what the research actually studied, and grouped the studies into five main hypotheses, which are shown in Table 7. Note that several studies considered multiple of these hypotheses, for example studies may consider both whether exertion game interventions provide exercise, and further to that whether they have effects on body composition.

*Table 5* Five Research hypotheses addressed by the studies in our sample

| Research Hypotheses Addressed | Number of Studies |
|---|---|
| 1: In the short term, during gameplay, are exertion games equivalent to other forms of exercise effect (e.g. raised heart rate, breathing rate increases)? | 65 |
| 2: In the long term, can exertion games provide sustainable exercise, or motivate people to change their overall exercise behaviours? | 36 |
| 3: Can exertion games have an effect on health related body metrics, such as targeting weight loss in obesity, improvements in blood pressure, circulation, or improve player fitness? | 21 |
| 4: Can exertion games have short or long term effects on cognition? | 12 |
| 5: Can exertion games be used to improve bodily control, visual-motor coordination in the elderly, physiotherapy for people with disabilities, or as part of rehabilitation programs after injuries, strokes and other debilitating medical conditions? | 35 |

Table 6 and Table 7 show the location and type of the studies in our sample. The majority of studies were based in a lab; the second largest group investigated exertion games with children within schools. A small number of studies (10%) explored what happens when an exertion game is part of someone's wider home life.

*Table 6* Location of the study

| Location of research | Number of studies |
|---|---|
| Lab/hospital | 79 |
| School | 26 |
| Non-specific “in the wild” study (e.g. at home, outside running) | 14 |
| Elderly activity centre, nursing home etc. | 7 |
| other (summer camp, swimming pool, sports centre) | 6 |

*Table 7.* Types of study in selected articles

| Type of study | Number of studies |
|---|---|
| Pilot test of intervention (no control or comparison) | 44 |
| Controlled study, between subjects | 39 |
| Controlled study, within subjects | 19 |
| Comparison of interventions, within subjects | 18 |
| Comparison of interventions, between subjects | 9 |
| Survey | 2 |
| Qualitative interviews | 1 |

# Discussion and conclusions

Of the five hypotheses listed above, the first three are the most relevant to the GetAMoveOn project’s aim of considering encouragement of physical activity with technology. In this section, we discuss the evidence from our review studies relating to each of these hypotheses, and follow this with two concluding sections as to a) what this means for users or purchasers of exertion games, and b) what is missing from exertion gaming research as it currently stands – both in the design of exertion games, and in carrying out valid studies of their effectiveness.

### 1) In the short term, during gameplay, are exertion games equivalent to other forms of exercise effect (e.g. raised heart rate, breathing rate increases)?

The first question is a broad one – whether there is demonstrable evidence that playing an exertion game occasions the type of behavioural (e.g., movement) or physiological (e.g., HRV, ECG) markers indicative of exercise. In order to answer this question, we examined the sample of 65 papers that report studies using short term measurements of physical activity (we mark these papers as [a] in appendix A). This includes studies that examine exertion or movement during play, or directly afterwards.

First, we looked at the types of studies included in this sample. Table 8 and Table 9 demonstrate the breadth and variety of short term study based research looking into exertion games. We will consider question 1 in detail here with reference to the large number (18) of controlled studies in our sample. Specifically, question 1 asks whether exertion games encourage exercise that is equivalent to other forms of exercise. Thus, we must examine studies that compare exertion games to another non-gaming form of exercise. Studies that only compare two different types of exergames, or just study a single exertion game do not help answer this question.

*Table 8.* Outcome measures observed in those studies that reported only short term measures of movement and/or exercise.

| **Outcome measures found in the literature** | **Count** |
|---|---|
| Cardiovascular measures (HRV, V02 etc) and measures of energy expenditure | 30 |
| Self-reports of enjoyment, engagement etc (scales and qualitative interviews) | 30 |
| Movement (accelerometry, Kinect, wii, exercise bike) | 12 |
| Perceived exertion scales | 12 |
| Measures of body kinematics (e.g. joint angles) | 5 |
| Measures of energy expenditure | |

*Table 9* Distribution of study types in those studies that reported only short term measures of movement and/or exercise.

| **Study type** | **Count** |
|---|---|
| Pilot test of intervention only (no control or comparison) | 26 |
| Comparison of interventions, within subjects | 14 |
| Comparison of interventions, between subjects | 7 |
| Controlled study, within participants | 12 |
| Controlled study, between participants | 6 |

*Controlled studies with between-subjects design (6 studies)*

Six studies were initially coded as controlled studies with between-subjects designs. Through carefully reading of study methodology, only two of these studies specifically examined the effects of playing an exertion game on movement or exercise versus an appropriate control condition. The first study (Pasco et al., 2017), compared one group who played an exercise bike-based exergame (n=94) versus another group instructed to use an exercise bike under normal gym conditions (n=69). Moderate-to-Vigorous Physical Activity (MVPA) was significantly higher for the control condition, who used the exercise bike without any game. Thus, in this situation, the game seems to have distracted participants into exerting themselves less than they normally would have in a similar environment. The second paper, Kajastila et al., (2014) describes a game for the training of novice trampoline skills. Twenty-nine participants were divided into three groups – one who self-trained in trampoline skills, while the other two groups used a training game. Player movement on trampoline was measured via a video camera and computer vision technology. All three groups improved in trampolining skills – there was no difference in observed movement for the computer game conditions. Thus, the between-subjects controlled studies in our sample demonstrate little evidence of games promoting movement or exercise.

*Controlled studies with within-subjects design (12 studies)*

Twelve studies in our sample were initially coded as controlled studies with within-subjects designs. Through carefully reading of study methodology, only six of these studies specifically examined the effects of playing an exertion game on movement or exercise versus an appropriate control condition. All six studies reported that participants recorded similar or higher levels of exertion in the exergame condition than the control condition. O'Connor et al., (2001) compared a game-based exercise intervention for wheelchair users (n=15) against a control condition involving exactly the same hardware set-up, with the only difference being that in the control condition the game screen only displayed heart rate and wheelchair speed. The game condition demonstrated significantly higher average ventilation rate and average oxygen consumption, but no difference was observed in heart rate measures. Monedero et al., (2015) compared a 30-minute game-based cycling session with a standard 30-minute cycling session (n=34). Cardiovascular measures were all higher during the game condition. Gao and Mandryk (2012) found comparable measurements of heart rate during the playing of a casual exergame and running on a treadmill (n=24). Barkley and Penko (2009) compared V02 and heart rate measurements while 12 participants played Wii Sports Boxing, with those while they walked on a treadmill or played a sedentary game. Cardiovascular measurements were significantly higher during the game condition. Höchsmann et al, (2015) compared cardiopulmonary measurements of twelve participants when they played Wii Fit Plus with those recorded in an independent test of cardiopulmonary functioning. Wii Fit Plus was found to encourage moderate aerobic exercise, with a V02 mean at 40% of V02 peak. Finally, Chittaro and Sioni (2012) examined a game based walking task against a non-game walking task in a study with 15 participants and found no difference in walking measurements across conditions.

*Summary of findings of question 1*

A few observations can be made based on the above analysis. Firstly, there are surprisingly few studies that compare exergames against control conditions in terms of behavioural or physiological measures of movement or exercise. Secondly, in the eight studies identified, the control condition is often quite a mundane task such as walking on a treadmill or riding an exercise bike in a standard gym setup. It is perhaps unsurprising that participants do not work extremely hard in these control conditions. Future research should aim to compare exergame outcomes with those related to more interesting non-game exertion activities. Thirdly, apart from the Pasco study (which had a negative result for exergaming), these studies all have very low participant numbers (min 12, max 24). Future work would benefit from more robust study designs. Finally, despite these criticisms, these studies provide some early evidence that play of some (but not all) games can motivate or facilitate exercise or movement that is comparable to other forms of exertion.

### ***2)*** In the long term, can exertion games provide sustainable exercise, or motivate people to change their overall exercise behaviours?

### 3) Can exertion games have an effect on health related body metrics, such as targeting weight loss in obesity, improvements in blood pressure, circulation, or improve player fitness?

We consider these two hypotheses together, as they the same set of studies is relevant here. To answer these questions, we considered the set of 36 articles which a) ran studies for greater than 1 week, and b) were not studying purely rehab, balance or cognitive effects (relevant to questions 4 and 5 which we do not cover here).

**Exertion gaming interventions without compulsion or encouragement**

Only 3 studies in our long term sample involved participants given free play with exertion games without researcher involvement. All showed negative results. Howie, Campbell & Straker (2015) studied an exertion game targeted at children with developmental coordination disorder, and showed no significant differences in accelerometer measured exertion levels or sedentary behaviour, along with self-reports that suggested players were spending less time in outdoor activity suggesting that this game even risked displacing more beneficial outdoor physical exercise. Baranowski et al. (2012) gave groups of children exertion games to play at home, and saw no effects on physical activity levels; and the home only Dance Dance Revolution group studied in Chin et al. (2008) had a 64% drop out rate from the study, with the home participants only playing for less than 5 minutes a day on average over the 12 weeks, and showing median gameplay of zero minutes in the second 6 weeks.

This severe drop off in usage over time is a problem, as in order for exertion games to have long term health effects, it is fundamental that they are either played for a long time, or have ongoing effects after players stop. As game academics, we have always been sceptical of claims that an exertion games in isolation can have long term effects, simply because the evidence from traditional computer gaming is that people simply do not play any particular game for a long time. Academic research providing exact figures is relatively limited, but there is extensive information from commercial games testing companies and game studios relating to game retention rates. As a commercial game designer writes:

*“An appropriate benchmark for duration is somewhere between two months and six months. That implies a churn of 15%-50% and a retention rate of 50-85%. According to flurry, for iOS and Android apps, 24% of customers continue using after three months. After 6 months, this percent shrinks to 14%, and, by 12 months, only 4% are left.*

*DeltaDNA says that typical day one retention rates are 20-40%. Only 16% of games have retention rate of over 50% (September 2014, source: Nick Parker on* Twitter*) Everyplay’s data suggests that ARPU increases dramatically among players who spend more than ten hours playing a game (October 2014, source:* gi.biz*) Raf Keustermanns of Plumbee also stated at the Social Games Summit 2011 that any dev should expect to lose 96% of their user base within 12 months.* Playnomics *have found that approximately 85% of players do not return after the first day.” (Lovell 2011)*

These figures are extremely low; if we can expect at most 4% of players to be still playing a game after a year, it is hard to see any chance of real health impact in any intervention involving free choice from participants as to whether to play the exertion game. The published studies of free play with exertion games do not suggest that exertion games are immune from these effects.

**Exertion gaming with an element of compulsion or encouragement**

Almost all exertion gaming studies in our long term sample (33 of 36, marked with [c] in bibliography) involved groups of participants given some form of regular structured intervention, such as a weekly session of gameplay, or integration of exertion games into school physical education classes. Clear differences can be observed between such interventions and non-compulsory play – for example the Dance Dance Revolution study cited above (Chin et al. 2008) showed significantly lower drop out rates (15% vs 64%) in an intervention group who were given an hour a week multiplayer exertion game class in a school setting in addition to home play.

However, whilst there is evidence that structured interventions may have positive effects on drop out rates, the evidence on exertion gaming effects on physical activity or health is mixed even when considered as a structured intervention. 24 of these studies involved comparison of exertion games with a control condition. Of these, 7 reported positive change from exertion game group versus control, 8 reported worse results for the exertion game group compared to control, 8 reported no significant differences, and 1 reported a mix of both bad and good results.

*Exertion Gaming as a Treatment for Illnesses*

Kempf and Martin (2013) gave Wii Fit machines to patients with diabetes, with instructions to use them for 30 minutes a day for 12 weeks. This is probably the most positive study we found in our survey, participants in the intervention showed improvements both on physiological measures and self-reported quality of life measures versus a no-intervention control group. Similarly, Gomes et al. (2015) tested supervised exertion gaming as a treatment for asthma, showing improvements in maximum energy expenditure (although not mean) compared to a group who did treadmill exercise for the same time.

*Compensation Effects and Drop Off in Studies*

In several of the negative result studies confounding factors may be relevant; one key element is the activity that the exertion game is replacing - Duncan & Staples (2010) studied a 6 week school based exertion game intervention which children took part in during free play-time (US:recess). They found that whilst in the first week only, participants walked more steps (the key metric in the game) than in normal free play, the intervention group did less accelerometer measured exercise than the normal free-play group for all weeks of the intervention. The increase in steps without increased activity further suggests that players may focus on ‘gaming’ the game, finding lower effort ways to achieve specific game metrics such as step counts. Drop off as described above may also be a problem - even in structured interventions such as in sessions organised by school teachers, large drop off effects have been observed in how much exercise participants do, for example Macvean & Robertson (2013) saw a drop off over 7 weeks from 60% of session time spent in MVPA, to 20%; similar effects have been observed in a large scale study of mobile gaming in schools (Xu et al. 2012), where players in the last quarter of a year-long study were seen to achieve even lower levels of activity than observed in baseline testing before the study. These results suggest that exertion game excitement wears off steeply in the same way as seen in sedentary games.

*Biological markers of long term health change*

In relation to body composition effects; 28 (21%) of all our articles suggested that exertion gaming might have positive long term effects on weight and obesity. However few observed such effects. Scharrer and Zeller (2014) considered this by surveying schoolchildren as to whether they played active or non-active video games, and overall gameplay habits. Whilst many of their participants did play commercial active video games, they found no significant effects on BMI of level of exertion gaming or amount of gaming overall. Due to the long term nature of weight loss, as expected, studies show no changes in body composition over 6 weeks (Warburton et al. 2007) or 12 weeks (Cowdery et al. 2015). Two longer term studies in our sample did demonstrate statistically significant weight loss albeit with small effect sizes: Staiano Abraham and Calvert (2012a) studied a 20 week researcher led exertion gaming intervention, and found that in groups of obese students who played cooperatively, an average of 1.65kg weight loss occurred, and a study of a year-long Dance Dance Revolution game intervention (Gao et al,.2013) showed slight changes in percentage of children becoming overweight after one year of the intervention; these particular effects should be interpreted carefully however, as their intervention was modified after pilot testing from being purely DDR, to 15 minutes of DDR plus 15 minutes of exercise training by jumping rope or doing aerobic dance, because childrens' attention span for DDR was found to be too short for a 30 minute session.

Whilst evidence for the role of exertion games in obesity is largely lacking, there is some data relating to fitness and health changes in response to exertion games interventions. Vojciechowski et al. (2017) demonstrate that in comparison to a control group who did no exercise, an intervention (young adult) group who did an hour of Kinect gaming for 12 weeks showed significant improvements in speed and agility; similarly, in elderly participants, a 14 week program of Wii gaming was shown to improve physical fitness, agility and strength (Maillot et al. 2014).

Whilst exertion games presented as a structured and supervised intervention may be better than a control group who does nothing, given the requirement for structure and supervision for them to work, it is perhaps more appropriate to compare them to an alternative exercise. Several studies do this - Warburton et al. (2007), ran a 6 week x 90 minutes study comparing an exertion game bike with riding at their own chosen intensity on a traditional exercise bike. They found that participants in the exertion game condition only showed improvements in VO2 max and blood pressure measures; they note that this is largely explained by much lower levels of attendance in the exercise setting. Further to this, Adamo, Rutherford and Goldfield (2010) present a variation on this experiment where rather than use an exercise bike with no distraction, control group participants are allowed to listen to music of their choice while cycling. In their study, the music plus cycling condition had better exercise adherence, spent significantly more time cycling and cycled further than the exertion game group, leading them to conclude that *the high cost of investing in the Gamebike may be unwarranted*. Several other studies also show exertion gaming interventions which are no different to (Anderson-Hanley et al. 2012), are less effective than traditional exercise (Wu, Li and Theng, 2015), or even in one case, no different to no exercise at all and significantly less than real sport (Jenney, McKeown and Dougall, 2014).

*Motivational Effects of Exertion Gaming*

Finally, we consider the long term evidence for the potential motivational effects of exertion gaming. While many short term studies claim motivational effects due to measures such as situational interest (Sun and Gao, 2016) or future buying intention (Song, Pen and Lee, 2011), such measures may be highly affected by novelty (Chen, Darst and Pangrazi, 1999), so are unlikely to have generalizable validity from short term studies. Evidence from longer term studies suggests that intrinsic motivation to play the game is strongly correlated to energy levels in exertion games (Gao, Podlog and Huang, 2012; Staiano, Abraham and Calvert, 2012c). Li and Lwin (2016) attempted to break down motivation in relation to feelings of presence, enjoyment and identification with game characters; they found that the key factor for their measures of motivation was level of enjoyment, which mediated all other factors. One other key element of motivation that has been studied, is that provided by other players, via the use of competition vs cooperation between participants – interestingly there are nuanced results on this with Staiano, Abraham and Calvert (2012a,c) finding that cooperative conditions motivated players more strongly, whereas a study of short term effects by the same authors found positive effects of competition (Staiano, Abraham and Calvert 2012b). Shaw et al (2016) also showed competition to motivate players more during short term study. No study in our dataset reported significant effects on exercise beyond the study period – with for example Garde et al. (2016) showing rises during game intervention, immediately followed by falls to baseline in the following non-intervention week.

*Summary of findings of question 2*

In summary, we would argue that the current research evidence suggests that hypotheses 2 and 3 are only plausible with significant qualification – there is some evidence that exertion games may have positive effects on fitness and health when considered as part of a structured, supervised intervention. One study (Kempf and Martin 2013) suggests that there may be potential for exertion games as a semi-supervised intervention with specific patient groups, but that has yet to translate to wider populations, and in more common target populations such as children, effects of drop-off in long term interventions means effects may be non-existent (Baranowski 2012, Howie, Campbell & Straker, 2015) or even negative (Xu et al. 2012)..

The element of compulsion or encouragement in a supervised intervention has the potential to avoid some effects due to the low retention rate typical of video games, although when considering such research, we should be clear that it only provides evidence on the utility of such exertion games as part of such a structured intervention, with the obvious implications for costs and staff required to run the intervention for anyone considering deploying such interventions.

We also note as in the short term intervention sections that these studies, supervised exertion game interventions are compared against either a no activity control, or a simple exercise control such as a treadmill or exercise bike. As Adamo, Rutherford and Goldfield (2010) found, more realistic choice of control condition may have significant effects on responses. For example, there is no comparison study to other popular supervised exercise interventions such as aerobics, spin or circuits classes. Further to this, we must consider whether exertion gaming is displacing an alternative activity, as this could potentially have negative results (Duncan & Staples 2010, Campbell & Straker 2015).

## Conclusions Part 1: Advice for those buying, using or deploying exertion games

Companies selling exertion games market their expensive products to schools, gyms and members of the public as having proven health benefits – being *"a perfect fit to target endemic health issues, such as childhood obesity"* (Young, 2017), using phrases such as **"***Exergaming is an essential component to an active and healthy lifestyle.*"(ExergameFitness, 2017). The story told is that exertion games are more enjoyable, more highly motivating than traditional sporting and exercise activities, and that children and adults will exercise longer and harder when given these games. We would advise users to exercise caution in relation to these claims. In particular:

1) Current evidence is that exertion games only have any proven chance of 'working' as part of a supervised activity intervention. As such, they have few proven advantages to other supervised fitness activities such as exercise classes, team sports, going outside for a run or similar. There is limited or no evidence that exertion games are more fun than such activities, which do not require as much expensive technology.

2) Current exertion gaming technology (and the vast majority of games in general) have limited long term playability – investments in expensive exergaming hardware should be considered with the knowledge that for any given group of players, there may be limitations on how long the system will motivate them. We would particularly caution against investing in game specific exertion gaming systems where new games cannot be installed as these will inevitably become stale.

3) Not all exertion games are equal, and not all games involving movement are meaningfully exertion games – the range of reported exertion levels in 'exertion games' ranges from no different to sedentary gaming (Jenney, McKeown and Dougall, 2014), to significant amounts of MVPA (Whitehead et al, 2010) as would be expected of a traditional exercise or sport. When buying exertion games, you should be wary of games that do not require a meaningful level of physical exercise to play.

4) We advise care if replacing traditional sporting or exercise activities with exertion games. Sport and exercise have proven benefits for physical (Warburton, Nicol and Bredin, 2007) and psychological health (Eime et al., 2013), health related quality of life (Bize et al. 2007). Traditional physical activity has proven benefits in both children (Janssen and LeBlanc, 2010) and the elderly (Chodzko-Zajko et al. 2009). There is as yet limited evidence that exertion gaming achieves the same benefits.

## Conclusions Part 2: Advice for researchers studying exertion games

1) Firstly, we would suggest that as with all games related research, results will always be reliant on how enjoyable the specific game is – as Li and Lwin (2016) found, enjoyment of the game is the key factor affecting game motivation and hence likelihood of playing it. See Marshall et al. (2016) for more discussion of how to design enjoyable exertion games.

2) The current evidence suggests that purely creating and deploying an exertion game is in most cases not an intervention in itself – it should be considered as part of a wider intervention. Exertion games have shown few positive results except as a supervised intervention. As such, if we are to claim long term health behaviour change or bodily composition changes as motivations for our games, it is essential that we perform long term studies of the game in the situation and with the participants we are claiming it will succeed in. By doing this we must seriously consider factors such as how the intervention fits into participant's lives and why and when they will play.

3) We identify a key research gap in both short and long term research on exertion gaming, which is a lack of realistic control conditions. Specifically, when considering control groups for exertion game interventions, we should consider how they compare to use of interesting forms of exercise (as in Adamo, Rutherford and Goldfield 2010). Given the evidence that exertion games work best as part of expert led interventions, if we are considering such interventions, we should potentially consider studying control groups of organised group exercise which are likely to have similar or lower cost to organised exertion game interventions.

4) Exertion games researchers should be aware of research and practitioner knowledge relating to retention effects in gaming. In particular, they should note that the vast majority of games do not have long term playability, which has the potential to be a fundamental limit on what exertion gaming can do, and on the economic viability of exertion gaming as an intervention.

5) Games are not risk free - when considering settings to run games in, we should take extreme care to build games in such a way that they do not replace more beneficial exercise, such as seen in the school playtime study by Duncan & Staples (2010) and study of exertion gaming for developmental coordination disorder (Howie, Campbell and Straker 2015).

6) Exergame-based movement interventions rarely demonstrate awareness of, and grounding in, the wider research on the design of behaviour change interventions. One potentially fruitful path forward for exergame research is in building more closely on the theoretical and empirical work ongoing in this burgeoning research field (e.g. Abraham & Michie, 2008; Michie et al., 2009; 2011).

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## Appendix A: All papers included in review

Note: Papers are marked [a] if relevant to section on short term effects, [b] if it is a study of a long term free play intervention, and [c] if it studies a long term structured intervention.

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