Are Exer-Games Exercise? A Scoping Review of the Short Term Effects of Exertion Games

Joe Marshall, and Conor Linehan

***Abstract*—Background: Exertion games are video games that require exercise. They are widely presented as health interventions, to encourage sedentary populations to take exercise at levels recommended by health professionals.**

Objectives: We consider whether games encourage acute exercise at levels sufficient to engender exercise-related health benefits, and in what conditions that occurs.

Methods: We performed a scoping review of empirical research that examines whether exertion game play engenders exercise, searching Google Scholar, Scopus and PubMed.

Results: From 3171 search records, we found 243 studies of acute short-term exercise in games. While some observed moderate levels of exertion, players of many games fail to meet recommended levels. Few games encouraged vigorous levels seen in sports. Variation in results for games across different studies suggests that exertion motivation is highly dependent on non-game contextual factors. There is evidence games make exercise more enjoyable or reduce perceived exertion, but many studies suffer the methodological problem of comparison with boring control conditions.

Conclusions: Exergames have only been found comparable to exercise such as walking, jogging and dancing under very specific circumstances. To improve evidence for games as exercise interventions, we must improve study designs and focus on understanding better the circumstances likely to bring about genuine exergame exercise.

***Index Terms*—Exertion game, exergame, exercise.**

I. Introduction

EXERTION games are games in which the core play activities require the players to exercise. Academic interest in such games began when researchers observed the amount of exercise demonstrated by players of the arcade game Dance Dance Revolution [1]. Academics and commercial game developers have since designed a wide range of games that deliberately encourage participants to exercise. Some such as Wii Fit, have been extremely commercially successful.

Beyond their entertaining qualities, exertion games are often presented as health interventions, targeting for example childhood sedentary behaviour and obesity [2]. For games to positively affect health via exercise, 3 things must be true [3]:

1) Exertion games must encourage sufficient exercise levels in the short-term to have positive health effects.
2) People must choose or be encouraged to play over the long time periods required to achieve health effects.
3) Opportunity costs of exertion games must not outweigh any direct health benefits. For example, money spent on games may replace exercise equipment, or time spent playing may replace time spent doing sports activities with better evidenced health benefits [3].

In this article we produce a scoping literature review [4] of empirical studies addressing the first of these questions.

J. Marshall is with The Mixed Reality Lab, School of Computer Science, University of Nottingham, Nottingham, NG8 1BB, UK email:joe.marshall@nottingham.ac.uk

C. Linehan is with the School of Applied Psychology, University College Cork, Cork, Ireland. email:conor.linehan@ucc.ie

Manuscript received ???, 2005; revised ??.

This paper has supplementary downloadable material available at http://ieeexplore.ieee.org, provided by the authors. This contains the full list of papers identified and underlying analyses for each figure. This material is 582 KB in size

II. Background

A. What are exertion games and why are people excited?

We define exertion games as games that require energetic movement to play. Examples of such games include fitness focused games that deliberately aim to induce exercise, such as the Wii Fit series (Nintendo, 2007-2014), and Xbox Fitness (Microsoft, 2013-201), along with full body movement games not framed as 'exercise games', such as Dance Dance Revolution (Konami, 1998-2016), Wii Sports (Nintendo, 2006-2018), Kinect Adventures / Sports (Microsoft, 2010-2014).

Many commentators have suggested that exertion games could help address identified health problems, such as the perceived low levels of physical activity in children, and increased obesity levels in many populations [2]. Such research often takes the view that people already play games frequently, and that choosing to play exertion games instead of sedentary games would lead to health benefits.

B. What do existing reviews say?

We are not the first researchers to review existing evidence for exertion games as health interventions. Below, we summarise the reviews that have examined the short-term exercise effects of exertion games.

Firstly, we found three meta reviews. The first considered 18 studies and found exertion games caused higher heart rates and oxygen consumption than rest [5], and that exertion games were similar in exertion level to exercise controls. Lower body exertion games encouraged more energy expenditure than upper body games. Two other reviews considered exertion game exercise levels, one finding an average level of only light exercise from 15 studies [3], and a second review of 9 studies [6], showing that these exertion games elicited moderate levels of exercise as recommended by public health organisations. We also found a range of systematic reviews, which considered from 9 to 52 studies in total and had variable results (see Table I for a summary of these studies).

TABLE I
EXISTING REVIEWS OF EXERTION GAMES

	#Studies	Summary
[7]	28	Exertion games might help inactive children to start exercising, but aren't a substitute for exercising because only light to moderate exercise.
[8]	52	Don't recommend exertion games as intervention for children because intensity isn't high enough.
[9]	21	All studies reported energy expenditure above rest, but sometimes below comparison exercises.
[10]	12	Exertion games are light-moderate activity, activity levels highly variable, lower body games higher than upper body.
[11]	27	The majority of studies exhibited at least moderate exercise.
[12]	32	Exertion games were light to moderate exercise.
[13]	14	Exertion games do promote exercise, but aren't as intense as the activities they simulate.
[14]	35	In the lab, games are better than a slow walk, but worse than 5.7km/h walking or running, but against field studies exercise results are mixed.
[15]	45	Enjoyment of exertion games predicts exercise levels.
[16]	11	Overweight gamers don't achieve moderate intensity exercise.
[17]	9	Exertion gaming increases heart rate and other physiological measures.
[18]	15	Wide range of energy expenditure in different games.
[19]	11	Exertion games are mild to moderate exercise.
[20]	12	Review of reviews. Exertion games have positive effects on energy expenditure, but magnitudes are variable.

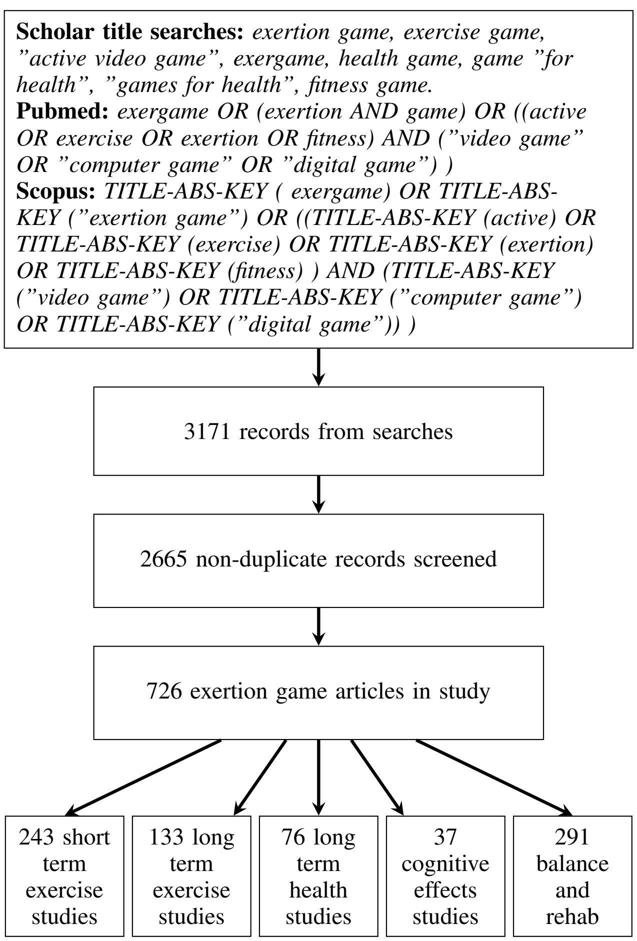


Fig. 1. Search process and numbers of articles found

C. Going beyond the existing meta reviews

Existing reviews have reached widely differing conclusions, for example one review concludes that exertion games are too low intensity to count towards public health goals for exercise [7], whilst another suggests that exertion games do in fact induce enough exercise to meet such goals [11]. The reason for the disparity in these results across reviews is the poorly defined nature of the question being asked. We argue that the answer to the question 'are games exercise?' is so clearly contingent on the nature of the game being played, the context in which it is played and characteristics of the group playing the game, that one cannot review exergaming as a single entity. Combining results in meta reviews, to come to conclusions such as 'overall metabolic equivalent associated with AVG play was 2.62' [3], is lacking in meaning when, as we see in our review, this can mask a range from extremely light to very vigorous exercise. We also believe that because games are diverse, a review which uses highly rigorous selection criteria will inevitably lead to a small sample of the possible research on exertion games, and a different sample to those in other reviews - indeed in Parisod et al's 'review of reviews' in this area [20], we see that the vast majority of studies included in any of the 15 reviews they consider are only included in 1 review, with each study considering a completely different subset of the literature. Instead, we deliberately use highly inclusive selection criteria, to present a broader picture of the wide range of existing research results relating to these games, and do not simply aggregate what is clearly a highly heterogenous set of results.

III. DATA GATHERING

We performed a four step scoping review based on the process described in Arksey and O'Malley [4], first piloting to identify the research questions of interest and inclusion criteria, then a search to find all potentially relevant studies, followed by a screening process to narrow down to a set of relevant papers. Figure 1 shows this process. J.M. carried out initial searches, and both authors independently performed initial exclusion and filtering of papers.

We first did a pilot study, searching Google Scholar (on 03 April 2017) for terms identified at the top of Figure 1. Relevant papers were inductively categorised based on the question they attempted to answer; both reviewers identified and agreed on the five key research themes at the bottom of Figure 1.

On 18 Jan 2018 we carried out full searches in scopus, pubmed and google scholar for search terms shown in Figure 1. Duplicates were removed. We included articles matching the following criteria: i) In English, ii) About exertion games, iii) Primary literature describing a study, iv) The study captures data relating to physical activity or health (e.g. we excluded papers that tested accuracy of exertion game gesture recognition), v) In a peer reviewed venue.

We identified 726 exertion game articles, and assigned these into the 5 categories established in the pilot study (Figure 1). 243 studies considered short term exercise effects of exertion games, i.e. what happens to users during and immediately after gaming, as opposed to multi-day studies of lasting effects of game interventions.

IV. Results

We further split the analysis of short term effects of exertion games into discussion of four questions:

- How much exercise do exertion games encourage (i.e. quantitative measurements of exercise intensity)?
- How do exertion games compare to other forms of exertion (both in terms of exercise amount and enjoyment, immersion, perceived level of exertion etc.)
- How do different features of exertion games alter participant exercise levels and experience?
- How do different user groups experience exertion games differently?

A. How much exercise do exertion games encourage?

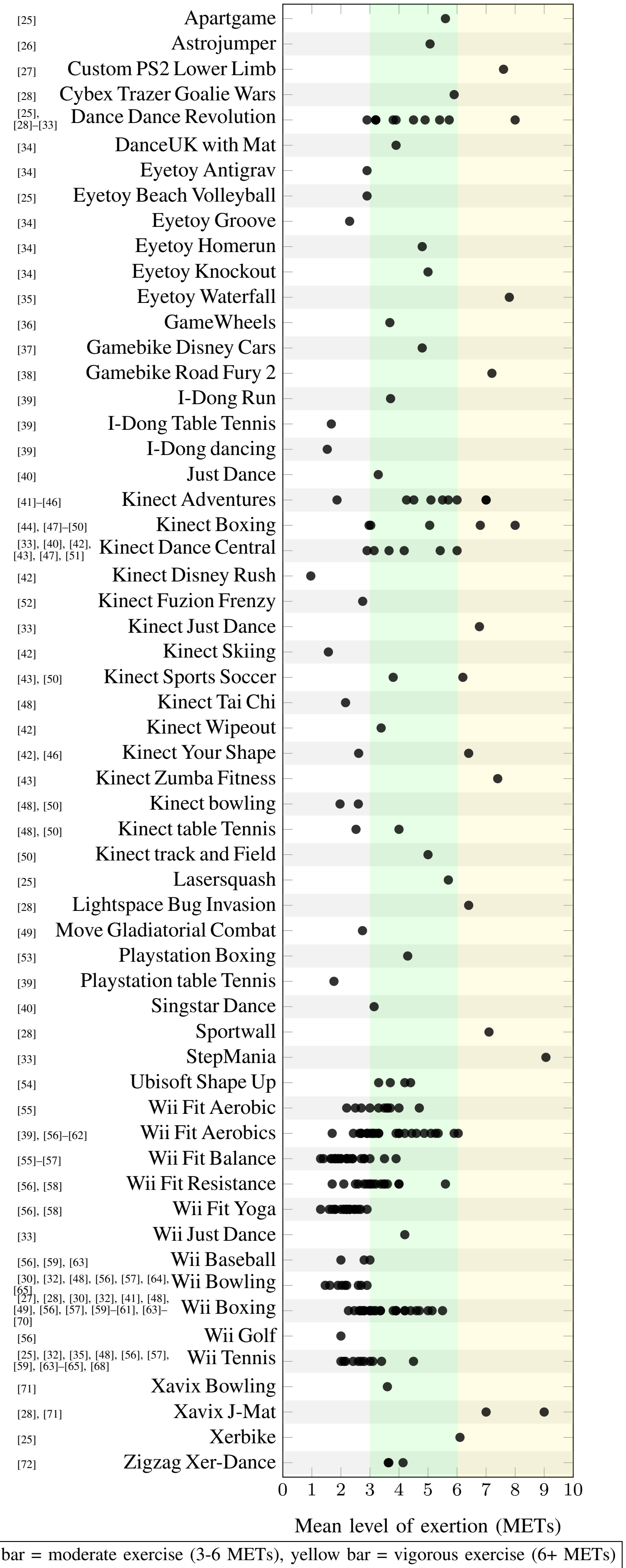
We considered all studies which took an absolute measure of exercise intensity in one or more identified exertion game. We extracted the mean intensity of exertion and converted to Metabolic Equivalent of Task ($1\ MET = \frac{1\ kcal}{kg \cdot h} = \frac{3.5\ ml\ O_2}{kg \cdot h}$) [21]. For some articles, this was not possible, as they used energy expenditure or VO2 without normalising for weight (e.g. [22]), or measures such as minutes above an HR threshold [23] or activity counts [24]. In Figure II, we plot 207 data points from the 48 articles which met these criteria. Each point is a measurement of mean MET for an individual game. Of these, 94 measurements were below 3 METs, so did not achieve moderate levels of exercise. 92 achieved moderate activity (3-6 METs), and 20 achieved vigorous activity (>6 METs).

World Health Organisation [73], USA [74] and [75] British recommendations for adults all prescribe at least 150 minutes of moderate physical exercise (3-6 METs) per week or 75 minutes of vigorous exercise (6+ METs). For children, they also prescribe 3 sessions/week of vigorous activity (e.g. jogging). Only 20 measurements (9.8% of results) showed vigorous exercise. Further, whilst exertion games may contribute to fulfilling recommendations through moderate exercise, in almost 45% of studies, people did not even reach moderate levels. If people in optimum conditions of academic health labs, doing studies about exercise, whilst wearing exercise measurement equipment, do not exercise hard enough, it is not strong support for use of exertion games as a health intervention, as others have noted, for example Scheer et al. conclude that "Overall, playing a physically active home video game system does not meet the minimal threshold for moderate intensity physical activity, regardless of gaming system [49]".

Strong results for some specific games suggest that extreme variance in results is dependent on game design, for example dance games almost all achieve moderate exercise in our results, and as Fawkner et al. [72] note, may offer real potential for exercise particularly in specific at-risk groups such as adolescent girls.

The wide ranges of measurements for popular games, highlight that exertion may vary strongly based on chosen difficulty levels, skill or other factors. This shows that exertion games can be effective exercise if played in the right way, but that how the game is played can vastly alter intensity of exercise.

TABLE II
Graph of metabolic rates observed in exertion game studies.



B. How do games compare to other forms of exercise?

It is clear that exertion games have the potential function as useful exercise activities. A second question commonly addressed by research is how they compare to other forms of exercise. This work explores whether games have the potential to make exercise more enjoyable, or to encourage people to exercise harder, perhaps by distracting them from how hard they are working. Results are shown in tables III and IV.

Table III shows comparisons in 60 studies in our dataset, between games and traditional forms of exercise in terms of whether measured activity levels were greater or lower in the exertion game compared to the exercise. Positive (20), negative (18) and even (19) comparisons between game and exercise are roughly balanced. In particular, compared to walking on a treadmill, or gently riding a stationary bicycle, exertion games in many cases can at least equal the intensity of exercise.

However, one major criticism of this body of work is exactly the comparison described above; that the vast majority of these studies compare exertion gaming to walking on a treadmill or cycling on a stationary bike, often with no other stimulation. These control conditions arguably flatter exertion games in that they are comparing against the most monotonous and simple forms of exercise, performed at low intensity. In contrast, studies comparing gaming to instructor led aerobic dance [76], [89], climbing exercises [69] and Irish dance lessons [87] all found exertion games produced less physical activity.

Beyond intensity, Table IV lists significant differences observed in relation to enjoyment and/or perceived exertion. These two factors are heavily studied as games are hypothesised to create more enjoyable forms of exercise, or to distract from perceived exertion, encouraging users to exercise more and harder. We can see from this table that compared to control conditions, games were more enjoyable than the exercise controls, although this was not always in tandem with greater physical activity. There is also some evidence [37], [38], [110] that players may perceive effort as relatively lower during exertion game play compared to non-distracting control conditions. However, again these control conditions were largely uninteresting treadmill or stationary cycling exercises, which limits the ecological validity of these results. Interestingly, where aerobic dance classes were compared with dance games, one study found that children enjoyed the games more [76], whereas another study found that adults preferred instructor led fitness lessons [89].

One key finding is that games which simulate exercise activities, such as Wii Tennis, are different to the underlying exercise activities. One interesting study compares the specifics of this difference in relation to rock climbing games [109], showing that while climbing games do not teach the same movement skills, they did however require similar tactical skills to real climbing, so could potentially aid in that element of skill development.

C. How do different features of exertion games alter participant exercise levels and experience?

In this section, we discuss research which investigates how different features of exertion games (33 papers) affect game

TABLE III
MEASURED ACTIVITY LEVEL IN EXERTION GAMES VERSUS TRADITIONAL EXERCISE ACTIVITIES

	Exertion Game		Exercise Activity
[28]	Cybex Trazer	>	Treadmill at 4.8 km/h
[76]	DDR	<	Aerobic Dance
[77]	DDR	<	Gamebike, self selected pace
[77]	DDR	=	Stationary Bike + Tv, self selected pace
[28]	DDR	=	Treadmill at 4.8 km/h
[78]	DDR	=	Treadmill + Tv at 2.4 km/h
[30]	DDR	=	Walking at 5.7 km/h
[37]	Disney Cars	>	Stationary Bike
[79]	EA Sports	>	6 Minute Walk Test, self selected pace
[80]	EA Sports	=	Treadmill at ”moderate effort”
[81]	EA Sports	Mixed	Treadmill at ”brisk walk”
[82]	Expresso HD bike	>	Just Exercise Bike, self selected pace
[53]	Eyetoy	=	Heavy Bag Boxing
[78]	Eyetoy	=	Treadmill + Tv at 2.4 km/h
[79]	Family Trainer	>	6 Minute Walk Test
[83]	Gamebike	<	Stationary Bike, self selected pace
[38]	Gamebike	>	Stationary Bike at 55% peak power
[84]	GameBike	>	Stationary Bike at 25-50% peak power
[77]	Gamebike	>	Stationary Bike + Tv, self selected pace
[85]	GameCycle	>	Arm Ergometer
[86]	GameWheels	>	Wheelchair Treadmill
[87]	Irish dance game	<	Irish Dance Lessons
[88]	Just Dance	=	Dancing To Online Videos
[89]	Just Dance	<	Dance Fitness Class
[90]	Kinect Adventures	=	School Recess (Free Play)
[91]	Kinect Adventures	>	Treadmill at 4.2 km/h
[46]	Kinect Adventures	<	Treadmill Running , self selected pace
[46]	Kinect Adventures	<	Treadmill Running at 55% VO2 reserve
[28]	Light Space	>	Treadmill at 4.8 km/h
[92]	LocoSnake	=	Walking around a field
[93]	Mixed exergaming	<	Physical Education Lesson
[94]	Mixed exergaming	>	Physical Education Lesson
[95]	Mixed exergaming	>	Physical Education Lesson
[96]	Pedal Tanks	>	Walking Outdoors , self selected pace
[97]	Pedal Tanks	>	Walking Outdoors , self selected pace
[98]	Rock Band	<	Treadmill at 30% VO2 max
[28]	Sportwall	>	Treadmill at 4.8 km/h
[99]	Wii Boxing	=	Heavy Bag Boxing
[69]	Wii Boxing	<	Prusik Climbing
[63]	Wii Boxing	=	Treadmill at ”brisk walk”
[28]	Wii Boxing	=	Treadmill at 4.8 km/h
[69]	Wii Boxing	=	Treadmill at ”brisk walk”
[66]	Wii Boxing	>	Treadmill at 4 km/h
[30]	Wii Boxing	=	Walking at 5.7 km/h
[79]	Wii Fit	<	6 Minute Walk Test
[100]	Wii Fit	=	Arm Ergometer
[101]	Wii Fit	=	Treadmill at 4.2 km/h
[102]	Wii Fit	<	Treadmill at ”brisk walk”
[103]	Wii Fit	>	Treadmill at 5.6 km/h
[104]	Wii Fit	<	Treadmill Running , self selected pace
[105]	Wii Fit, Boxing	<	Stationary Bike at ”moderate effort”
[106]	Wii Fit, Dance	>	Physical Education Lesson
[106]	Wii Fit, Dance	=	School Recess (Free Play)
[63]	Wii Sports	<	Treadmill at ”brisk walk”
[57]	Wii Sports, Fit	<	Running
[107]	Wii Sports, Fit	<	Stationary Bike at ”light effort”
[107]	Wii Sports, Fit	<	Treadmill at ”light effort”
[57]	Wii Sports, Fit	=	Walking, self selected pace
[108]	Wii Tennis	=	Tennis lesson
[28]	Xavix	>	Treadmill at 4.8 km/h
[46]	Your Shape	<	Treadmill Running, self selected pace
[46]	Your Shape	=	Treadmill Running at 55% VO2 reserve

(DDR = Dance Dance Revolution)

TABLE IV
DIFFERENCES IN ENJOYMENT AND PERCEIVED EFFORT BETWEEN EXERTION GAMES AND EXERCISE

Game	Comparison with	Exercise
[76] DDR	Less exercise but higher self efficacy and enjoyment.	Aerobic Dance
[37] Disney Cars	increased exercise, without increasing perceived effort	Stationary Bike
[81] EA Sports	Mixed results for exercise but games more enjoyable	Treadmill at "brisk walk"
[38] Gamebike	Increased exercise, perceived effort no different	Stationary Bike at 55% peak power
[89] Just Dance	Less enjoyable than	Dance Fitness Class
[109]Kinect Climbing	Involved different lower body movements than	Wall climbing
[101]Wii Fit	Same intensity, more satisfying	Treadmill (4.2 km/h)
[110]Wii Fit	Same intensity felt easier	Walk (65% HR max)
[110]Wii Fit	Fixed intensity perceived as lower effort	Stationary Bike (65% max hr)
[105]Wii Fit, Boxing	Less exercise but more enjoyable	Stationary Bike at "moderate effort"
[107]Wii Sports, Fit	Less exercise but more enjoyable	Treadmill "light effort"

(DDR = Dance Dance Revolution)

play, exercise and player experience. We break these down thematically rather than providing an exhaustive list of studies, as typically multiple studies examine the same game features, and results are more nuanced than the pure between-group comparisons of exertion level or enjoyment described in the previous sections. Table V shows these results.

These articles demonstrate that a range of factors affect how people exercised in games. One key factor is multiplayer modes - with multiple studies showing that people exercised more vigorously when playing against an opponent, and yet more vigorously when against a human opponent than against a computer. One interesting study found, in contrast, that humans playing Kinect in a limited shared space, exercised less hard than in single player modes, presumably due to space constraints [118]. Multiplayer modes also engendered reduced perceived effort and greater motivation in participants.

The type of multiplayer mode and partner behaviour also affects exertion. On competitive vs cooperative play, results are currently unclear, with one study [119] reporting participants using more energy playing cooperatively than competitively, whilst another by the same authors showed less effort in local cooperative play versus remote competitive play [118].

Studies with virtual partners have also demonstrated the Khler effect [137], a well known effect in which performance is highest when a virtual exercise partner is manipulated to be just slightly better than the player, rather than worse or a lot better [115]. Similarly, how a virtual character talks, and the role of that character can also affect exercise performance, with one study showing that if exercise *partners*, who are also shown to be exercising, give encouragement such as "You can do it", this decreases performance, whereas if a non-exercising exercise *trainer* encourages, performance increases [120].

Another feature that can affect games is how the games are framed. Multiple studies have shown that players do more exercise during games that are themed as exercise games than entertainment, but enjoy the exercise games less. However effects have also been demonstrated with even simple cosmetic manipulations such as making avatars obese (which reduced exercise performance [124]–[126]), or adding narrative cutscenes to a game (which increased performance [123]).

TABLE V
EFFECT OF DIFFERENT FEATURES OF EXERTION GAME PLAY

Factor	Effects
Type of opponent or partner	People play more vigorously against a computer opponent than alone [108], [111]–[115] People play more vigorously with a human opponent than with a computer [41], [113], [116], [117] Except one study, with less exercise when humans cooperated in a shared physical space than single player [118]. People perceive less effort for similar exertion in multiplayer modes [91], and self reported motivation is higher [118].
How other players behave	One study found that players use more energy when they play cooperatively than competitively, especially when playing with friends. [119]. Whilst another found that local co-op play was lower intensity than remote competitive play [118]. People are more active when their opponent is slightly better than them (rather than worse, or a lot better) [115] If a virtual exercise **partner** gives you encouragement in the form of "you" statements, it decreases performance compared to a silent partner. [120] If a virtual exercise **trainer** gives you encouragement in the form of "you" statements as you exercise alone, it increases performance. [120]
How games are framed	People do more exercise in fitness themed games than entertainment themed games [46], [121], [122]. But people enjoy entertainment games more [122] Players moved more when narrative cutscenes were added to Wii Sports [123] Players move less if avatars in games are obese [124]–[126] Players with low body image dissatisfaction preferred to see their image on screen and vice versa. [127]
Choice of game or play style	People exercise harder when playing a variety of games, compared to a single game [128]. Strong preferences for lower effort games [129]. More exercise in the same game standing than seated [130] People exercise harder when they find games: more engaging, enjoyable, or if the physical actions are 'realistic' [131], [132]
Adaptiveness and Skill	Games that track heart rates can encourage players to push themselves harder or reach target heart rates [133], [134]. Games which adapt to player fitness levels increase enjoyment and motivation [135] Games that exaggerate player's physical abilities are more enjoyable than those that present realistic depictions [136]

Studies found that giving people choices from a variety of games encourages more exercise compared to giving them a single game [128], although when given such choices, players preferred games that are less effort to play [129]. People were found to exercise harder with games they found more engaging or enjoyable, but also in games that were felt to be more realistic [131], [132]. One study demonstrated however that giving people the (non-realistic) effect of exaggerated physical abilities may be an effective way to increase enjoyment [136].

These articles show that a wide range of exertion game features affect the heavily interlinked factors of how people exercise and how enjoyable or motivating they find games. Many factors are not even directly about gameplay, such as visual framing, the presented purpose or theme of the game, the variety of choice of games, and who or what a person is playing the game with.

This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.2995370, IEEE Transactions on Games

TABLE VI
AGES OF STUDY PARTICIPANTS

Age Group	Number of Studies
Children	77
College age adults	71
Adults (other)	34
Elderly	12

TABLE VII
HOW DIFFERENT PLAYER GROUPS EXPERIENCE EXERTION GAMES

Game	Group 1	Comparison with	Group 2
Gender and Age			
[42] Kinect	Male	more energy used	Female
[45] K. Adventures	Male	more energy used	Female
[140]Xavix Bowling	Male	more active than	Female
[88] Just Dance	Male	same energy used	Female
[42] Kinect	Teenagers	use more energy	Children
Weight Status			
[61] Wii Fit	Obese	less energy used	Normal
[141]DDR	Overweight	less active than	Normal
[42] Kinect	Overweight	more energy used	Normal
[29] DDR	Overweight	same VO2 as	Normal
[142]K. Boxing	Overweight	less active than	Normal
[39] Various	Overweight	same energy used	Normal
[28] Various	Overweight	same exercise, but enjoyed more	Normal
Health Status			
[143]Wii Fit	With CP	same energy used	Healthy
[144]Various	Post-stroke	less active than	Healthy
[145]Various	Post-stroke	less active than	Healthy
Player Skill			
[146]DDR	Skilled	more active than	Non-skilled
[147]K. Swimming	Skilled	played less time	Non-skilled
[148]Neverball	Skilled	did less execise	Non-skilled
[147]K. Swimming	Swimmers	equally active	Non swimmers
[149]K. Swimming	Swimmers	equally good	Non-swimmers

(K. = Kinect, DDR = Dance Dance Revolution)

D. How do different user groups experience exertion games differently?

One clear limitation of exertion gaming research relating to exercise levels is that the vast majority of work has been done on children or college age adults. Table VI shows the ages of study participants in our dataset (n.b. only reviewing articles relating to short term exercise - a large amount of work has been done in relation to rehab and balance in the elderly [138]). Younger adults are well known to exercise more [139], there is limited evidence as to the effects of exertion games particularly on middle aged adults, who are likely to do less exercise in general.

Whilst we can say little about adults of different ages, we did find a range of research which compares how paired groups of users grouped by personal characteristics play exertion games (19 papers). This work is summarized in Table VII.

Multiple studies [42], [45], [140] (although not all [132]) found that male players exercised harder in exertion games. This fits with known disparities in levels of exercise across genders (e.g. [150]). However, we note that some studies - particularly those focusing on dancing games - did find exergame-related increases in exercise for adolescent girls [72].

Weight status also showed effects on how people played exertion games, although, as can be seen in Table VII, results of weight status are highly varied, with overweight groups using more, the same, or less energy (normalised for weight), than normal weight participants. Whilst this research has yet to provide clear answers, it is clear that to be effective with a range of participants, game design and testing must take into account the need of those with differing weight status.

Health status also appears to have mixed results on game-play, but shows some evidence that health conditions such as stroke may reduce intensity of play.

Finally, research has considered the effect of player skill on gaming intensity. This seems highly game specific - for example in Dance Dance Revolution, high skilled players can dance faster and were more active than other players; whereas in Neverball [148] and Kinect Michael Phelps Swimming [147], players who were more skilled at the game were able to do less exercise.

Another point worth noting is that skill in exertion games often doesn't map to the actual exercise that is being simulated. For example, participants level of swimming skill is not correlated with performance in a swimming exertion game [147]. This finding could be explained by the motions required in the game being different to real swimming, similar to the climbing games discussed above [109].

V. CONCLUSION AND KEY LESSONS

The sometimes unspoken hypothesis of exertion games is simple and appears intuitive - if we make games that encourage people to move, they will do exercise, and reap the same health benefits that regular exercise is known to provide, thus helping people meet public health recommendations for exercise. This paper demonstrates that the reality is far more complicated; clearly exertion game play can encourage exercise to levels that meet public health recommendations. But even in lab settings, many games did not encourage even moderate levels of exercise. It is clearly far more complicated than assuming that if one builds a game which encourages people to move, they will move when they play it, and that movement will reach recommended intensity levels. This body of research leads to three key lessons for researchers in the area:

A. Context is important

Exercise is a complex social behaviour that involves far more than the moment of exercise itself. We can see from the massive variation in results for games which were studied multiple times, such as Wii Boxing and Dance Dance Revolution, that it is hard to say that any specific game always encourages exercise. Whilst there are clear patterns, as observed in previous research [5] that lower body games such as dance games lead to higher typical exertion levels, even within such games we see ranges from less than 3 METs exertion to greater than 6. Clearly, as we can see in Tables V & VII, level of exercise may be affected by many factors such as participant characteristics and skill level, difficulty level choices, and experimental conditions such as instructions given, time structure of experiments, what other activities were done in the experiment, what display was used, relationships between players, culture and player background etc. Given the fact that in real-world settings, people typically have control over their game systems, and a choice as to whether to play

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the game and how hard to play, it is hard to argue that the existing body of evidence demonstrates that an exertion game is superior to for example a ball, or other simple piece of exercise equipment.

One key target context of exertion games is schools; in this context, where a level of coercion exists, and settings are more controlled, there is some promise, with one study [106] showing increased exertion levels in exertion gaming versus standard physical education lessons. However, children in this study also achieved similarly increased levels of exertion in free play at recess, so again it shows little evidence of advance over simply letting children run outside.

B. Exercise is more than exertion

We found little discussion in this work of wider questions relating to the nature of exercise. A fundamental point which is missing in measurement of exertion games purely by the quantity of exertion performed, is the wider purposes of exercise. For example, whilst school physical education may use less energy than some exertion games [106], that may have been because those lessons were also teaching children valuable skills that they may take forward into a lifetime of doing exercise, a benefit that may not be equally present in exertion games. Similarly, whilst many papers reference WHO recommendations of 150 minutes moderate aerobic exercise per week, we found no discussions of accompanying recommendations for strength training. In addition to this, specifically in interventions targeted at adults, there is increasing evidence that reducing prolonged sedentary behaviour may have strong positive effects independent of quantity of moderate to vigorous exercise (e.g. [151]). As such, regular getting up and moving may be more important than intensity - meaning that studying ongoing regular engagement will be more important in such cases. We caution, however, that in children a previous review showed that negative effects of sedentary behaviour were not found when exercise levels were controlled for [152].

C. We need to consider realistic alternatives to exertion games

When designing comparative studies of exertion games, we suggest that rather than compare against trivial and monotonous (but easily arranged) comparison conditions, such as treadmill walking or gentle exercise biking, researchers should use realistic comparisons, such as more entertaining sporting activities. It is important to remember that our studies may be used to promote the use of exertion games as alternatives to existing exercise activities. The data shows that only 10% of studies reported vigorous activity levels from exertion games [8], showing that such games are not yet equivalent to more intense sports. We can see this in the few studies in our dataset that compare exertion games against non-monotonous forms of exercise [69], [76], [87], which showed greater activity levels in traditional exercises versus exertion games.

Furthermore, the fact that context is so important suggests that for games to have genuine health benefits, they will need to be part of a structured and supported intervention. Such structures are likely to have added costs, over and above hardware and software for games themselves. As such, when considering the potential benefit of exertion games, it is important to consider the total cost of providing the intervention and game in comparison to the costs of other interventions such as instructor led exercise which may lead to greater exercise and social benefits.

ACKNOWLEDGMENT

The pilot study described above was funded by EPSRC GetAMoveOn (EP/N027299/1).

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This article has been accepted for publication in a future issue of this journal, but has not been fully edited. Content may change prior to final publication. Citation information: DOI 10.1109/TG.2020.2995370, IEEE Transactions on Games

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