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Research Article

User Experiences While Playing Dance-Based Exergames and the Influence of Different Body Motion Sensing Technologies

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Dance Dance Revolution is a pioneering exergame which has attracted considerable interest for its potential to promote regular exercise and its associated health benefits. The advent of a range of different consumer body motion tracking video game console peripherals raises the question whether their different technological affordances (i.e., variations in the type and number of body limbs that they can track) influence the user experience while playing dance-based exergames both in terms of the level of physical exertion and the nature of the play experience. To investigate these issues a group of subjects performed a total of six comparable dance routines selected from commercial dance-based exergames (two routines from each game) on three different consoles. The subjects' level of physical exertion was assessed by measuring oxygen consumption and heart rate. They also reported their perceived level of exertion, difficulty, and enjoyment ratings after completing each dance routine. No differences were found in the physiological measures of exertion between the peripherals/consoles. However, there were significant variations in the difficulty and enjoyment ratings between peripherals. The design implications of these results are discussed including the tension between helping to guide and coordinate player movement versus offering greater movement flexibility.

1. Introduction

Exercise involving dancing to music is a popular form of physical activity and from the arcade beginnings of Dance Dance Revolution (DDR), dance-based exergames (i.e., video games that use body movement to control them and require physical exertion to play them) have now become a popular mainstream activity [1]. Over the years a variety of different body-movement-based video game controllers have been developed to try to create more immersive video game play experiences. With the advent of many different types of low cost sensor devices, this trend is likely to continue. More recently, three different consumer body motion sensor peripherals for consumer video games consoles have come to the fore and attracted considerable interest (i.e., Nintendo Wiimote, Sony Playstation Move, and Microsoft Kinect) for their potential to open up new possibilities for body-movement-controlled video games. Given their growing popularity and broad age and demographic appeal, there is now significant interest in their potential to promote physical activity and health [2–4] rather than just simply a novel form of game controller, and exergames have already been incorporated into physical education activities in schools [5, 6].

A low level of physical fitness is an important risk factor for premature mortality [7]. Despite the unequivocal health benefits of regular exercise, physical inactivity is a major health problem globally and has a wide range of health problems associated with it including high blood pressure, high cholesterol, type 2 diabetes, coronary heart disease, stroke, and some cancers [8]. In England, UK in 2008, health statistics indicate that 17% boys and 15% girls between the ages of 2 and 15 years were classified as being obese along with a quarter of men and women aged 16 and over [9]. The UK government's recommended amount of physical activity for children is at least 60 minutes of moderate intensity activity on every day of the week and for adults at least 30 minutes per day of moderate intensity exercise on five or more days of the week [10]. Recent data for England indicate that between the ages of 2 and 15 years, only a third of boys achieved this target for physical activity compared with a quarter of girls and only 39% men and 29% women reached the minimum recommended amount [9].

Given the meteoric rise of video games to become a very popular form of entertainment, they are not something that can easily be ignored. While "*all things in moderation*" is a good maxim to live by, it is more realistic and pragmatic to tap into the engaging nature of video games and steer players towards becoming healthier by replacing a proportion of their sedentary game play time with active games that require significant physical exertion [11]. It is perhaps unsurprising that making physical activity more enjoyable has been shown to increase participation [12].

DDR is based on a game controller which comprises a simple set of foot switches arranged in a 3 × 3 matrix on a pad that is approximately 0.8 m × 0.8 m in size. The game requires the player to step on the correct arrow on the dance pad in time with on-screen visual arrow cues, and points are awarded depending on how accurately the player times each step and for accumulating sequences of correct steps. Increasing the speed at which the arrows appear on the screen and the complexity of the arrow sequences makes the game harder and requires higher levels of motor skill and more rapid physical movement to perform. One of the first studies to assess the level of energy expenditure associated with playing DDR [13] (by measuring rates of oxygen consumption) reported levels of exertion that would meet the lower end of the intensity range of the American College of Sports Medicine's guidelines for aerobic exercise [14]. A further study of DDR, this time in children [15], had similar findings. When comparing experienced DDR players with beginners they found that the experienced players could play the game at a higher skill level and this led to greater levels of energy expenditure [16]. An international online survey of DDR players found that the main reasons people played the game was because it was fun, provided some form of exercise, and was something challenging to do [17]. Finally, it has recently been reported that a suitably modified form of DDR could be used by older adults (70+ years old) [18].

From a health perspective, the higher the level of physical exertion required to play an exergame, the greater the benefits that are likely to accrue. The arrival of dance-based exergames based on body motion sensing peripherals is therefore of significant interest in that they may have the potential to facilitate the desired higher levels of energy expenditure. However, because the various peripherals differ in the number of limbs that they track (and therefore the amount of active skeletal muscle mass), it is possible that they differ in their potential health benefits. The Wiimote (Nintendo) peripheral incorporates a triaxial accelerometer to detect motion and an optical sensor that enables the determination of where on the screen the controller is pointing to. The Playstation Move (Sony) peripheral incorporates both a tri-axial accelerometer and a tri-axial angular rate sensor and a magnetometer to correct for drift. A ball mounted on the end of the controller and illuminated from the inside by coloured LEDs is tracked by a camera mounted above the screen, and given that the size of the ball is known, it can be tracked in three dimensions. Finally, the Kinect (Microsoft) peripheral is entirely camera-based and uses an infrared 3D depth scanning approach to motion tracking.

The first aim of this study was therefore to assess whether there were any influences of the different body motion tracking technologies on the levels of energy expenditure elicited while playing dance-based exergames as determined by direct measurement of oxygen consumption. The second aim was to assess if the technologies differed in the nature of the user experiences while playing the games in terms of perceived levels of physical exertion, game difficulty, and enjoyment ratings.

2. Methods

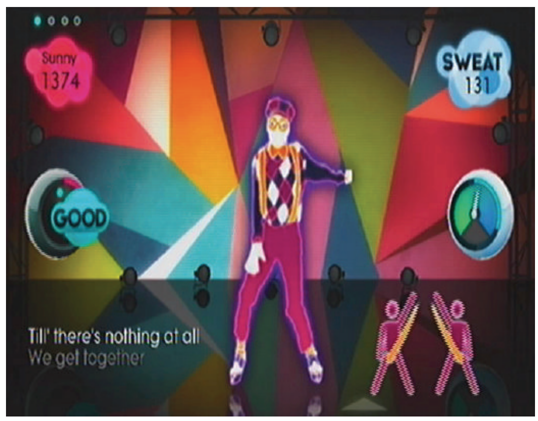
Subjects were recruited from within the student population at Heriot-Watt University. All participants gave written, informed consent and completed a health screening questionnaire. The study was subject to local ethics committee approval. Subjects' height and body mass were measured using a portable stadiometer (Holtain, Pembrokeshire, UK), and weighing scales (Seca 761, Birmingham, UK) respectively. In total, 11 subjects (9 male) were recruited and completed the study. Mean (±SD) age was 19.4 ± 1.5 years, height 1.76 ± 0.10 m, weight 74.6 ± 12.4 kg, and body mass index 24.0 ± 2.9 kg/m^2.

Three different consumer video games consoles (Nintendo Wii, Sony Playstation 3, and Microsoft Xbox 360) and, their separate associated body motion sensing technologies (as described in the Introduction) were used in the study. The exergames used in the study were Just Dance 2 (Ubisoft Entertainment), SingStar + Dance (Sony), and Dance Central (Harmonix) and for the Wii, Playstation 3, and Xbox 360 consoles, respectively. Six songs/dance routines (two from each game) were selected for use in study on the basis that the routines were all of similar tempo (beats per minute) and involved comparable amounts of arm and leg movements. The routines selected were as follows: Microsoft Kinect– "*Just Dance*" by *Lady Gaga* (Kinect1) and "*Drop It Like It's Hot*" by *Snoop Dogg* (Kinect2); Sony Playstation Move– "*U Can't Touch This*" by *MC Hammer* (Move1), and "*It's Like That*" by *Run-Dmc* Vs. *Jason Nevins* (Move2); Nintendo Wii– "*The Power*" by *Snap*! (Wii1) and "*Hey Ya*!" by *Outkast* (Wii2). Screen shots showing the game play screens from each of the three games are shown for illustration in Figure 1.

Physical exertion levels during the game play periods were assessed using a wearable, wireless telemetric recording system (Oxycon Mobile, VIASYS Healthcare, Hoechberg, Germany). Subjects wear a face mask and expired air flow is measured with a turbine impropeller and is simultaneously analysed for oxygen and carbon dioxide fractional concentrations. These measurements are then cross-product integrated on a breath-by-breath basis to determine the rates of oxygen consumption and carbon dioxide production. Before each testing session, the expired air flow sensor was calibrated using two separate flow rates according to the manufacturer's specifications and the gas analysers calibrated using a precision gas mixture. The gas analysis unit and the combined battery pack and radio transmitter unit are both held in place by a harness worn on the subject's back with

(a)

(b)



(c)

Figure 1: Game play screen shots for each body motion tracking peripheral. (a) Kinect (Dance Central), (b) Playstation Move (SingStar + Dance), and (c) Wiimote (Just Dance 2).

virtually no restriction on movement. Subjects also wore a heart rate monitor chest strap (Polar, Kempele, Finland) under their clothing, the signal from which is automatically picked up by the telemetric system. Physiological data were averaged over the duration of each game play period.

Immediately after completing each dance routine, participants completed three simple psychophysiological self-report measures. The first measure involved rating their perceived level of physical exertion using a numerical scale [19] (i.e., how hard a subject felt they were exercising). The second measure concerned how difficult subjects perceived each routine and used a visual analogue scale (VAS) comprising of a 100 mm line anchored with the labels "*Very Easy*" at one end and "*Very Difficult*" at the other with subjects asked to make a mark somewhere along the line [20]. The third and final self-report measure related to the level of enjoyment the subjects experienced also used a VAS; this time anchored by the labels "*Very Enjoyable*" and "*Very Boring*."

The familiarisation session involved the subjects being introduced to the body motion sensing peripherals and the two selected dance routines on each of the three games consoles. Both the order of the consoles and the order in which each subject played each pair of routines were randomised. To help familiarise the subjects with the corresponding sensations of physical exertion used in the self-report measure (as described above), immediately after the end of each routine the subjects were asked to rate their perceived level of exertion. After completing each pair routines on a given console, subjects had a short (five minutes) seated rest break to permit the equipment to be changed over to the next console.

In the measurement session, subjects were fitted with the telemetric physiological recording system (as described earlier) and wore it throughout the session. Subjects were seated, and baseline measurements taken for five minutes before the first game was played. All dance routines were played once except for the Xbox 360 games (Kinect1 & Kinect2) which were played twice because of their shorter duration in order for the game play time to be similar across all consoles. The order and timing of the routines were the same as for the familiarisation session and immediately after the end of each routine the subjects completed each of the self-report measures.

All data are presented as mean ± standard error of the mean (SEM). Data were compared using repeated measures analysis of variance except for each pair of game scores on the same technology platform which were compared using paired-sample t-tests. The association between game enjoyment and difficulty ratings was assessed using Pearson's product-moment correlation. The threshold for statistical significance was set at $P < 0.05$.

3. Results

The mean improvement in game scores between the familiarisation and testing sessions for each of the dance routines ranged from +13 to +35%. Comparing the game scores between routines using the same body motion sensing technology (and games console), the mean score for Kinect1 was significantly higher versus that for Kinect2 (+18%, $P < 0.05$) and the Move1 routine was also significantly higher than that for Move2 (+8%, $P < 0.05$). However, there was no significant difference between the mean scores for the two routines on the Wii console (Wii1 & Wii2).

Due to a loss of telemetric data capture with two of the subjects, complete sets of physiological data are only available for nine subjects. There were no differences in mean heart rate between any of the pairs of routines on the same console or between the different body motion sensing technologies (Figure 2). Similarly, there were no differences in the mean rates of oxygen consumption between routines or motion sensing technologies (Figure 3).

With regard to the psychophysiological self-report measures, there were also no differences in the mean ratings of perceived level of physical exertion between routines or motion sensing technologies (Figure 4). However, both Move1 and Move2 were reported by the subjects as being significantly more difficult than all the other routines on the other two consoles (Figure 5). Finally, comparison of the levels of perceived enjoyment of each of the routines indicated that the Kinect1 routine was rated significantly more enjoyable than Move1, Move2, and Wii2 routines (Figure 6) and the Kinect2 routine was rated significantly more enjoyable than the Move2 routine (Figure 6).

The results were also analysed according to the randomised order in which the subjects performed each of the routines and no evidence of any order effects was found (data not shown).

In order to investigate whether there was any association between perceived game difficulty and self-reported enjoyment ratings for each routine and body motion sensing technologies, the group means of each set of enjoyment rating scores were plotted against the corresponding group means of the difficulty ratings. The results of this analysis revealed a positive correlation between increasing perceived game difficulty and declining game enjoyment ratings (Figure 7).

4. Discussion

The main findings of this study were that while the three different consumer body motion sensors differ in the underlying technologies, and therefore the type and number of body limbs they are able to track the motion of, the separate dance-based exergames developed for each video game console all required comparable amounts of physical exertion (equivalent to moderate exercise) to play them. However, while the

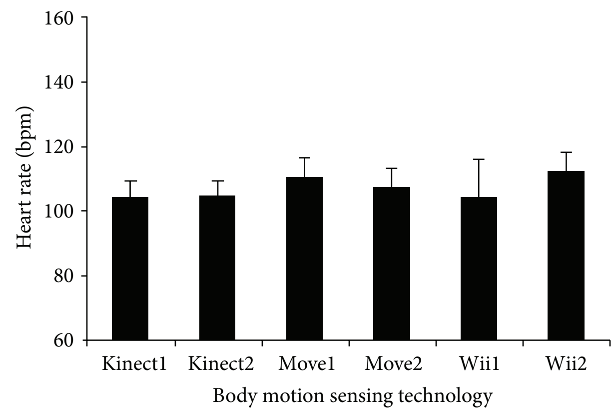


FIGURE 2: Heart rate (beats per minute) during each of the different dance routines using the various different body motion sensing technologies. Data are shown as mean ($n = 9$) and error bars indicate SEM.

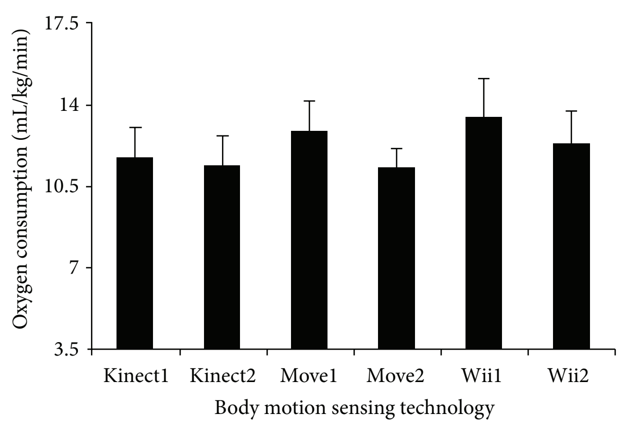


FIGURE 3: Oxygen consumption (standardised between subjects by expressing it in terms of mL per minute per kg body mass) during each of the different dance routines using the various different body motion sensing technologies. Data are shown as mean ($n = 9$) and error bars indicate SEM.

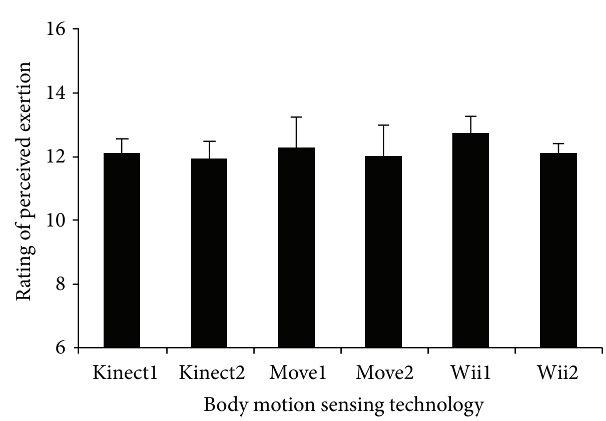


FIGURE 4: Rating of perceived exertion reported immediately after performing each of the different dance routines using the various different body motion sensing technologies. Data are shown as mean ($n = 11$) and error bars indicate SEM.

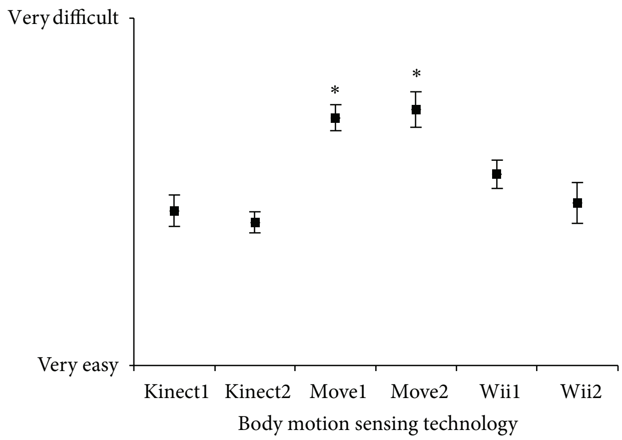


Figure 5: Rating of perceived game difficulty reported immediately after performing each of the different dance routines using the various different body motion sensing technologies. Data are shown as mean ($n = 11$) and error bars indicate SEM. *indicates significantly more difficult versus the other sensing technologies ($P < 0.05$).

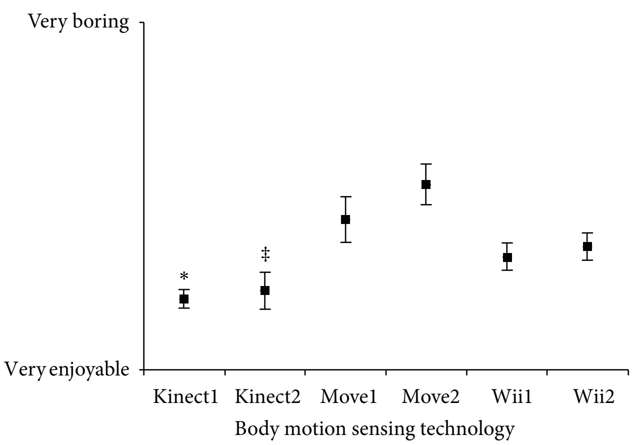


Figure 6: Rating of perceived game enjoyment reported immediately after performing each of the different dance routines using the various different body motion sensing technologies. Data are shown as mean ($n = 11$) and error bars indicate SEM. *indicates significantly more enjoyable versus Move1, Move2 and Wii2 ($P < 0.05$). ‡indicates significantly more enjoyable versus Move2 ($P < 0.05$).

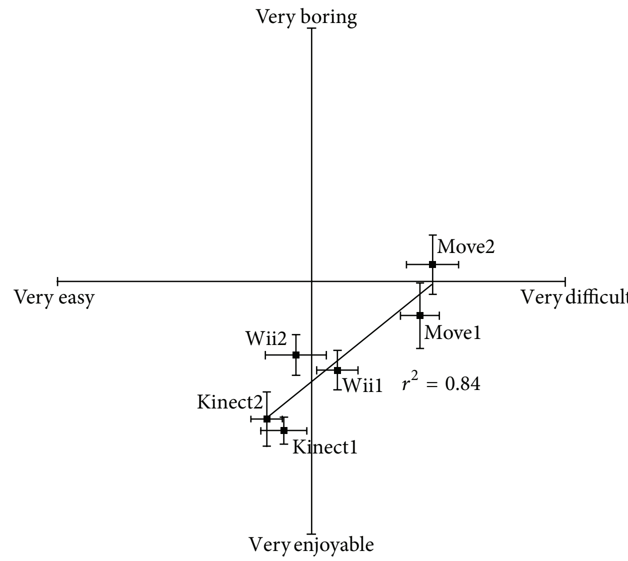


Figure 7: Group means ($n = 11$) for rating of game enjoyment plotted against rating of game difficulty for each separate dance routine and body motion sensing technology. Error bars indicate SEM. The data points were significantly correlated ($r^2 = 0.84$, $P < 0.05$).

perceived level of physical exertion that the subjects reported after completing each of the routines were comparable, the games were rated differently by the subjects in their levels of difficulty and this appeared to influence the level of enjoyment that they experienced.

Dance-based exergames normally comprise of a range of different songs and associated routines. The routines selected for use in the current study were selected on the basis that they all were at similar tempos and all involved comparable amounts of arm and leg movements. The results are somewhat surprising in that it was expected that routines using the Microsoft Kinect peripheral would elicit from the subjects more body movement during game play compared to the other two peripherals. This was because of its full body motion tracking capability compared to the more limited tracking of only one arm by the other two peripherals. The absence of an observed difference in the measured rates of oxygen consumption between peripherals tends to suggest that the technological differences between the three body motion sensing peripherals do not matter in this regard. Furthermore, the measured rates of oxygen consumption in this study are comparable to previously published studies of dance-based exergames using original foot-switch game controllers [13, 15, 21].

It has previously been suggested that interactive forms of exercise may provide a degree of distraction from the sensations of exertional discomfort [22], which would be a significant benefit, particularly if the player is unaccustomed to exercising. It has already been shown [20] that a variety of different exergames can promote a flow state experience [23] that is in fact closer to sport than exercise because of the challenge-based nature of video game play. However, this issue has not been specifically investigated in relation to dance-based exergames. It is therefore of interest to consider whether the results of the present study show any evidence of distraction from the sensations of physical exertion. The numerical rating of perceived exertion scale has been designed and validated so that the values (reduced by a factor of 10) correspond reasonably closely to heart rate [19]. Thus, if dance-based exergames were also to provide a degree of distraction, then the mean ratings of perceived exertion values shown in Figure 4 would be expected to be lower, given the magnitude of the mean heart rates reported in Figure 2. Rather, the ratings of perceived exertion values are a little higher than might be expected for traditional forms of exercise at a comparable intensity. One possible explanation is that the significant involvement of the arms in the dance routines might have given the subjects the impression that the exercise was of a higher overall intensity than it actually was. Such a situation could arise since the arms have proportionally smaller skeletal muscle mass compared to the legs and therefore may be working at a higher metabolic rate. A further possible explanation for this observation is that the dance-based exergames require the player to focus specifically on rhythmically coordinating the movements of their limbs and this increased need for conscious proprioceptive awareness resulted in a greater instead of a lesser-perceived level of exertion.

Game developers are well versed in the need to pay careful attention to the balance of challenge versus player skill balance in order to present them with a meaningful challenge [24]. However, the results of the other self-report measures indicate that while the difficulty and enjoyment ratings of each pair of dance routine games on the same console were comparable, there were significant differences in the ratings between the various consoles (Figures 5 and 6). Furthermore, the correlation analysis presented in Figure 7 suggests that the games that were perceived to be easier were also the ones that the subjects reported as being more enjoyable and conversely higher levels of perceived difficulty were associated with reduced levels of enjoyment. There are several potential reasons that may account at least in part for these observed differences. The first is that there were significant differences between the games (and therefore peripherals) in the level of motor skill required to play them. The second is that the games differed in their thresholds of acceptability for timing accuracy of a player's movements. The third potential reason is that the body motion tracking peripherals differ in their underlying technologies and affordances and as a consequence vary in the type and number of limbs that they can track. The Kinect peripheral, by virtue of being able to track all four limbs, is best placed to potentially help guide and coordinate player movement. In contrast, the movement of a single arm detected by the Wiimote peripheral is only responsive to changes in relative rather than absolute position. As a consequence, the tracked arm is unlikely to need to follow such precise trajectories in space; moreover the player will also have considerable freedom of movement in their nontracked limbs. Finally, the Playstation Move peripheral by spatially tracking the absolute position of the motion of the player's arm requires greater spatial precision of movement, but the absence of any detection of lower limb movement means that it is less able to guide and coordinate player movement. Unfortunately it is not possible to make a clear distinction between these potential explanations outlined above. However, it does seem unlikely that any of the three games used in the current study would intentionally be designed to be significantly more difficult at the beginner level, given that they will have been subject to extensive play-testing. Instead, it seems more likely that the subjects found the games, that either more fully tracked and guided their movements, or permitted significant movement freedom, to be more enjoyable compared to the games that closely tracked a single limb (arm) but at the same time gave less overall feedback. This interplay between the degree of movement precision required and the nature and extent of the feedback given to a player is an important issue that needs to more fully investigated in order to help inform the design of future exergames.

In terms of the potential to promote health benefits, it is likely that most players who encounter dance-based exergames in social or physical education settings will do so at beginner or possibly intermediate skill levels and that considerable amounts of practice will be required to progress beyond these levels. Thus, from a health perspective, it would be highly desirable for dance-based exergames to be designed such that, even at beginner to intermediate skill levels, the games maximise the amount and intensity of body movement while at the same time providing an enjoyable and engaging game play experience. It is however recognised that this would not necessarily be an easy outcome to achieve. The most likely way in which this might be achieved would be to steer game progression towards increasing step rates coupled with less of an emphasis on increasing the complexity of moves (i.e., faster repetitive movement instead of greater complexity). It is probable that such an approach will also need some adjustment (reduction) in the temporal accuracy requirements for movements to be scored (at least at less advanced skill levels). Finally, the initial skill demands should be set at a very low level to make a game as widely accessible as possible and straightforward for players to follow, and the game should be carefully structured in a way that effectively facilitates player motor skill development and progression.

5. Conclusion

The results of this study suggest that while the three different body motion sensor peripherals differ in their underlying technologies and affordances, contrary to what was expected, they do not appear to differ in the amount of physical exertion they facilitate when used to incorporate body movement into dance-based exergames. However, based on the self-reports measures from the subjects, there appear to be differences in the game play experiences that they offer. While the reasons for this remain unclear and warrant further investigation, there is one particular issue that has been highlighted and is of major importance. Specifically, it is the relative influences on game play experience of whole body motion tracking that is able to more holistically guide and support player movement versus restricted limb motion tracking that is agnostic to the movement of nontracked limbs and therefore as a consequence offers players greater freedom of movement. Finally, the potential commercial and health benefits of widespread adoption and sustained use of dance-based exergames are significant. There is, therefore, also a need to investigate the factors that help to sustain long-term playing of dance-based exergames and how these might be optimised, if these benefits are to be realised.

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