Balancing Physical and Cognitive Challenge: A Study of Players' Psychological Responses to Exergame Play

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ABSTRACT

Exercise video games have a recognized potential for use as tools for effective exercise. Current exergames do not consistently strike a successful balance between the "fun gameplay" and "effective exercise" aspects of the ideal exergame. Our research into exergame design addresses the question of what balance between an exergame's physical exertion and gameplay challenge is most successful from a user experience perspective. We have applied existing gameflow research and established exercise guidelines, such as those published by the American College of Sports Medicine, to a collection of four custom exergames: Astrojumper-Intervals, Washboard, Sweet Harvest and Legerdemain implement full-body motion mechanics that support different types of exercise, and vary in game complexity and level of physical challenge. This paper will present data collected on players' flow experiences and changes in mood state as a result of play, along with player feedback. We will compare the psychological responses to each of these games and discuss the importance of challenge-type balance as an exergame design consideration.

Categories and Subject Descriptors

K.8.0 [**Personal Computing**]: General - Games—*games for health*

General Terms

Design, Experimentation, Human Factors

Keywords

Exercise video game, player experience, flow, exergame comparison, evaluation.

1. INTRODUCTION

The ideal exergame is both fun and effective. It should involve sufficient physical activity to contribute towards improving or maintaining some aspect of fitness, and gameplay should be an enjoyable experience that immerses players in an activity, encouraging them to complete and replay games. Literature that discusses the design of successful player experiences in traditional video games often mentions the concept of "flow" as an optimal play state, attained by allowing a player to constantly make interesting strategic decisions regarding game challenges and thereby exercise their skills within the game, and rewarding them for doing so [4]. Challenges can be seen to have two sides: the amount of cognitive effort required to overcome them and the pace at which the game presents them; the appropriate balance between these is dependent on player skill [19]. Exergames add another dimension to the problem of balancing challenge and skill. While it is still necessary to consider the cognitive demands of challenges presented by the game and how players' development of game-playing skills and strategies will be enabled, exergame designers must additionally consider the physical demands of the game and what forms or degrees of exertion players will engage in to meet them. Sinclair et al. [15] touch on this problem in their discussion of exergame attractiveness and effectiveness; respectively, the cognitive and physical dimensions of exergame-play. Of exergames' principal research challenges, attractiveness-effectiveness balance is perhaps one of the most important as an exergame's success in both areas directly affects its ability to motivate repeated play: it seems reasonable to believe that a game which is neither fun nor able to assist with a player's exercise goals will not be played often, but exercise must be performed regularly in order for health benefits to be obtained.

Flow in gaming is an active research subject, and also discussed in the literature is the lack of both theoretical and empirical understanding of how body movement as a method of interaction, which is relevant to the area of exergame design, affects the user experience in a video game context [11, 5, 14]. Our research relates to both of these areas. We have developed a set of exergames and exergame prototypes that implement experimental game mechanics and support different types of exercise with full-body physical interactions that are an integral part of the game experience, and have examined how existing concepts of flow and game balance work when applied to these games. The exergame comparison study presented in this paper focuses on discovering insights into the balance of exertion and gameplay that is most successful from a player experience perspective.

2. RELATED WORK

A recent workshop paper [18] touched on the gaps in our knowledge of player experiences when playing traditional video games, and briefly discussed the different ways in which the player experience can be viewed, which include subjective feelings during play, motivations to play video games, and the potential impact that different game designs or content may have on the experience. Exergames, which add a physical aspect to gameplay, present additional questions regarding how play is experienced. When examining player experience, Chen [12] states that the concept of flow is used often because of the intuitive relationship between challenge and ability.

Several studies by educational game researchers have gone beyond suggesting flow as a useful construct, and have looked at the benefits of serious games that promote flow, linking it to positive learning outcomes [6, 13, 7, 16]. Flow has also been connected to increases in positive affect [24], and this is relevant since other studies have shown that positive affect can impact motivation to participate in exercise activities [25, 23]. While multiple studies of player experience in traditional video games have been conducted using variations of the flow concept [17], fewer researchers have used exergames in similar flow studies.

One such study was conducted by Thin et al. [2] comparing the play experiences of 14 young adult males participating in exergame activities and a cycling exercise. Six different exergames were used, including two Sony PS2 games that utilized the EyeToy camera, and four Wii games that utilized the Wiimote controllers (tennis and boxing) and the balance board (step aerobics and hula hoop games). Participants engaged in these games and the cycling exercise in random order, for approximately six minutes each with three-minute breaks in between. In the breaks between each activity participants responded to several visual analogue scales that evaluated their perceived game difficulty and mood state. Once all activities were completed, participants were given Jackson and Eklund's Flow State Scale-2 (FSS-2) [21] questionnaire in order to measure the extent of flow experienced throughout the study. The multiple short activity sections, each involving different equipment and separated by rest breaks and scale questions, may have negatively affected the quality of data gained from the FSS-2 questionnaire, but the authors did have several notable results. Interestingly, flow scores from the FSS-2 were found to be closest to published values for sports, as opposed to traditional exercise or dance. When compared with published mean scores for exercise activity or dance, the flow dimensions of challenge-skill balance and action-awareness merging were significantly higher for exergames.

Our four exergames, which are described in the following sections, were developed as individual experiments into game mechanics and creative movement types that could effectively support different forms of physical activity, as might be required by a balanced workout program. In addition to evaluating players' physiological responses to these games using such measures as heart rate, energy expenditure and perceived exertion ratings, we also collected data on psychological responses, including flow experiences and mood state changes. The psychological aspect of players' responses to our exergames is the focus of this paper.

3. EXERGAMES

Our exergames, which include Astrojumper-Intervals, Legerdemain, Sweet Harvest and Washboard, each involve a different type and amount of physical challenge, and different level of game complexity. All games were developed for the PC, using the OpenSceneGraph graphics engine and the Microsoft Kinect for full-body tracking, with position and orientation data from the player skeleton detected using the Flexible Action and Articulated Skeleton Toolkit (FAAST) [9].

3.1 Astrojumper-Intervals

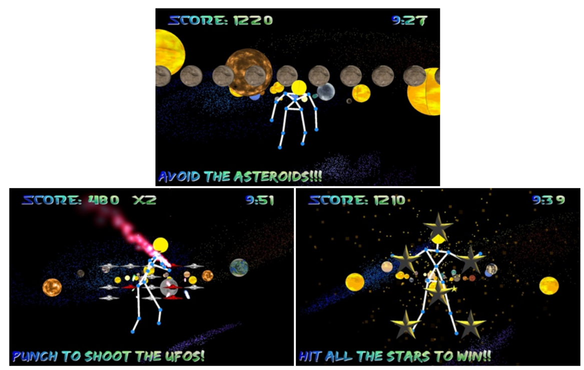

Figure 1: Astrojumper-Intervals Gameplay Screenshots

In Astrojumper-Intervals [1], planets fly through space toward the player who must move from side to side, jump, or crouch to dodge them. The player earns bonus points and score multipliers by hitting bright gold planets that are mixed in with the obstacle planets. The game focuses on aerobic activity, and is structured to include a beginning warm-up phase, a main exercise phase, and a final cool-down phase in accordance with the ACSM's guidelines for workout stages [3]. During the warm-up phase, planets initially move very slowly and gradually speed up. This is reversed in the final cool-down phase. At intervals throughout the main exercise phase, players are presented with higher-difficulty physical challenges in the form of three different mini-games (pictured in Figure 1). During these mini-games, players make rapid punching or throwing motions to shoot lasers at waves of UFOs, move quickly to hit patterns of flying stars, or jump or crouch to avoid approaching rows of asteroids.

3.2 Legerdemain

Legerdemain is a wizard duel-themed game that supports a combination of aerobic activity and anaerobic exercise in the form of light to moderate upper-body strength training for muscular endurance. In Legerdemain, players attempt to defeat a series of different opponents by casting spells. Resistance training mechanics let the player cast spells by moving their hands in specific patterns while wearing weighted

Figure 2: Legerdemain Gameplay Screenshot

wristbands, where the amount of weight used is factored into the player's spell casting power. Traditional weightlifting exercises like pulldowns, curls or extensions use a variety of movement types in order to work different muscle groups and the game's spell patterns were chosen to encourage similar variety, but were also modified to require movement across a larger physical space while playing. Vertical movement was emphasized to bring about the exertion that comes from lifting weight, and the movements needed to hit all parts of a spell pattern could have players leaning or crouching down to bring their hands near the ground, or reaching up above their heads. The result is that aspects of the game's workout are more functional, involving movements that do not replicate traditional exercises, but are closer to those of everyday activities. In addition to moving across the play space to complete spell patterns, other aerobic activity may occur as players duck under or dodge around projectile spells cast at them by the game opponents. Legerdemain consists of a beginning tutorial section followed by three levels that are each at most five minutes in length. Players earn points based on the amount of time that passes in the game and on how well they are performing relative to the game opponent. Each level presents a different game opponent, with different abilities and behaviors that gradually increase the game's difficulty.

3.3 Sweet Harvest

Sweet Harvest is a warm-up game that includes a series of light-intensity stretching and aerobic activities, all of which increase slightly in difficulty each time they repeat throughout a play session. Three of the activities are different types of stretches: in two of these, apples and bananas appear in a line on the screen, either at shoulder height where players are then prompted to use alternating arms and reach across the body to collect the fruit, or at knee height, where players step to one side and bend their knee in a side lunge to collect fruit. In the third stretch activity, fruit falls on both sides of the screen and players reach both arms out to the side to catch as many as they can. In addition to the stretches, a fourth activity involves a swarm of ants moving toward the player, who holds a fruit basket in their hands during this stage and must move or jump around in order to kick the ants away with their feet before the ants reach the basket. This activity adds variety to the gameplay and is intended to encourage more movement and increase players' heart rates.

The game utilizes several other mechanisms to encourage actual stretching. For example, players must keep their feet

Figure 3: Sweet Harvest Gameplay Screenshots

inside the bounds displayed at the bottom of the screen, and are not allowed to collect any fruit if they step out of bounds. This prevents players from simply moving from side to side to get closer to fruit that appears farther away from them. Throughout the stretching activities, a swarm of bees is visible flying across the top of the screen. If the player moves too quickly while collecting fruit, the bees will fly down toward the fruit, and if the player continues moving quickly the bees will steal the fruit and the player will lose points; this is intended to encourage slower, more deliberate stretching motions.

3.4 Washboard

Figure 4: Washboard Gameplay Screenshot

In Washboard the player does sit-ups to control the position of a floating spiky creature, seen on the left side of the screen in Figure 4. For our study, the Kinect was positioned above the player in such a way as to be able to detect the player's head throughout the up and down motions of a sit-up, and if the player was sitting up fully the creature was at the top of the screen, and at the bottom of the screen if the player was fully reclined. The goal of this game is to earn points by moving the creature to collide with the balloons that move across the screen from right to left, with the additional, optional goal of earning bonus points by avoiding the diamonds that also move across the screen. The game lasts for a total of five minutes. The gameplay and goals are straightforward, but different forms of sit-up exercises that improve the variety of gameplay are prompted by altering the patterns of balloons that appear on screen.

4. PLAYER EXPERIENCE STUDY

Astrojumper, Legerdemain, Sweet Harvest and Washboard were developed using the same approach to exergame design, where gameplay was built around a targeted form of exercise and gameflow theory, but all differ in the complexity of their rules and level of physical challenge presented. Figure 5 demonstrates how the gameplay complexity and physical challenge level of each game may be compared in relation to one another, where the "game complexity" ordering is based off of the number of gameplay rules implemented, and the "physical challenge" ordering is based off of physiological data collected from participants (e.g. ratings of perceived exertion and energy expenditure data, not included here as the focus of this paper is the psychological aspect of the play experience).

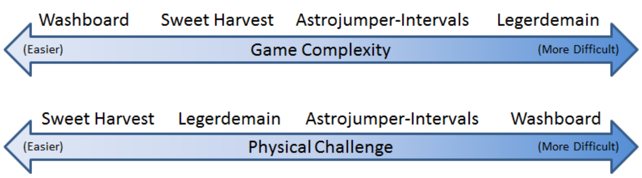

Figure 5: Relative Game Complexity and Physical Challenge of Exergames

Washboard has the simplest gameplay, and presents the most difficult physical challenge: the only requirement is to hit balloons that move across the screen, but the sit-up movements required to accomplish that goal, and to continue to do so throughout the game session, can become very strenuous. Sweet Harvest's goals are nearly as straightforward, as the instructions and fruits that appear on the screen guide players through each motion; however in contrast to Washboard, the physical demands of Sweet Harvest's gameplay are very low. The game goals presented by Astrojumper-Intervals are also relatively easy to understand (e.g. dodge objects) but their variety adds some complexity, and the aerobic movements required to play successfully over a 15-minute play session are moderately strenuous. Finally, the intensity of exertion necessary to do well in Legerdemain can nearly match that of Astrojumper-Intervals, especially with the use of weights as in the user study, but the larger number of game rules and the need to adapt to different opponent strategies results in Legerdemain being the most complex of the four games.

In this study, we wanted to investigate any impact the characteristics of game complexity and physical challenge level, or any particular game elements, had on player reactions and experiences. To do so we examined trends in player feedback and used two quantitative measures, the Flow State Scale-2 (FSS-2) [21] and the Positive and Negative Affect Schedule (PANAS) [8]. The FSS-2, used to examine the extent to which exergame players experienced flow, consists of 36 items asking respondents to indicate their level of agreement with various statements relating to nine dimensions of flow: challenge-skill balance, action-awareness merging, clear goals, unambiguous feedback, total concentration on the task at hand, sense of control, loss of self-consciousness, transformation of time, and autotelic (intrinsically rewarding) experience. The FSS-2 was originally developed to measure flow experiences in sport and performance settings and while there is a more general version of the instrument, the version we used was the original, which was recommended for use in a movement-based context [21, 22]. Additionally, in order to examine changes in players' mood states resulting from participation in an exergame, players were given the Positive and Negative Affect Schedule (PANAS) [8] before and after playing the game, in which they were asked to state their feelings at the present moment.

4.1 Procedure

Volunteer participants were recruited from among the university student population, and studies were conducted on an individual basis in a research lab, in sessions lasting 30-50 minutes. All participants filled out a demographic survey and the PANAS, after which they played one of the four exergames: either Astrojumper-Intervals or Legerdemain for approximately 15-20 minutes, or Washboard or Sweet Harvest for 5-10 minutes. Following the game, they were given the FSS-2 questionnaire, followed by the post-game PANAS and a final survey where they were asked to freely respond to questions about their favorite parts of each game and suggestions they had for improvements.

4.2 Participant Characteristics

Figure 6 summarizes several characteristics of the study participants, grouped by exergame condition. Participants were asked to self-rate the amount of activity (not necessarily exercise) present in their daily life on a 7-point scale (1 = "Not active at all," 7 = "Extremely active"), and also state the number of hours spent playing video games per week on a 5-point scale (2 = "1-3 hours per week," 3 = "4-6 hours per week"). No significant differences in participants' average age, rating of lifestyle activity level, or hours per week spent gaming were found between the groups for each game condition.

Game	Gender	Age (years)	Lifestyle Activity Rating	Gaming Hrs/ Week
Astro-Intervals (N = 19)	Male (12); Female (7)	M = 22.36	M = 4.17	M = 2.05
Legerdemain (N = 19)	Male (14); Female (5)	M = 22.57	M = 4.17	M = 2.26
Sweet Harvest (N = 31)	Male (27); Female (4)	M = 23.9	M = 3.8	M = 2.71
Washboard (N = 28)	Male (21); Female (7)	M = 23.62	M = 4.61	M = 2.27
(Total) (N = 97)	Male (74); Female (23)	M = 23.11	M = 4.19	M = 2.32

Figure 6: Participant Characteristics

Flow dimension score results were calculated according to instructions in the FSS-2 manual, and are displayed in Figures 7 and 9. The lowest possible score for a flow dimension is 1 (the participant did not experience the aspect of flow), and the highest possible score is 5 (the participant did experience the aspect of flow). A score of 3 may indicate some degree of agreement or, alternatively, ambiguity of relevance to the person's flow experience; we will generally regard it as not strongly showing that a dimension of flow was or was not felt as part of the experience [22].

	Legerdemain	Washboard	Sweet Harvest	Astro-Intervals
Concentration	4.276 (0.577)	4.139 (0.582)	4.161 (0.792)	4.092 (0.718)
Clear Goals	4.118 (0.516)	4.213 (0.484)	4.145 (0.562)	4.092 (0.528)
Sense of Control	3.987 (0.69)	4.111 (0.625)	4.048 (0.53)	3.908 (0.608)
Loss of Self-Consciousness	4.026 (0.849)	4.093 (0.809)	3.96 (0.839)	3.776 (0.82)
Unambiguous Feedback	4.145 (0.608)	4.139 (0.641)	3.782 (0.771)	3.763 (0.733)
Autotelic Experience	4.132 (0.679)	3.926 (0.635)	3.798 (0.881)	3.974 (0.558)
Challenge-Skill Balance	4.053 (0.504)	3.935 (0.685)	3.839 (0.546)	3.697 (0.715)
Action-Awareness Merging	3.618 (0.747)	3.583 (0.838)	3.532 (0.793)	3.579 (0.759)
Transformation of Time	3.526 (0.916)	3.343 (0.815)	3.355 (0.901)	3.395 (0.822)
Flow Score (Sum)	35.882 (4.184)	35.482 (4.045)	34.621 (4.056)	34.276 (3.615)

Figure 7: Means and standard deviations of item scores for each flow dimension, for individual exergames

(All Exergames)	Mean	SD
Concentration	4.164	0.675
Clear Goals	4.148	0.519
Sense of Control	4.026	0.601
Loss of Self-Consciousness	3.974	0.824
Unambiguous Feedback	3.95	0.711
Autotelic Experience	3.935	0.718
Challenge-Skill Balance	3.88	0.618
Action-Awareness Merging	3.573	0.779
Transformation of Time	3.393	0.854
Flow Score (Sum of Item Scores)	35.044	3.615

Figure 8: Flow dimension scores for all exergames

We compared mean flow scores for the exergames, both individual and overall, with published descriptive mean scores for non-competitive exercise and sports ([22], similar to comparisons made in [2]. For the combined (all games) participant group, mean flow scores for challenge-skill balance were higher than those for both exercise (exercise M = 3.74; p = 0.029) and sports (sports M = 3.69; p = 0.003); scores for the clear goals dimension were higher than those for exercise (exercise M = 3.98; p = 0.002); scores for the concentration dimension were higher than those for both exercise (exercise M = 3.69; p < 0.001) and sports (sports M = 3.7; p < 0.001); and scores for the sense of control dimension were also higher than those for both exercise (exercise M = 3.8; p < 0.001) and sports (sports M = 3.7; p < 0.001). Mean scores for the autotelic experience dimension were higher for exercise than for exergaming (exercise M = 4.18; p = 0.001), and it is possible that traditional exercise would have clearer presumed benefits and result in more personal satisfaction for a participant, in contrast to the act of engaging in a game-based workout for the first time.

Individually, Legerdemain scored better in challenge-skill balance than exercise (p = 0.015) and sports (p = 0.006); and Washboard scored better in clear goals than exercise (p = 0.019) and better in feedback than sports (p = 0.032). All games individually scored better in concentration than exercise (Astrojumper p = 0.025, Legerdemain p < 0.001, Washboard p < 0.001, Sweet Harvest p = 0.002) and sports (Astrojumper p = 0.029, Legerdemain p < 0.001, Washboard p = 0.001, Sweet Harvest p = 0.003). Sweet Harvest and Washboard scored better in sense of control than exercise (Washboard p = 0.016, Sweet Harvest p = 0.014) and sports (Washboard p = 0.002, Sweet Harvest p = 0.001). Finally, Sweet Harvest scored lower than exercise in the autotelic experience dimension (p = 0.022) as did Washboard (p = 0.048). Other comparisons yielded no statistically significant differences.

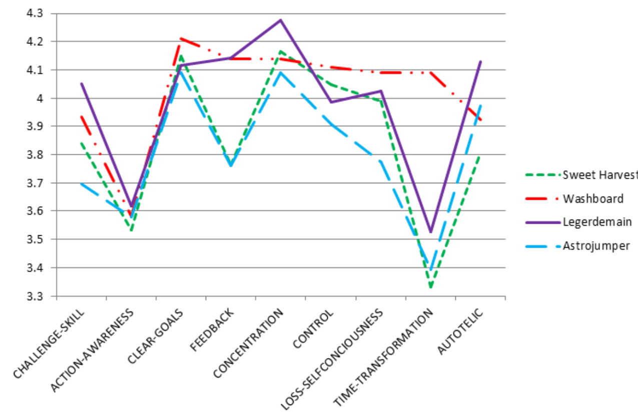

Figure 9: Comparison of mean flow dimension scores from Figure 7

4.3 Changes in Mood State

Positive and negative affect are the two primary dimensions of a person's emotional experience. Positive affect (PA) refers to a state of being enthusiastic and alert; as described by [8], high PA is, "a state of high energy, full concentration, and pleasurable engagement," while a person with low PA may in contrast feel sad or lethargic. Negative affect (NA) refers to feelings of distress or "unpleasurable engagement," and a person in a high NA state may feel anger, contempt or fear. A low NA state, however, may be one of calmness [8].

Game	PA Change (Post – Pre)	NA Change (Post – Pre)
Astrojumper-Intervals (N = 19)	M = 4.0, SD = 6.76; p = 0.019	M = -1.11, SD = 3.7; p = 0.21
Legerdemain (N = 19)	M = 2.78, SD = 5.35; p = 0.036	M = -1.32, SD = 1.42; p = 0.001
Sweet Harvest (N = 31)	M = 0.82, SD = 6.2; p = 0.47	M = -2.99, SD = 3.997; p = 0.000
Washboard (N = 27)	M = 2.09, SD = 4.56; p = 0.025	M = -3.22, SD = 3.19; p = 0.000
All Exergames (N = 96)	M = 2.19, SD = 5.77; p = 0.000	M = -2.35, SD = 3.42; p = 0.000

Figure 10: Pre- to post-game changes in PA and NA; p < 0.05 indicates a statistically significant difference between pre- and post-PA or NA

With the above definitions of PA and NA in mind, we might consider the most successful outcome to be the one in which PA is increased, and NA is decreased. For the overall group of exergame players, we can see this was the case (M = 2.19 point increase in PA, $p < 0.001$; M = 2.35 point decrease in NA, $p < 0.001$). While at least small PA increases and NA decreases are seen for each individual game, the Legerdemain and Washboard groups showed statistically significant results for both an increase in PA and decrease in NA, while Astrojumper-Intervals and Sweet Harvest did not (Figure 10). We will note, however, that the decrease in NA achieved by Legerdemain was not as great as that resulting from playing Sweet Harvest ($p = 0.04$) or Washboard ($p = 0.009$); likewise Astrojumper was not as effective at decreasing NA as Washboard ($p = 0.044$).

We also examined the relationship between changes in mood and flow scores, as the literature suggests that a better flow experience during play might result in an improved mood. No correlations between the change in negative affect and individual flow item scores were seen, but changes in positive affect were statistically significantly correlated with all flow dimensions except for clear goals and feedback (for all exergames, N = 96), as follows: challenge-skill balance ($r = 0.43$, $p < 0.001$); action-awareness merging ($r = 0.322$, $p = 0.001$); concentration ($r = 0.31$, $p = 0.002$); sense of control ($r = 0.319$, $p = 0.002$); loss of self-consciousness ($r = 0.284$, $p = 0.005$); time transformation ($r = 0.266$, $p = 0.009$); and autotelic experience ($r = 0.457$, $p < 0.001$).

4.4 Player Feedback

At the conclusion of a study session, participants were asked for feedback about what they either liked or disliked about the game they had just played. Comments for all games commonly mentioned the opinion that they were fun, creative ways to exercise and in most cases felt like an effective workout; the most commonly stated negative aspect was the Kinect's tendency to occasionally lose track of the player's position, making control of the game difficult. In order to identify broad patterns among feedback received, the participants who mentioned a game aspect that they liked were counted, as were the participants who mentioned a game aspect that they disliked (those including both positives and negatives in their comment were counted twice), with numbers compared to the total number of respondents. The majority of those who played Washboard, Legerdemain or Astrojumper gave positive feedback. For Washboard, 23 of 27 (85%) gave positive comments and 9 of 27 (33%) gave negative comments; for Legerdemain, 16 of 20 (80%) were positive and 4 of 20 (20%) negative; and for Astrojumper, 15 of 20 (75%) were positive and 7 of 20 (35%) negative. Sweet Harvest's results showed a different trend: 16 of 30 respondents (53%) mentioned aspects of the game or play experience that they liked, but 18 of 30 (60%) commented on what they disliked about the game. The following list contains descriptive examples of participants' comments for each of the four games.

Washboard

- "I like the game play. It made time go by quicker then I thought it was and I didn't realize how much I was actually exercising until after when my abs were burning."
- "I liked how it worked my abs and how challenging it was to get my position just right to get all of the balloons. I didn't like how the speed slowed down and sped up. It messed with me and when it slowed down, I had to hold my position longer!"

Legerdemain

- "I really liked the game because I lost track of time and got a good workout in while still having fun. I think the level of difficulty is good and the user interface is very easy to follow and understand. Thanks!"
- "Some of the enemies [...] were not affected by the wall spell and I was unsure why. Sometimes it felt like the enemies were moving too fast towards me to perform an adequate spell in time. Overall, I enjoyed the game despite my issues with the kinect."
- "I enjoyed how complex it seemed at times. It really kept me pushing myself as the levels got higher."

Astrojumper

- "i liked the exercise part of the experience but the game itself got boring after awhile."
- "The game itself is a simple concept but it was very fun and I feel like I've gotten my workout done for the day"

Sweet Harvest

- "Was not too hard, but still challenging and fun to do. More activities could be added to avoid repetitive exercises. I wasn't exactly sure what I was supposed to do in the ant section."
- "Accuracy in stretching motions, cute/fun appearance. Did not like responsiveness of Kinect. One part was impossible because my wingspan was not wide enough and that's why I was not NUMBER ONE. :)"

5. CONCLUSIONS

Previous work that has discussed the importance of designing games to support flow, or the relationships between flow, emotion (affect) and enjoyment seems to be supported by our results from this study. We did find correlations between the change in positive affect and most flow dimensions, as stated above, and while correlations between PA and the flow scores for clear goals and feedback were not found to be statistically significant here, the importance of including these in game design is still very clear from past research.

From the results presented above, we might consider Washboard and Legerdemain to be the more successful of the four exergames. PANAS results from these two game groups show both increased PA and decreased NA following game sessions, and these games have the highest average scores for each flow dimension from the FSS-2 questionnaire. Also, Washboard and Legerdemain player comments showed the greatest differences between numbers of participants who commented positively as opposed to negatively about the game. This pattern is interesting as these are the two games that offer the highest level of challenge, but in different areas:

the physical challenge of completing Washboard's sit-ups workout is arguably the most difficult among all four games, but Legerdemain's gameplay complexity perhaps offers the highest cognitive challenge, especially for first-time players. Astrojumper-Intervals was also able to noticeably increase players' positive affect, and although it had the lowest average scores for six of nine flow dimensions, showed a similar majority of positive over negative comments from players. The greatest overall difference in participant response was seen for Sweet Harvest, with no significant change in PA and a slight majority of negative comments over positive from players.

From the literature on flow experiences in gaming, we know that challenge-skill balance is an integral part of flow and one of the most important aspects of a game. Balancing between game challenge and player skill, or continuously providing opportunities for players to practice their abilities and then increasing the challenge level, and so on, is an intuitive concept that is useful when planning a game's structure and pacing. Design or implementation details, though, are not necessarily straightforward. Through our experience in designing and studying the exergames presented here, we have realized the importance of considering that challenges may be of different types, and that the combination of different (e.g. physical or cognitive) skills needed to respond to different challenge types is a significant factor in creating a positive flow experience within an exergame.

We have seen from our previous work with Astrojumper that game mechanics which combine physical and cognitive challenges, such as the planet-dodging mechanic which requires players to continuously make quick decisions and movements, can be very successful from a player experience standpoint [20], and that increasing both physical and cognitive challenges together can improve an exergame experience [1]. The study presented in this paper has shown that an even higher level of challenge, and/or a higher focus on one type of challenge over another as seen in Legerdemain and Washboard, can still result in a good experience. Also, our results with Sweet Harvest have provided a reminder that low challenge levels do not result in the best player response, lending empirical support to Sinclair's dual-flow model for exergames [15].

The data collected here have provided us with indications regarding which of our exergames, and which combination and level of challenge types, is the most successful from a player experience perspective in regards to an initial game experience. In future work, it would be valuable to conduct a longitudinal study investigating how players' flow experiences and other responses to play change with longer-term exposure to different exergames, and investigate if one type of challenge is more important than another in motivating repeated play, although both challenge types need to be present to some extent in order to support both the exercise and gaming aspects of an exergame. We saw in this study that, for example, participants who mentioned wanting more time with the Washboard game cited its efficacy as a workout tool instead of a source of entertainment. On the other hand, Legerdemain's higher game complexity and cognitive challenge held players' attention for a 20-minute game (a session of Washboard only lasted for 5 minutes) and distracted them from the physical exertion of play, as indicated by player comments. Additional study in this area will help us further develop our knowledge of how flow in exergames may be best considered, and benefit exergame designers in creating experiences that provide both entertainment and effective exercise.

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7. REFERENCES

[1] A. Nickel, H. Kinsey, T. Barnes and Z. Wartell. (2012). Supporting an Interval Training Program with the Astrojumper Video Game. Meaningful Play 2012.

[2] A. Thin, L. Hansen and D. McEachen. (2011). Flow Experience and Mood States While Playing Body Movement-Controlled Video Games. Games and Culture. DOI: 10.1177/1555412011402677.

[3] American College of Sports Medicine (ACSM). (2000). ACSM's guidelines for exercise testing and prescription (6th ed.). Baltimore, MD : Lippincott Williams and Williams.

[4] B. Brathwaite and I. Schreiber. (2009). Challenges for Game Designers. Boston: Course Technology, 2009. Print.

[5] C. Hummels, K. C. J. Overbeeke and S. Klooster. (2007). Move to get moved: a search for methods, tools and knowledge to design for expressive and rich movement-based interaction. Personal and Ubiquitous Computing, 11(8), 677-690.

[6] D. Choi, J. Kim and S. Kim. (2007). ERP training with a web-based electronic learning system: The flow theory perspective. International Journal of Human-Computer Studies, 65, 223(243). DOI: 10.1016/j.ijhcs.2006.10.002.

[7] D. Pavlas. (2010). A Model of Flow and Play in Game-based Learning: The Impact of Game Characteristics, Player Traits, and Player States. (Unpublished Dissertation, Orlando: University of Central Florida, Department of Psychology.

[8] D. Watson, L. Clark, and A. Tellegen. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. Journal of Personality and Social Psychology, 54(6), 1063-1070.

[9] E. Suma, B. Lange, A. Rizzo, D. Krum, and M. Bolas. (2011). FAAST: The Flexible Action and Articulated Skeleton Toolkit. Proceedings of IEEE Virtual Reality, (pp. 247-248).

[10] G. Borg. (1998). Borg's perceived exertion and pain scales. Human Kinetics, Champaign, IL, USA.

[11] K. Graft. (2009). Games At-a-Glance: Wii Quality. Retrieved from next-gen.biz/features/games-at-a-glance-wiiquality.

[12] J. Chen. (2007). Flow in Games (and Everything Else). Communications of the ACM, 50(4), 31-34.

[13] J. Harley. (2003). To what extent is the deep enjoyment of flow experienced in primary class-room

learning, and under what teaching and learning conditions might the deep enjoyment of flow be facilitated. Ph.D. thesis, Sydney University of Technology.

[14] J. Moen. (2006). KinAesthetic Movement Interaction: Designing for the Pleasure of Motion (Unpublished Dissertation, Stockholm: KTH, Numerical Analysis and Computer Science).

[15] J. Sinclair, P. Hingston and M. Masek. (2007). Considerations for the design of exergames. In Graphite '07: Proceedings of the 5th international conference on computer graphics and interactive techniques in australia and southeast asia (pp. 289-295). New York, NY, USA : ACM.

[16] J. Webster, L. Trevino, and L. Ryan. (1993). The dimensionality and correlates of flow in human-computer interactions. Computers in Human Behavior, 9 (4), 411426. DOI: 10.1016/0747-5632(93)90032-N.

[17] L. Nacke and C. Lindley. (2008). Flow and Immersion in First-Person Shooters: Measuring the player's gameplay experience. FuturePlay '08.

[18] P. Wyeth, D. Johnson and P. Sweetser. (2012). Conceptualising, operationalizing, and measuring the player experience in videogames. Extended proceedings of the Fun and Games Conference, IRIT Press, Toulouse, France, pp. 90-93.

[19] S. De Castell and J. Jenson, eds. (2007). Worlds In Play: International Perspectives on Digital Games Research. New York: Peter Lang Publishing. Print.

[20] S. Finkelstein, A. Nickel, Z. Lipps, T. Barnes and Z. Wartell. (2011). Astrojumper: Motivating Exercise with an Immersive Virtual Reality Exergame. Presence: Teleoperators and Virtual Environments, 20(1), 78-92.

[21] S. Jackson and R. Eklund. (1992). Assessing Flow in Physical Activity: The Flow State Scale-2 and Dispositional Flow Scale-2. Journal of Sport and Exercise Psychology, 24, 133-150.

[22] S. Jackson, R. Eklund and A. Martin. (2010). The FLOW Manual - The Manual for the Flow Scales. Mind Garden Inc. (mindgarden.com), Queensland, Australia.

[23] S. Soundarapandian, P. Ekkekakis and A. Welch. (2010). Exercise As An Affective Experience: Does Adding A Positive End Impact Future Exercise Choice? Medicine and Science in Sports and Exercise, 42(5), 102-103.

[24] T. Rogatko. (2009). The influence of flow on positive affect in college students. Journal of Happiness Studies, 10, 133-148.

[25] W. D. Russell and M. Newton. (2008). Short-Term Psychological Effects of Interactive Video Game Technology Exercise on Mood and Attention. Educational Technology and Society, 11 (2), 294-308.

[26] Y. De Kort and W. Ijsselsteijn. (2008). People, places, and play: a research framework for digital game experience in a socio-spatial context. ACM Computers in Entertainment, 6(2), Article 18 (July 2008). DOI: 10.1145/1371216.1371221.