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Enhancing player engagement through game balancing in digitally augmented physical games

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ABSTRACT

Game balancing can be used to compensate for differences in players' skills, in particular in games where players compete against each other. It can help providing the right level of challenge and hence enhance engagement. However, there is a lack of understanding of game balancing design and how different game adjustments affect player engagement. This understanding is important for the design of balanced physical games. In this paper we report on how altering the game equipment in a digitally augmented table tennis game, such as the table size and bat-head size statically and dynamically, can affect game balancing and player engagement. We found these adjustments enhanced player engagement compared to the no-adjustment condition. The understanding of how the adjustments impacted on player engagement helped us to derive a set of balancing strategies to facilitate engaging game experiences. We hope that this understanding can contribute to improve physical activity experiences and encourage people to get engaged in physical activity.

1. Introduction

Many physical games involve competition between players. Matching players with similar skill levels in these games is important in order to provide the right amount of challenge for players, which can help in enhancing player engagement (Campbell et al., 2008; Chen, 2007; Jackson and Csikszentmihalyi, 1999; Kretchmar, 2005; Mueller et al., 2012). One approach for providing the right level of challenge is through game balancing (Bateman et al., 2011). Mueller et al. (2012) define "game balancing" as game adjustments that make the exertion activity not too strenuous, yet challenging for players, to optimize engagement levels. Therefore, understanding game balancing design can be important for enhancing player engagement.

Game balancing in physical games such as sports can be different from balancing digital games. In sports it is often applied static adjustments, which are set at the beginning of the game and remain unchanged, such as "ladders" that aim to match players with similar skill levels, score adjustments by giving additional points to the weaker player (Altimira et al., 2014), or the handicap applied in golf (Swartz, 2009). It is also noteworthy to point out that game balancing is important not only to enhance player engagement but also for preventing players from being exposed to unhealthy levels of intensity (Mueller et al., 2012).

In digital games there are more opportunities for game balancing. For example, a virtual table tennis game can be easily balanced by controlling the physics of a virtual table tennis ball to assist the weaker player. In digital games, balancing is often done on a software level, which allow us to alter the speed of the player's car in a racing game (Cechanowicz et al., 2014), or to provide target assistance techniques in a Wii shooting game (Bateman et al., 2011). In addition, digital technology can also be used to measure the player's performance or the player's effort during the game (Mueller et al., 2011) and dynamically balance the game accordingly (Mueller et al., 2012). Therefore, it is not surprising that researchers are trying to use digital technology to enhance the player's experience and for game balancing (Altimira et al., 2016; Mueller et al., 2012).

Prior research has studied game balancing: some of prior research focused on parallel games such as jogging (Mueller et al., 2012), dancing (Gerling et al., 2014), or car racing (Cechanowicz et al., 2014), where the player's activities are performed independently and therefore

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do not influence the opponent's activity (Mueller et al., 2008b). In contrast, other research focused on non-parallel games (Altimira et al., 2016; Vicencio-Moreira et al., 2015), where a player functions as an obstacle that an opponent has to overcome in pursuit of the game's goals (Mueller et al., 2008b). Game balancing in non-parallel games might need to moderate this influence (Altimira et al., 2016). Some game adjustments such as a score adjustment could help balancing such games, however they might fall short in moderating the influence each player has on the other. In consequence, we are looking into balancing solutions that can moderate the influence each player has on the other in non-parallel games. Altimira et al. (2016) showed how digital technology can be used to achieve this moderation by adjusting the table tennis playing surface area and altering the player's performance. However the authors studied only static adjustments, not dynamic adjustments that are altered as the game proceeds and hence may be more suitable to adapt to players better. Moreover, the authors focused only on altering the playing surface to achieve this moderation. Other sport equipment could also be altered, such as the table tennis bat, to impact on the player's performance.

To add to prior understanding of game balancing, we build on the work of Altimira et al. (2016) to study the effects of altering the sports equipment, i.e. the bat-head size and the table size, on game balancing and player engagement. In addition, we also investigated applying these adjustments both statically and dynamically.

We chose to alter the bat-head size and the table size as two different types of adjustments to sports equipment that could also be applied to other sports in a similar way. The table in table tennis is the equipment shared between the players, similar to the court in basketball. On the other hand, the bat is a type of sport equipment that belongs to an individual player, similar to a golf club. Since the bat-head size and table size can also be adjusted both statically and dynamically, these adjustments were suitable for our study in order to investigate the effects of the frequency of the update of the adjustment on game balancing and player engagement. We envisioned that by dynamically altering the sports equipment, we would be able to adapt to different players more effectively, and control the players' performance better than other commonly used adjustments, such as asking the players to play with the non-dominant hand.

This work makes the following contributions: it provides (i) insight into how static and dynamic game adjustments of sport equipment can affect the player experience and enhance player engagement in physical games; (ii) insight into how game adjustments can be used to moderate the influence of one player's actions on the other's performance; (iii) insight into how digital technology can be used to dynamically adjust a sport equipment to support game balancing and enhance player engagement in physical games; and (iv) provides of a set of game design strategies to facilitate engaging experiences when balancing physical games.

We note that the focus of this work is on enhancing our understanding of game balancing design in physical games so that it will aid those interested in using game balancing to design more engaging experiences. Our work aims to emphasise how digital technology can be used in designing novel balancing techniques. Although game balancing itself can enhance player engagement through providing the right level of challenge according to Flow Theory (Chen, 2007; Csikszentmihalyi, 1990), there are still challenges in game balancing design. For example, players might perceive the adjustment of the game as unfair, which could lower their engagement (Altimira et al., 2014). Therefore the design of game adjustments is important for player engagement as it can change the player's perception of the game. To overcome these challenges we need to understand game balancing design better. Contributing to this understanding is the main goal of the work we present in this paper.

2. Literature review

Prior work on game balancing shows that balancing can enhance player engagement as it can enhance competition between players and provide greater challenges to players (Abuhamdeh and Csikszentmihalyi, 2012; Kraaijenbrink et al., 2009; Mueller et al., 2012). This highlights the importance of applying game balancing. However, different game adjustments can be more suitable for game balancing according to the gaming context, and they can lead to different levels of player engagement.

Gerling et al. (2014) studied different game adjustments, such as score adjustment, varying the precision of the input movements, and changing the number of movements each player had to perform. They concluded that score adjustment was more suitable for closing extreme performance gaps between players, and adjusting the precision of the input movements was more suitable for reducing small differences and for asymmetric physical input (the example in their study is a player using a wheelchair playing against a player without any mobility impairment).

Different game adjustments can also lead to different player engagement. For example, Cechanowicz et al. (2014) showed that aggressive balancing techniques that led to more lead reversals were preferred in a racing game. Gerling et al. (2014) found that awareness of the adjustments could influence the players' self-esteem. Similarly, Stach et al. (2009) found that if players are aware of the adjustment could negatively impact their experience. Bateman et al. (2011) studied different target assistance techniques in a Wii shooting game to balance players' skills. They found that the type of assistance affected the game score, and the players' differences in score affected the fun ratings. Finally Altimira et al. (2016) showed that game adjustments that encourage different styles of play in a table tennis game can be used for game balancing and can provide different levels of engagement.

Game adjustments can even lead to a decreased level of player engagement. Altimira et al. (2014) investigated game balancing in a traditional table tennis game and in a digital table tennis game by giving a six-point advantage to the weaker player, or by asking the stronger player to play with the non-dominant hand. In this study, the stronger player reported a decreased engagement compared to the no-adjustment condition when they had to play with the non-dominant hand in the traditional table tennis game, and when the weaker player had a score advantage in the digital table tennis game.

A drawback of game adjustments like asking a player to play with the non-dominant hand, is the lack of control over the impact of these adjustments on the player's performance. For example, asking a player to play with the non-dominant hand can have little effect if he or she is skilled in playing in this condition, or it can also overbalance the game if he or she does not have enough skills in playing with the non-dominant hand.

This prior research shows the importance of studying and understanding (i) the suitability of different game adjustments for game balancing in different gaming contexts (e.g. players with different capabilities as shown by Gerling et al. (2014) work); and (ii) the effects of game adjustments on player engagement. In this work we focus on (ii) when balancing non-parallel physical games, and on investigating how digital technology could be used to design novel balancing techniques.

2.1. Balancing physical games

In traditional physical games there are many different ways to balance a game. First, there are “ladders”, where the system matches players with similar skill levels. One drawback of this approach is that it can prevent friends from playing together. Other balancing techniques are score adjustments, which gives additional points to the weaker player, or performance adjustments such as asking the stronger player to play with the non-dominant hand in table tennis (Altimira et al., 2014). In golf, there is a well established handicap system (Swartz, 2009).

In addition to balancing the player's skills, balancing physical games also looked at balancing the fitness levels of people. For example, Mueller et al. (2012) and Stach et al. (2009) showed how game balancing could be used to adjust the player's exertion intensity, how this shaped the player's experience and the impact this had on the player's engagement. Mueller et al. (2012) showed how balancing the fitness levels of joggers created a new social jogging experience. Similarly, Stach et al. (2009) used a heart rate scaling mechanism where the performance of the players' avatars was based on the players' efforts relative to their fitness level. Mueller et al. (2012) and Stach et al. (2009) showed that to balance physical games we can take into account the fitness level in addition to the player's skills. In addition, they also highlight the usefulness of digital technology in game balancing, as it can capture the player's effort and dynamically adjust the player's intensity.

Dynamic adjustments could help improve the player's experience (Hunicke, 2005) and thus in enhancing player engagement. For example, they could be used to adjust the game challenges for players according to the player's performance, or they could change the game according to the player's affective state in order to optimize their experience (Tijs et al., 2008). However, these might not always improve the player's experience compared to static adjustments. For example, Bateman et al. (2011) tested differences between the static and dynamic frequency of updates in the players' score differential and the fun ratings in a Wii shooting game, but they did not find any differences. This shows that we still need to understand the design of dynamic adjustment better in order to exploit all of its potential for enhancing player engagement.

It is not easy to enhance player engagement as it is a complex construct that can be affected by several factors, such as the challenge, feedback provided, perceived control, interest and interactivity (O'Brien and Toms, 2008). Player engagement can also be associated with the perceived in-game autonomy, competence and relatedness (Ryan et al., 2006), and it can decrease when the game becomes more predictable (Salen and Zimmerman, 2003). Competitors are optimally motivated when they feel they have equal chance of success (Atkinson, 1957), and greater outcome uncertainty can lead to greater enjoyment (Abuhamdeh et al., 2015). Moreover, certain perceptions of failure can have a negative impact on a player's self image and feelings of competence (Juul, 2010), and losing frequently might reduce the player's interest in the game (Ahn et al., 2009), which can also influence player engagement. Finally, people play games for many reasons, such as for the challenge or the desire to play with others (Lazzaro, 2004). This shows that we might need to take into account multiple factors to understand the design of game balancing to enhance player engagement.

Investigating the effects of game adjustments on player engagement when they are applied statically and dynamically could help us understand how we could exploit the dynamic adjustments that enhance player engagement.

2.2. Research gaps and research questions

Our analysis of prior work suggests that our understanding of the effects of game balancing on player engagement is still incomplete. We identify a gap in how we could moderate the influence of one player's performance on the other player in non-parallel games. In particular, there is a gap in understanding how we could design dynamic adjustments and static adjustments to moderate this influence, and the benefits of applying each adjustment to enhance player engagement.

To address this research gap we studied static and dynamic adjustments of bat-head size and table size in a digitally augmented table tennis game to explore their effects on player engagement. In particular, we explored the following research question: **How does game adjustment design that alters the sport equipment statically and dynamically affect game balancing and player engagement in a non-parallel game?** To address this question, we defined the following sub-questions:

- RQ1: Do different game adjustments impact game balancing differently?
- RQ2: Do different frequencies of the updates in game adjustments impact game balancing differently?
- RQ3: Do different game adjustments impact player engagement differently?
- RQ4: Do different game adjustments impact player engagement differently depending on players' skill status (more skilled player or less skilled player)?
- RQ5: Do different game adjustments impact player engagement differently depending on the frequency of the adjustment, i.e. static and dynamic?
- RQ6: Is there an interaction effect between the different game adjustments, frequency of update and the player's skill status?

3. Methodology

This section describes the research method, which includes a justification of the chosen game, the study design, the participants of this study, the game adjustment design, the set up of the study, the procedure (the steps participants followed during the study), and the data collection and analysis methods.

3.1. The game

We chose to study a digitally augmented table tennis game because table tennis is a non-parallel physical game, which enabled us to study the impact of game adjustments when one player plays against another. Although there are other games that have these characteristics, such as tennis, we decided to study table tennis because the setup of a table tennis game in a lab environment is easier than other games as it does not require a great amount of space. In addition, prior work already showed how digital technology can be integrated into this game to provide feedback about the players' performance (Baca, 2008), and to augment the game with digital visual information (Mueller et al., 2008a, 2009, 2010a, 2010; Ishii et al., 1999). We decided to apply similar technology in order to study how that technology could be used for game balancing and to enhance player engagement.

To augment the game we projected images onto the table surface to:

- Show the boundaries of different table sizes (in the table adjustment condition). Note that we did not change the physical table, but only the playable surface area, which allowed us to easily dynamically change the game.
- Show an image of the bat each participant had to use at the beginning of each point (in bat adjustment condition).
- Show the location of where the ball hit the table and the participants' scores (in both the table and bat adjustment conditions).

3.2. Study design

The study was in a 3×2×2 split-plot design (Lazar et al., 2010, p. 54). Each pair of participants first played table tennis with the different game adjustments defined in this study to warm-up. Afterwards, they played three 21-point games with each of the game adjustments. We defined the game adjustment as a within factor with three levels: no-adjustment (regular table tennis game), bat and table adjustments. The

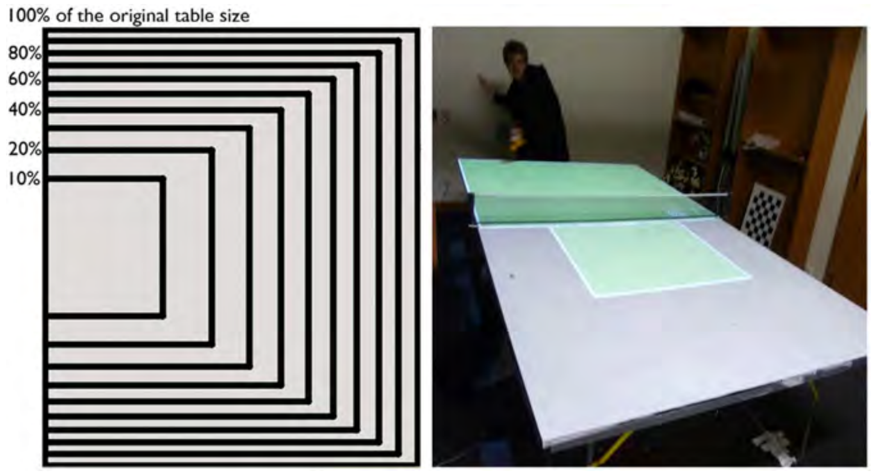

Fig. 1. Table adjustment design. On the left the different table sizes are shown (the net is on the left end). The table size shrinks towards the centre of the net and all table adjustments have the same aspect ratio. On the right a participant is playing with the table adjustment.

order of the game adjustments was counterbalanced to avoid any order effects.

We defined the frequency of update as a between factor with two levels: static and dynamic. Each pair of participants was randomly assigned to one of these two frequencies updates. Therefore, each pair of participants played with the table and bat adjustments, but only in the static or dynamic frequency of update. We note that since in the no-adjustment condition we did not alter the game, this condition was the same for the participants that were assigned to play in the static frequency of update and those assigned to play in the dynamic frequency of update.

As the third independent variable we defined the players' skill status as a between factor with two levels. As we matched participants with different skill levels, in every match one participant was assigned as "the more skilled player of the match", and the other as "the less skilled player of the match".

We chose a split-plot design because we wanted to limit the number of conditions per participant to reduce the impact of his or her fatigue on the results. We defined as a within factor the game adjustment, which allowed us to explore the differences in playing with the table adjustment, bat adjustment and no-adjustment during the semi-structured interviews.

3.3. Participants

We selected a sample of the population aged 18+. The participants were recruited from the university using posters and were rewarded with a cafe voucher. Each participant filled out an online pre-experiment questionnaire, which assessed their frequency of playing table tennis: never, less than once a month, once a month, 2–3 times a month, once a week, 2–3 times a week or daily. We discarded the participants who had never played table tennis. In total, we recruited 42 participants: 16 females and 26 males with an average age of M=26.1 years and SD=10.1. Twenty-two of these participants played in the static frequency of update condition and the other 20 in the dynamic frequency of update condition. In the pre-questionnaire we also assessed the participants' self-reported table tennis skill level as novice (2 participants), beginner (17), competent (11), proficient (12) and expert (0).

We used the information from the pre-questionnaire to pair the participants. The objective was to create pairs of participants with as large as possible a difference in skill level between the participants in each pair. The pairings were as follows: competent vs. proficient (2 pairs), beginner vs. competent (8), beginner vs. proficient (9), novice vs. proficient (1) and novice vs. competent (1). Once all participants were matched, we randomly assigned each pair of participants to play the game with the either the static or the dynamic frequency of update.

As we required self-assessment of participants' skills, there was a possibility of creating pairs whose participants' skill level was actually quite similar. Therefore, we decided to discard any pairs whose difference in skill level was significantly smaller than that of the other pairs. We checked the results of the final score difference between the participants of each pair in the no-adjustment condition, and looked for outliers by applying the Z-value test to detect those Z values greater than or equal to 3 (Aggarwal, 2013). We did not find any pairs with a significant difference, so we concluded that there was a satisfactory difference between participants' skills in all pairs, and did not discard any pairs.

3.4. Game adjustment design

In this section we first explain the design of dynamic and static adjustments, and then describe the design for the table and bat adjustments.

3.4.1. Dynamic and static adjustments

In the dynamic adjustments, we adjusted the difficulty level after each game point according to the difference in score between the participants in order to keep the game outcome more uncertain, which is important for player engagement (see 2.1). The more advantaged a participant was in the score, the harder the challenges he or she had to face: playing with a smaller bat-head or a smaller table. In contrast, in the static adjustment, the bat or table size was set before the first game point.

3.4.2. Table adjustment design

To adjust the table size we did not physically alter the table, but we used digital technology to make the participants' experience playing with a smaller table (see Fig. 1). We mounted a projector on the ceiling facing down towards a physical table tennis table. This projector displayed an image of a table tennis table on top of the physical table tennis table.

To design the table adjustment we conducted a pre-experimental study with 8 participants to evaluate the experience of playing with different table sizes, and to evaluate the perceived level of difficulty [1-"very easy", 5-"very hard"] of playing with different table sizes [regular table size, 10% of its original size] (see Fig. 1). This informed the relationship between the table size and difficulty level (see Fig. 2).

Based on the results of this pre-experimental study we designed the dynamic and static adjustments. In the dynamic adjustment condition

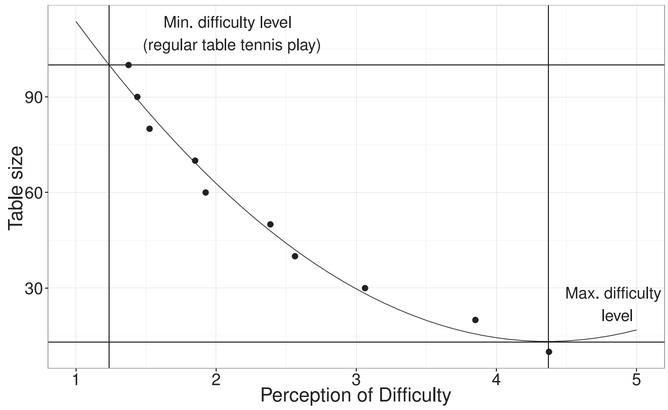

Fig. 2. Results of the pre-experimental study of table adjustment design, showing the participant's perception of difficulty of playing with different table sizes (percentage size of table compared to full size). Black dots represent the data collected from the pre-experimental study. A polynomial of degree two is fitted to the data.

we used a linear mapping between the range of differences in score [0,20] and the range of difficulty levels. The range of difficulty levels was based on the difficulty levels of playing with the different table sizes [regular table size (no-adjustment), 10% of its original size]. A difference in score of zero was associated with the level of difficulty of no-adjustment (minimum difficulty level defined for the game), and a difference in score of 20 points with the level of difficulty associated at the hardest adjustment (10% of the table size). For mapping the difficulty level to the different table sizes, we used the function shown in Fig. 2. We implemented software that calculated the game difficulty level to be set after each game point, and that updated the size of the virtual table projection.

For the static frequency of update, the size of the virtual projected table was fixed to 30% of the size of the regular table tennis table. This was the size that corresponded to the adjustment in the dynamic frequency of update when the score difference was 11 points. Eleven points is the rounded average of all possible score advantages in a 21 point game and we therefore considered it to be the most suitable score adjustment considering the possible differences in skill levels between the participants.

3.4.3. Bat adjustment design

For the bat adjustment we altered the head size of the bat and kept the handle unchanged (see Fig. 3). We used three bat adjustments: regular bat, a bat with a head 50% of the size of the original head, and a bat with 25% of the original head size. We felt that using three sizes was sufficient for investigating the player experience with different head

Fig. 3. Bat adjustment design. Regular table tennis bat (left), 50% head size (middle), 25% head size (right).

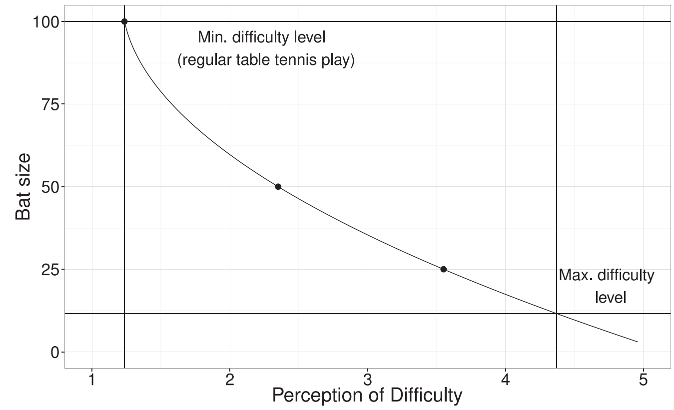

Fig. 4. Results of the pre-experimental study of bat adjustment design, showing the participant's perception of difficulty of different head sizes (percentage head-size compared to full head-size). A polynomial of degree two fitted the data.

sizes. We could not implement a change of head size using digital technology at this time, but this might be possible in the future. For this study, we projected on the physical table for three seconds the image of the bat each player had to use after each game point.

To design the bat adjustments we also conducted a pre-experimental study (in this case with 9 participants) to evaluate the experience and perceived level of difficulty of playing with different bat-head sizes. As with the table adjustment, we obtained the relationship between the different bat-head sizes and difficulty levels (see Fig. 4).

We used the results of this pre-experimental study to design the dynamic and static bat adjustments. For the bat dynamic adjustment design, we also used a linear mapping between the range of differences in score [0,20] and the range of difficulty levels. We defined the values of the minimum and maximum difficulty levels to be the same as in the table adjustment design (see Figs. 2 and 4), because this would allow for a more fair comparison between the bat and table adjustments. However, for the bat adjustment we only had a limited number of head sizes. Therefore, for each difference in score between the players, we could not always provide the bat with the right head size determined by the defined function in Fig. 4. Instead, we asked the participants to play with the bat whose head size was the closest to the right head size.

For the static frequency of update, the bat-head size was fixed to 25% of the size of the regular head as this was the bat used for the player with an advantage in the dynamic frequency of update when the score difference was 11 points.

3.5. Material and set up of the study

We used the following equipment: a table tennis table, bats with different head-sizes and a video projector mounted on the ceiling facing down towards the physical table. The table was painted in white, and the projector was used to project images onto the table surface, showing the boundaries of different table adjustments, the location of where the ball hit on the table, whether the ball hit outside the projected boundaries, and the scores of the players after each game point. To detect when the ball hit the table, we used four piezoelectric sensors placed underneath each side of the table. In addition, we used a PlayStation 3 camera (120 Hz update rate), which we placed on the ceiling facing down towards the table, to locate the position of the ball when the piezoelectric sensors detected a hit.

We developed software (see Fig. 5) that allowed us to interactively control the game (e.g. starting and stopping each game point) and the information projected onto the table (e.g. the scores after each game point). The software also saved all the information related to the game into a database, including the type of game adjustment applied and the players' scores.

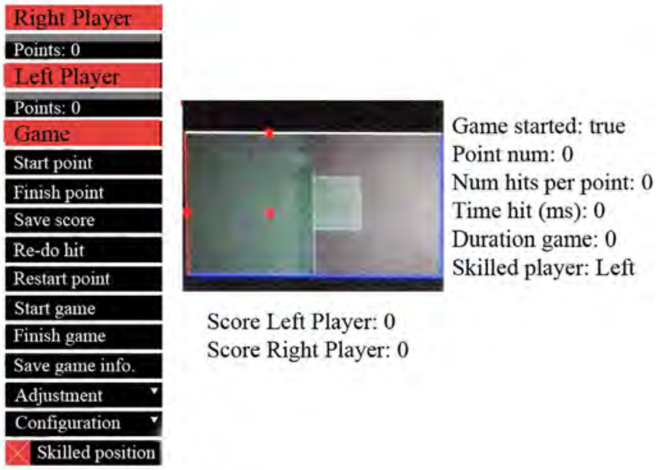

Fig. 5. Software interface used in the study.

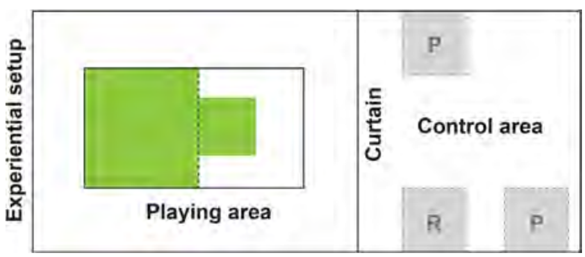

Fig. 6. On the left the playing area is shown and on the right the control and evaluation area. R is the main researcher desk. P are the participants' desks.

The experimental environment was divided into two spaces: a playing area and a control and player evaluation area (see Fig. 6). The playing area was where participants played the table tennis game, and the control and player evaluation area was where participants filled in the questionnaires and were interviewed. The main researcher controlled the software and took notes (e.g. observations from the gameplay or comments of the participants) in the player evaluation and control area. Although the main researcher did not have direct contact with the participants while they were playing, he could follow the game through the video feed from the camera mounted on the ceiling, which captured the whole table, but not the players.

The two physical spaces were separated with a curtain in order to prevent the presence of the main researcher from influencing the player experience. Similarly, while participants were answering the questionnaires, the main researcher moved into the playing area to avoid influencing their answers.

3.6. Procedure

The participants warmed up for 6 minutes playing table tennis in the three game adjustments (2 minutes each). Before starting the games, we asked the participants to play competitively. Participants played 21-point games in each of the game adjustments, to allow sufficient time for the participants to experience each condition. After each game, the participants completed a questionnaire to assess their engagement. At the end of the experiment the participants were interviewed in pairs through semi-structured interviews.

3.7. Data collection and analysis methods

We gathered data of the participants' difference in score and analysed the results using a repeated measures ANOVA with game adjustments as a within-subjects factor and the frequency of update as a between-subjects factor. For post-hoc tests, we used the Bonferroni correction for pair-wise comparisons. We also collected the win/lose ratio and used the Fisher's exact test to evaluate whether there was a relationship between the number of matches won by the more skilled participants and the frequency of update, and whether there was a relationship between the number of matches won by the more skilled participants and the table and bat adjustments.

To collect information about the participants' experiences we used the engagement scale questionnaire (five-point scale) from the O'Brien and Toms (2010) model of engagement. We adapted the wording of the rating statements to the gaming context (e.g. changing the statement "*The time I spent shopping just slipped away*" to "*The time I spent playing the game just slipped away*"). We excluded the items regarding the aesthetic factor as they were not relevant to the traditional table tennis game. For each participant and game condition, we obtained an engagement score by averaging the items of this scale. The player engagement scale in this study had high reliability (Cronbach's-α=0.83).

The engagement scores were analysed using a Multi-Level Model (MLM) for mixed-design (Field, 2012, p. 617). We defined the engagement score as the dependent variable and added to this model the following predictors in the following order: game adjustments, frequency of update, players' skill status, and the different interaction effects among these variables. This model informed us which predictors contributed significantly to the engagement scores and we used the results to answer the research questions from R3 to R6. We note that the model can provide more information than required for answering the research questions, such as the main effects of the frequency of update. However we report just those results that helped us to answer the research questions.

A MLM was used instead of the traditional ANOVA test because it can better handle missing data (Field, 2012, p. 860). We used an online survey tool for the engagement questionnaire, and we were not able to retrieve the data of three participants in one of the three game adjustments because of the system failure. Since we wanted to keep the rest of data of these participants, the MLM was more suitable. For the MLM we used post-hocs tests with Bonferroni corrections to compare between game adjustments.

For both repeated measures ANOVA and MLM, we performed the appropriate tests to validate the assumptions. We checked that the distributions were not significantly different from the normal distribution (Shapiro test $p > .05$), and that the variances between the groups we compared were not significantly different (Levene test $p > .05$). The significance level was set at α=0.05.

In addition to the engagement questionnaire, we also used two other methods for player experience evaluation. In one, we used post-playing evaluation by conducting semi-structured interviews to assess which game adjustments participants preferred, and to evaluate the different reasons for their preferences. The other method was in-place evaluation through direct observations using the camera mounted on the ceiling (see 3.5). The findings from these observations were used during the interviews for facilitating further discussion.

In the semi-structured interviews, we defined an initial set of questions and themes to be discussed with the players, focusing on understanding player engagement during the game. The initial planned questions included: "*Recall the different conditions, tell me something memorable, something that you found enjoyable? In which condition? Why?*". Follow-up questions were asked to understand the player's engagement better based on the themes that emerged from the players' reflections regarding their engagement, and the main researcher observations.

Interviews were audio recorded and this data was transcribed using a quasi-statistics method for the analysis, based on counting the number of times something is mentioned to measure the frequency of a phenomenon, and how events were distributed among categories of people (Becker, 1958). We used this analysis to identify the most frequently reported player experiences and to identify the most

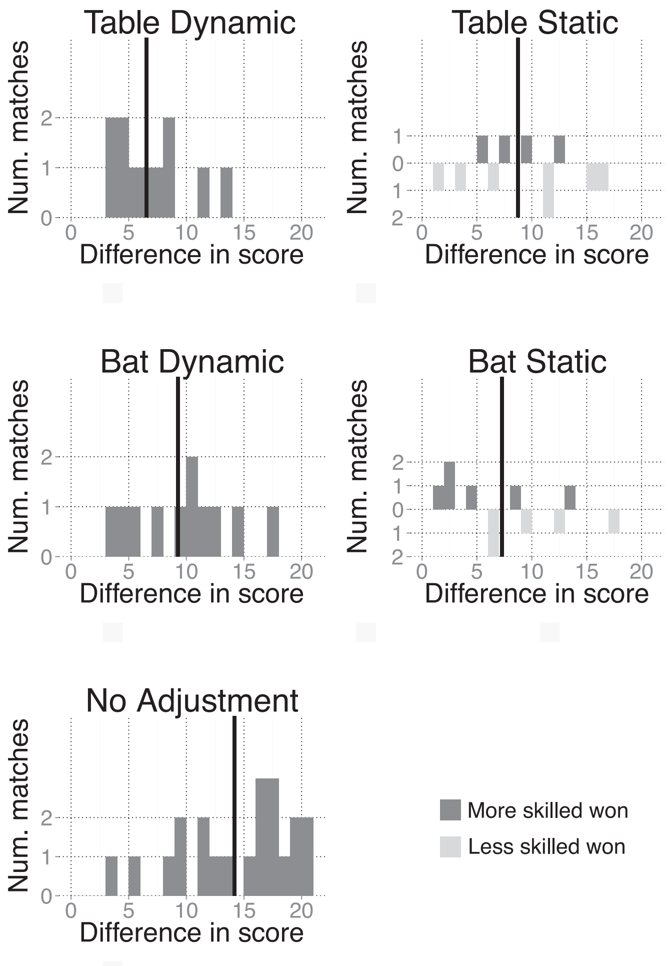

Fig. 7. Difference in score, in absolute values, of the game adjustments with the different frequency updates. The wins of the more skilled participants and the less skilled participants are shown. The vertical line represents the mean of the difference in score.

common experiences players have when the different game adjustments were applied. This provided a better understanding of the their engagement scores from the questionnaire.

4. Results

4.1. Game balancing

RQ1: Do different game adjustments impact game balancing differently? The table and bat adjustments significantly reduced the score differences (in absolute values) compared to the no-adjustment condition (see Fig. 7). A repeated measures ANOVA on the score difference between participants revealed significant differences between game adjustments (bat, table and no-adjustment), $F(2, 40) = 20.72$, $p < .001$, $\eta_G^2 = 0.32$. Pairwise comparisons with the Bonferroni correction showed that the score difference in the no-adjustment condition (M=14.2, SD=5.1) was greater than the one from the table adjustment (M=7.6, SD=4.2) with $p < .001$, and than the one from the bat adjustment (M=8.3, SD=4.7) with $p < .001$. No significant differences were found between the score differential of the table and bat adjustments (p=1.0).

Fig. 7 shows that in the no-adjustment condition the more skilled participants won all of the games. In contrast, the win/lose ratio was more balanced in the table and bat adjustments. Taking both static and dynamic frequency of updates into account, in the bat adjustment, the more skilled participants won 77% of the matches (17/22), while tn the table adjustment, the more skilled participants won 68% of the matches (15/22). The Fisher's exact test reported no significant relationship between the number of matches won by the more skilled participants and the table and bat adjustments (p=0.73).

To summarise, the table and bat adjustments reduced the score difference between the participants and balanced the win/lose ratio compared to the no-adjustment condition. However, no significant difference was found between the table and bat adjustments.

RQ2: Do different frequencies of the updates in game adjustments impact game balancing differently? Regarding the difference in score (in absolute values), we did not find any significant difference between the participants grouped in the static frequency of update condition and those in the dynamic frequency of update condition, $F(1, 20) = 0.94$, $p = 0.34$, $\eta_G^2 = 0.03$. However, the frequency of update had an impact on the win/lose ratio in the table and bat adjustments.

Fig. 7 shows that in the dynamic frequency of update of the table and bat adjustments, the more skilled participants won all games. However, the more skilled participants won only 55% of the matches (6/11) in the static bat adjustment, and 36% of the matches (4/11) in the table static adjustment. The Fisher's exact test indicated a significant relationship between the number of matches won by the more skilled participants and the frequency of update of the table and bat adjustments ($p < .01$).

To summarise, regarding the final score difference there was no significant differences between the participants grouped in the static frequency of update and those in the dynamic frequency of update. However, for the table and bat adjustments, the more skilled participants won significantly more matches when they played in the dynamic frequency of update than in the static frequency of update.

4.2. Player engagement

To analyse player engagement and answer the research questions from 3 to 6, we used MLM models as explained in Section 3.7. To answer the research questions we constructed a model with engagement scores as the dependent variable and we added the following predictors in this order: game adjustments (used to answer RQ3), frequency of update and player's skill status (used to answer RQ4), and the different interaction effects among these variables (used to answer RQ5 and RQ6). By analysing which predictors contributed significantly, we answered the research questions.

RQ3: Do different game adjustments impact player engagement differently? The game adjustments did impact differently on player engagement. There were significant differences among the

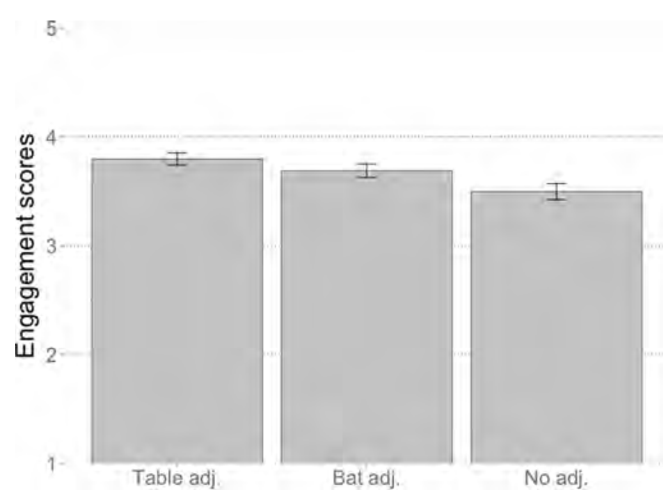

Fig. 8. Mean and standard error bars of the engagement scores of the table adjustment, bat adjustment and no-adjustment conditions.

no-adjustment (M=3.50, SD=0.47), table adjustment (M=3.80, SD=0.37) and bat adjustment (M=3.69, SD=0.41) conditions, $\chi^2(2) = 16.41$, $p < .001$ (see Fig. 8).

The post-hocs tests with Bonferroni corrections showed that participants were significantly more engaged playing with the table adjustment than without any adjustment ($p < .01$). Similarly, they were significantly more engaged playing with the bat adjustment than without any adjustment (p=0.02). We did not find significant difference in the participants' engagement scores between the table and bat adjustments (p=0.37).

In the interviews most of the participants reported that the no-adjustment condition provided a less engaging experience than the table or bat adjustments, mainly because of the difference in participants' skill level and the resulting gameplay this caused. For example, one participant explained that the no-adjustment condition was not enjoyable because he had to spend most of the time picking up the ball from the floor because of the difficulties in countering the attacks of his opponent.

The most frequently reported reasons for the increase of engagement in the table or bat adjustment were the increase in the challenge (e.g. a participant saying "*can I get it in the small space constantly?*"), the creation of new goals (e.g. saying "*I enjoyed the bat adjustment more because I could get better*"), and the closer scores as the less skilled participants were able to score more points.

RQ4: Do different game adjustments impact player engagement differently depending on players' skill status? There was no significant interaction effect between game adjustments and players' skill status, $\chi^2(2) = 0.34$, $p = .844$. However, we found a significant higher-order interaction effect (see RQ6 below).

RQ5: Do different game adjustments impact player engagement differently depending on the frequency of the adjustment? There was a significant interaction effect between game adjustments and the frequency of updates, $\chi^2(2) = 6.44$, $p = .039$. Since we found higher-order significant interactions involving game adjustments and frequency of updates (see RQ6 below), we did not investigate this research question further as the higher-order interactions supersede lower-order interactions (Field, 2012).

RQ6: Is there an interaction effect between the different game adjustments, frequency of update and the player's skill status? We found a significant three-way interaction effect between game adjustments, the frequency of updates, and players' skill status, $\chi^2(2) = 8.36$, $p = .015$. From Fig. 9 we note that:

1. The difference in engagement scores between the dynamic and static frequency of updates was greater for the more skilled participants than for the less skilled participants in both table and bat adjustments.
2. In the static frequency of update condition there did not seem to be any difference in the engagement scores among game adjustments, neither for the more skilled participants nor for the less skilled participants.
3. In the dynamic frequency of update condition, the engagement score differences between the table and bat adjustment conditions compared to the no-adjustment condition were greater for the more skilled than for the less skilled participants.

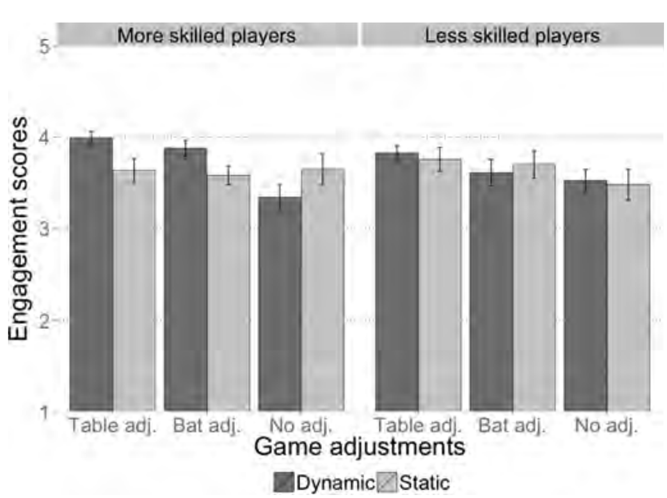

Fig. 9. Mean and standard error bars of the engagement scores of the table adjustment, bat adjustment and no-adjustment of the more skilled and less skilled participants playing in the dynamic and static frequencies of updates.

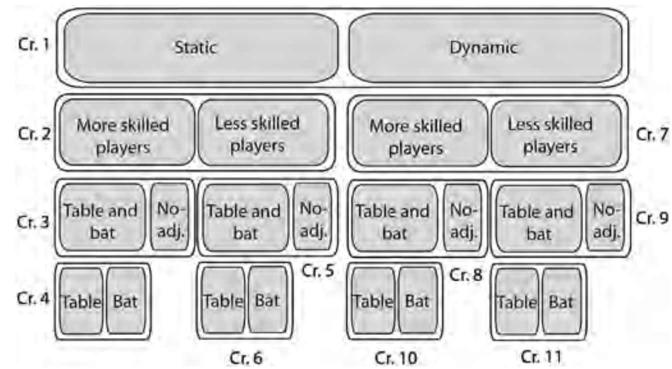

Fig. 10. Planned contrast analysis of engagement scores. For example, Cr. 1 (Contrast 1) compares engagement scores between static and dynamic frequency of updates; Cr. 2 compares the engagement scores between the more skilled participants and less skilled participants, who played in the static frequency of update; and Cr. 3 compares the engagement scores between the table and bat adjustment to the no-adjustment for the more skilled participants who played in the static frequency of update.

To make the three-way interaction clearer and to support the three points listed above, we conducted a planned contrast analysis (see Field, 2012) as it allowed us to compare the conditions shown in Fig. 10.

- For the more skilled participants who played in the static frequency update there were no significant differences between the table and bat adjustments, compared to the no-adjustment condition (Cr. 3: $b = -0.01$, $t(73) = -0.26$, $p = .80$, $r = .03$), nor between the table and the bat adjustments (Cr. 4: $b = -0.03$, $t(73) = -0.43$, $p = .67$, $r = .05$). For the less skilled participants, there was a significant difference between the table and bat adjustments, compared to the no-adjustment condition (Cr. 5: $b = 0.08$, $t(73) = 2.03$, $p = .046$, $r = .23$), but no significant difference between the table and bat adjustments (Cr. 6: $b = -0.03$, $t(73) = -0.43$, $p = .67$, $r = .05$). This supports point (2) outlined above.
- For the more skilled participants who played in the dynamic frequency of update there was a significant difference between the table and bat adjustments, compared to the no-adjustment condition (Cr. 8: $b = 0.20$, $t(73) = 4.48$, $p < .01$, $r = .46$), but no significant difference between the table and bat adjustments (Cr. 10: $b = 0.06$, $t(73) = 0.81$, $p = .42$, $r = .09$). For the less skilled participants there were no significant differences between the table and bat adjustments, compared to the no-adjustment condition (Cr. 9: $b = 0.06$, $t(73) = 1.55$, $p = .13$, $r = .18$), nor between the table and the bat adjustments (Cr. 11: $b = -0.1$, $t(73) = -1.57$, $p = .12$, $r = .18$). This supports point (3) outlined above.

The results of the engagement scores (Fig. 9) were in line with the participants' preferred game adjustments as reported in the semi-structured interviews (Fig. 11). In the interviews we asked the participants which game adjustment they preferred or whether they did not have any preference. The more skilled participants in the dynamic frequency of update condition preferred playing with an

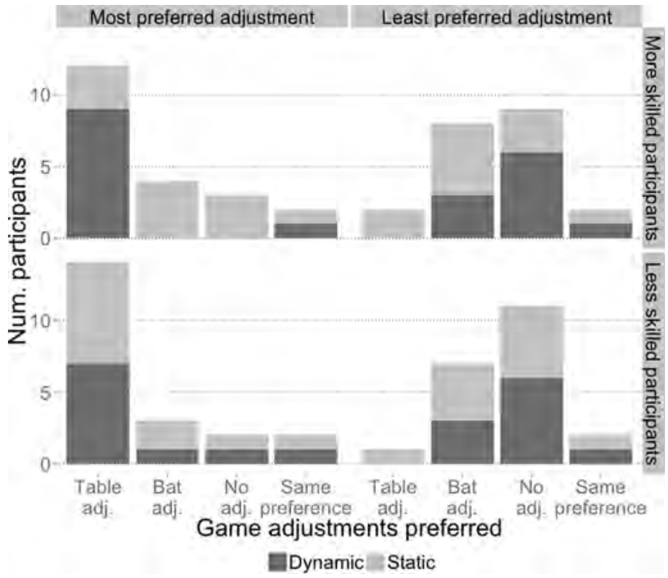

Fig. 11. Participants' preferences in each of the game adjustments. The most preferred game adjustment and the least preferred game adjustment are shown.

adjustment, in particular the table adjustment, and the least preferred was the no-adjustment condition. For the more skilled participants who played in the static frequency of update condition, there was no game adjustment that was significantly more preferred than the others (see Fig. 11). For the less skilled participants, they tended to prefer the table adjustment to the bat and no-adjustment conditions, regardless of the frequency of update.

From the qualitative analysis we identified different factors that contributed to altering player engagement: the sense of control and variety of gameplay, the training of strokes, the sense of achievement and the style of play.

4.2.1. Sense of control and variety of gameplay

The more skilled participants explained how the table and bat adjustments altered their performance and how this influenced their engagement. Playing with a smaller bat-head size decreased their sense of control, which influenced player engagement. A total of 55% of the more skilled participants playing with the static bat adjustment and 36% of those playing with the dynamic bat adjustment reported that it was hard to hit accurately, which decreased their sense of control and thus increased the number of mistakes. This decreased player engagement, e.g. a participant saying "*playing with a small bat was quite challenging (...) I did not enjoy it as much as in the table (...) I could not hit the ball how I wanted*". This also influenced the opponent participant as well. When asked, "*How did the different game conditions influence your enjoyment?*", a participant answered: "*For the bat adjustment, the number of mistakes and seeing the other participant do things he would not normally do*". Playing with a smaller bat-head size also decreased participants' interest in the game because of the limitations on the variety of strokes, such as top or back spin, e.g. a participant saying "*the small bat was interesting, but only interesting over a short period (...) In the first half an hour you probably exhausted what you can do*".

In the table adjustment, 45% of the more skilled participants playing in the static frequency of update also stated that the game restricted the variety of strokes they could perform. In contrast, only 20% of the more skilled participants in the dynamic frequency of update reported the same. This suggests that the dynamic frequency of update might have helped in providing more variety of gameplay and a greater sense of control than the static frequency of update.

4.2.2. Training

The more skilled participants also reported that when the game adjustment prevented the practise of useful table tennis skills, their engagement decreased. One participant stated that the table adjustment was more worthwhile than the bat adjustment because with the regular bat they could practise and think about their skills. On the other hand, another participant commented that a downside of the table adjustment was that since the table shrank towards the centre of the net, this prevented playing strokes that bounce close to the edge. This participant stated that these strokes are usually the ones players look for when playing normal table tennis. Regarding the bat adjustment, another participant pointed out that using a different bat-head size could generate concerns for acquiring "bad habits" and it could limit the transfer of skills to a regular table tennis game.

4.2.3. Sense of achievement

The participants took the limitations imposed by the explicit table and bat adjustments as opportunities to create new goals, which helped to enhance their sense of achievement, and hence making the game more rewarding. This especially happened in the dynamic table adjustment because of the explicitness of the adjustment and the frequent and clear feedback of the table changes. Participants could reduce the table size every time they increased their advantage in the score. When asked, "*Tell me something you remember you found enjoyable?*", a participant answered: "*When the table got smaller whenever I kept scoring, it was like a goal to keep going*".

4.2.4. Style of play

We observed that the table and bat adjustments altered the style of play of the more skilled participants towards a more defensive style of play. Our observations were in line with participants' reports. Seventy per cent of the more skilled participants playing in the bat and table adjustment conditions stated that playing with the bat or table adjustment made them play more defensively. This change in style of play helped the less skilled participants countering their opponents' strokes, e.g. a participant saying "*the ball was coming nicer for me*".

4.3. Summary

The table and bat adjustments implemented helped reduce the difference in score between participants compared to the no-adjustment condition. While the more skilled participants still won all matches when the game was played in the dynamic frequency of update, the win/lose ratio for the more skilled participants was more balanced when the game was played in the static frequency of update.

Playing with either the table or bat adjustments helped with enhancing player engagement as it provided a more suitable level of challenge than the no-adjustment condition. However, the analysis showed that the engagement scores varied depending on players' skill status and the frequency of updates.

For the more skilled participants, the dynamic frequency of update was more engaging than the static one, and the table adjustment was more preferable to the bat adjustment. Playing with the dynamic frequency of update provided a higher sense of control and enabled a greater variety of shots to be practised than with the static frequency of update. Moreover, with the dynamic frequency of update, participants could set more goals and this helped to enhance the sense of achievement. The explicitness and frequency of update of the dynamic table adjustment enhanced the sense of achievement and made the game more rewarding than the dynamic bat adjustment.

Finally, the table and bat adjustments helped the less skilled participants to counter the attacks of the more skilled participants as these affected the style of play of the more skilled participants towards a more defensive style of play.

5. Discussion

This study shows how game adjustments that alter sport equipment statically and dynamically can affect game balancing and player engagement. The studied game adjustments effectively created a more balanced game and enhanced player engagement for players with different skill levels in comparison to the no-adjustment condition. Regarding game balancing, this study also showed the difference between dynamic and static adjustments. For example, the dynamic adjustment rewarded the more skilled players by allowing higher chance of winning (see Fig. 7). A similar finding was reported by Bateman et al. (2011). Rewarding the skilled players can be important for game balancing (Adams, 2010, p. 324).

We found dynamic adjustments enhanced player engagement more compared to than static adjustments as they allowed participants to adapt to the game better, and helped in providing new goals and in enhancing the sense of achievement for players (see 4.2.3). This helped in countering the downside of limiting the players' skills and the performances (e.g. variety of strokes that could be applied). In the following section we describe a set of game design strategies on how one could enhance player engagement reflecting the lessons learned in this study.

5.1. Game design strategies

The strategies below are not an exhaustive list but rather a starting point to understand how to facilitate engaging experiences with game balancing in physical games. While we note the limitations of the presented game design strategies being derived from one experiment with one physical game, they could be used as inspirational strategies for future game balancing designs and for encouraging future investigation into how they could be generalised to other types of games.

Goal 1: How can we make an engaging game adjustment that limits players' skills?

We formulated this goal inspired by how the table and bat adjustments limited the participants' skills such as by reducing the variety of shots that could be applied, and reduced the sense of control (see 4.2.1), while still being able to enhance player engagement.

Context: Game designers have two approaches to balance a game: help the weaker player (e.g. Bateman et al., 2011) or disadvantage the stronger player. In a digital game, where game designers have control over the virtual environment, both approaches can be relatively easy to implement. However, in a non-digital game it can be difficult to enhance a player's performance, and disadvantaging the stronger players might lead into disengagement (Altimira et al., 2014). Then, how can we design these game adjustments to be more engaging?

Strategy 1: Support the training of useful sport skills.

The first solution is to encourage players to train in useful sport skills that can be applied in a regular game. This can enhance player engagement not only for the pleasure of playing with the game adjustment, but also for the rewards that are external to this play, i.e. extrinsic motivation, (Vallerand, 2004). We derived this strategy inspired by the participants' reports of their experiences (see 4.2.2). Participants found the table adjustment more worthwhile than the bat adjustment as they could practise their table tennis skills more. However, another participant reported feelings of frustration in the table adjustment because he could not hit the ball into the corners of the regular table as he would normally do in a standard game.

Strategy 2: Provide opportunities for setting new short-term goals.

The second strategy is to offer the players with new short-term game goals to enhance their intrinsic motivation (Vallerand, 2004). Participants reported feeling more engaged by the new goals the game adjustments offered to them. This happened especially in the dynamic table adjustment, where participants reported feeling motivated to score to reduce the table size as much as possible (see 4.2.3). The challenges players face are important for games and sports (Jackson and Csikszentmihalyi, 1999; Lazzaro, 2004), so game adjustments that facilitate new goals for players should be encouraged to enhance player engagement. Prior work also identified the importance of providing short-term goals (Campbell et al., 2008). Vorderer et al. (2003) argue that success in a competition can increase the motivation to continue playing to face the next competitive challenge. This is another reason why short-term goals should be facilitated as they can enhance the players' motivation for playing.

Strategy 3: Provide dynamic gameplay.

Another strategy is to implement a dynamic adjustment to facilitate dynamic gameplay. Game adjustments that facilitate dynamic gameplay are those that can alter the player's actions and the level of challenge dynamically. Different ways of altering the player's actions can be useful for progressively controlling the influence of one player's actions on the other's performance. An example of dynamic gameplay is the dynamic table adjustment in the study reported here. In this condition, the more advantage a player had in the score, the more defensively this player had to play, which helped in moderating the influence this player had on his or her opponent (see Section 4.2.4. This progressive adjustment also helped the players to adapt to the game adjustments better and provided a greater sense of control compared to the static adjustments (see Section 4.2.1).

Goal 2: How can we make an explicit game adjustment engaging?

We formulated this goal inspired by the results of this study that showed explicit game adjustments can be used as an ingredient to enhance player engagement (see Section 4.2.3). In contrast, prior work showed that explicit adjustments can also have a negative effect on players (Baldwin et al., 2014) and can be less desirable than implicit adjustments (Cechanowicz et al., 2014; Gerling et al., 2014).

Context: A game designer might need to apply game adjustments for balancing a game that are difficult to hide. So, can we use the explicitness of an adjustment to design engaging experiences?

Strategy: Enhance the sense of achievement.

Explicit adjustments for game balancing should be used as an opportunity to enhance player engagement. One way we found the awareness of an adjustment could help in enhancing player engagement is through increasing the player's sense of achievement. In the dynamic table adjustment, players were motivated to keep scoring to reduce the table size as much as possible (see Section 4.2.3). This strategy can be aligned with the second strategy of goal 1, because one way to enhance the sense of achievement is to provide opportunities for setting new short-term goals.

Goal 3: How can we design an engaging game adjustment for balancing non-parallel games?

We formulated this goal inspired by the results of how the difference in skill level between participants impacted the gameplay of the table tennis game in the no-adjustment condition (see the answer to R3 in Section 4.2), and also by how the studied game adjustments helped moderating the influence of a participant's actions on the opponent's performance (see Section 4.2.4).

Context: This goal focuses on the design of game balancing in non-parallel games, where a player's actions affect his or her opponent's performance. A large difference in skill level between players in non-parallel games can impact the gameplay and reduce the players' interest and engagement in the game. How can we design game adjustments for balancing non-parallel games that moderate the influence of one player on the other player?

Strategy: Assist the less skilled players by altering the style of play of the more skilled players.

One solution is to change the style of play of the more skilled players. For example, in the table tennis game, the table adjustment induced a defensive play, which helped the less skilled participants to return the ball to the opponents' table more easily (see Section 4.2.4).

5.2. Limitations of the results

A first limitation of the results of this study is the novelty effect caused by playing with the different game adjustments. We acknowledge that this effect is difficult to control and it might require repetitive measures over time in order to address it. As this study did not aim to assess player engagement over time, it cannot be excluded that there might have been a novelty effect present.

We acknowledge that the game design strategies proposed are not an exhaustive list. However, the proposed strategies could be useful to help balancing physical games and build on prior design strategies for physical games, e.g. Gerling et al. (2014) and Mueller et al. (2012), by focusing on specific aspects of balancing such as making an explicit adjustment engaging, or balancing non-parallel games. In addition, the proposed strategies extend the ones already used in sports given the opportunities digital technology provides to enhance and dynamically alter the game.

Although limitation of this study is that the results and strategies were derived from one experiment and one physical game, however the study results are applicable to other games beyond table tennis. The game design strategies proposed could have implications for a wide range of physical games because they focus on game design goals and strategies that are not specific to table tennis. However, the game adjustment designs can be applied in a more straightforward manner to some games (e.g. tennis, badminton and squash), than others (e.g. basketball). Despite this limitation, the contribution of this work goes beyond the proposed game adjustment design. In games where the proposed game adjustments cannot be applied straightforwardly (e.g. basketball), this study could serve as an inspiration for more creative designs, such as altering the basketball court dimensions. See 5.3 for a discussion on the generalisation of the results to other physical games, which can indicate future research directions.

We also acknowledge that the proposed strategies might conflict with each other. For example, in this study the smaller table closer to the net altered the style of play of the stronger participant and this helped in moderating the influence of the player's actions over the opponent's performance. However, this change to the style of play prevented the participants from acquiring useful table tennis skills, such as long strokes. Dynamic adjustments might be a possible solution to resolve this conflict, and to implement game adjustments that moderate the influence of the player's actions over the opponent's performance, and that allow acquiring useful table tennis skills.

We assessed participants' skill levels using a pre-questionnaire. This was useful as it allowed us to pair the participants prior to the main experiment. Although this method of assessing the participants' skills was sufficient for the purpose of this study, we acknowledge that we might have obtained a more accurate assessment by observing the participants playing before the main experiment, or by using player rankings from a tournament or club.

Although we used a statistical test to check for incorrectly matched participants (see Section 3.3), we note that the test has limitations when the distribution has a high standard deviation. In this study, we concluded that all pairs were reasonably well matched by observing that the distribution of the final score difference between participants in the no-adjustment condition had a reasonably small variance, yet not having any outliers.

Finally, the limitations of current technology required a manual adjustment of bat-head size (i.e. asking the players to change bats by showing the bat they had to use at the end of a point, projected onto the physical table), and with a limited levels of adjustments. However, the study of this game adjustment could serve as a future direction and opportunity for future designs, and is therefore relevant for those who would like to use digital technology to enhance player engagement in physical games.

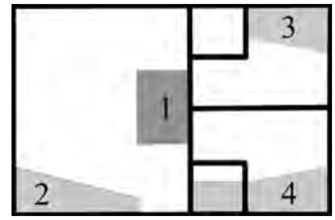

Fig. 12. Squash court. Light gray zones (2,3,4) identify the optimal areas for ball placement (Vučković et al., 2009). The dark gray zone (1) identifies the area from which it is easier to return a stroke.

5.3. Generalisation to other physical games

Table tennis belongs to the net/wall type of games (Breed, 2011), whose game strategy is to hit the ball away from your opponent into space, or strike the ball so that the opponent cannot return the ball successfully. Other sports belonging to this classification of games include badminton, squash and tennis. Although the insights of this research could be applicable to a wider range of games, the game adjustment designs used could be most easily applied in these net/wall games (e.g. squash). In table tennis we found adjusting the table to be useful because the ball-hit location on the table is important for scoring and for altering the players' styles of play. The table adjustment was used to (i) balance the game, (ii) moderate the influence of a player's actions on the opponent's performances, (iii) assist the weaker players by altering the style of play of the more skilled players, and (iv) enhance player engagement through enabling them to set new short term goals, providing dynamic gameplay and enhancing the players' sense of achievement. These effects of the table adjustment can be desirable for game balancing, but the approach to achieve them can be different in other types of non-parallel games.

We now outline how the study results could be generalised to other physical games, such as squash and soccer.

For squash, one way we could use the set of strategies is to first identify the areas of the court that are more difficult (areas 2,3,4) and more easy (area 1) to return the ball from (see Fig. 12). These areas were obtained through a study that identified where skilled players usually aim in competitive squash games (Vučković et al., 2009). We could implement the proposed strategies as following:

- Support the training of useful sport skills: restrict the skilled players to use one or more of the light gray zones (2,3 and 4 in Fig. 12).
- Set short-term goals for the players: alter the squash court dynamically according to the difference in score between the players.
- Implement dynamic gameplay: reduce the court size dynamically to progressively alter the players' actions and the level of challenge. For example, from full court to zone 1 in Fig. 12. This could help players in adapting to the game adjustments better and help game designers in having more control over the influence of the players' actions on the others' performances.
- Enhance players' sense of achievement: implement *achievable* short-term goals such as altering the game after each game point.
- Assist the less skilled players by altering the more skilled players' style of play: require the more skilled players to play only into zone 1 (see Fig. 12).

As described in this section, the adjustment of the squash court could be used in the same way as the table adjustment in table tennis for game balancing and implementing the game design strategies. Similar game design adjustments could be applied in other net/wall games such as tennis where the ball-hit location on the court is important for the gameplay and scoring. For other non-parallel games such as soccer or basketball, where the use of the field is different, the design of game adjustments that implement the proposed game design strategies is not as straightforward.

In soccer there are a number of game alterations we can learn from disciplines like Game Sense (Light, 2013) that can allow us to restrict players' performances and alter the players' styles of play to assist the weaker team in countering the stronger team. Game Sense includes game restrictions to modify the game, which could be used to our advantage for game balancing. For example Light (2013) describes different game modifications in soccer, such as altering the number of players on the field, altering the size of the space in which the game is played, altering the number of passes the players must perform, restricting the distance between players, altering the size of the goals, or altering which foot the players must use to kick the ball.

In parallel games it can also be desirable to design game adjustments that succeed in (i), (iii) and (iv) outlined above. However, (ii) would not be as important because there would be no need to moderate the influence of a player's actions on the other's performance. Regarding (iii), game adjustments could be designed to assist the weaker players (Bateman et al., 2011), but in non-parallel games the assistance might need to pay more attention to altering the players' performances than parallel games because of the influence a player can have on his or her opponent.

6. Conclusions

Practicing physical activity can provide health benefits, but people might not always find a suitable partner to play with because of the skill difference between players. However, this difference can be moderated through game balancing.

Understanding game balancing that enhances player engagement is challenging owing to the many factors that can influence engagement (O'Brien and Toms, 2008). In addition, balancing in non-parallel games should be able to moderate the influence players have on their opponents. Designing effective game balancing experiences requires an understanding of the effect of game adjustments on game balancing and player engagement.

We conducted a study using a digitally augmented table tennis game to investigate how different sport equipment adjustments with different frequencies of updates can impact game balancing and player engagement. The main contributions of this work are insights into how these adjustments can affect the player experience and enhance player engagement in physical games; insights into how digital technology can be used as a design resource to enhance player engagement by adjusting the game dynamically in traditional physical games; and providing design strategies for designing engaging balancing in physical games.

This study contributes to the field of Human Computer Interaction (HCI) by providing an understanding of different ways of using digital technology for altering the player's experience, balancing physical games, and enhancing player engagement. This research builds on other work that started exploring the benefits of using digital technology in sports and its potential to provide engaging experiences. These works show a promising future in the area of HCI and sports that focuses on the player's experience.

There are a number of possible directions for future work. First we could focus on resolving the conflicts of the game design strategies to optimize player engagement (see Section 5.2). For example, we could investigate how dynamic adjustments could enhance player engagement for both players (skilled and less skilled) by allowing skilled players to use the game adjustments for training skills, but also alternate these adjustments with other adjustments that assist the less skilled players in countering the more skilled players' play. We could also investigate how the game design strategies derived in this research could be implemented in other non-parallel games such as basketball or soccer, where the use of the field can be different to table tennis or squash (see Section 5.3).

To conclude we hope this work can inspire those who aim to design well-balanced exertion games and can lead to developing novel and engaging balancing adjustments in exertion games that can encourage people to practise and enjoy physical activity.

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