Adaptivity to Age, Gender, and Gaming Platform Topology in Physical Multi-Player Games

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Abstract

In games where players are competing against each other, it can be of interest to ensure that all players are challenged according to their individual skills. In order to investigate such adaptivity to the individual player in physical multi-player games, we developed a game on modular interactive tiles which can be used in both single-player and multi-player mode. We implemented simple adaptivity methods and tested these with different user groups including children and adults of both genders. The results show statistically significant differences in the game interactions between children and adults, and between male and female players. Also, results show statistically significant differences in the game interactions between different physical set-ups of the modular interactive tiles, i.e. the interaction depended on the topology of the modular tiles set-up. Changing the physical set-up of the physical game platform changes the interaction and performance of the players.

Introduction

Physical games can be both fun and physical challenging, as is seen with numerous physical gaming platforms currently emerging on the market, including Nintendo Wii, Microsoft Kinect, etc. (an overview of such physical gaming platforms and their history is presented in [1]). If we want the games to be challenging to a variety of users, it is important that the games can challenge the users at different levels appropriate to the individual user. In the physical games, we may imagine that a young child is at a different level than an older child, we may imagine that young adults are at a different level than most elderly, we may imagine that fully able users are at a different level than physical disabled users, etc.

Hence, it is interesting to investigate how different users perform differently, and based on this investigate how physical games may possibly adapt to match the physical capabilities of the individual user. In other words, it is interesting to investigate how to develop adaptive physical games. For instance, for modular playware [2, 3], it has been outlined that there exist different possibilities for such adaptation: "(1) *Hardware adaptation*, e.g. the user changes the physical form or size of the playware tool to fit the user level, (2) *Software adaptation*, e.g. the game automatically changes level to fit the user at run-time, (3) *Hardware and software adaptation*, e.g. the user builds a desired playware tool and software adapts to the built playware tool (e.g. to its topology) and the user interactions" [4]. In the present work, we will therefore make experiments with a platform that allows both hardware and software adaptation, though focusing on the software adaptation.

As introduced by Derakhshan et al. [5], an adaptation approach to playware is a run-time iteration of observation, classification, and adaptation. Related to the classification of users in physical playware games, Derakhshan et al. [5] classified the users into simple categories (young/old child, playing/not playing, continuous/discontinuous behavior, etc.) using an artificial neural network, whereas Yannakakis et al. [6, 7] introduced an approach for estimating expressed player satisfaction in real-time through physiological signals (e.g. heart rate) measured during physical gameplay. Lund and Thorsteinsson [4] used a simple approach of a run-time classification and adaptation based upon the reaction speed of the user. Likewise, we will use such an approach in the present work.

Experimental Set-up

In order to make experiments on different user groups' physical performance and impression of adaptive physical games of different difficult level, we developed the adaptive double mole game for the modular interactive tiles.

Modular Interactive Tiles

The modular interactive tiles are a distributed system where the tiles can be attached to one another to form the overall system. Each tile is self sufficient of processing power and each one has a battery that lasts approximately 30 hours in use. This makes the usage of the tiles very flexible because they do not need a computer or external power source. When connected to one another to form a playfield, they communicate to their neighbors through four infra-red (IR) transceivers located on the sides. In a set of tiles one tile usually differs slightly from the others and that is the master tile which has a XBee radio communication chip. The master tile is capable of communicating to other devices that have a XBee chip for example a game selector box or a PC that has an USB XBee dongle connected.

Figure 1: Left: The interior of the modular interactive tiles.
Right: A tile playfield being assembled.

When playing on the tiles, the player provides the tiles with an input in the form of pressure measured by a single force sensitive resistor which is located in the center of each tile. The tile can then react by turning on 8 RGB LEDs which are mounted with equal spacing between each other in a circle inside the tile. On the back side of the tiles there are four magnets which can be used to place the tiles vertically on a magnetic surface. The tiles have the means to detect whether they are placed horizontally or vertically with a 2 axis accelerometer. This feature can be used to change game parameters on the fly when the tiles are, for example, moved from a floor to a wall.

Double Mole

The game developed for the present work found inspiration from the well known game „Whack-A-Mole" where the objective is to hit the moles with a hammer before they go back into their holes. The game was implemented on the modular interactive tile platform in such a way that each tile was considered as a hole for a mole to appear in. Appearing moles were represented by 8 LEDs lighting up in either green or blue color and they appeared randomly around the tile set. The tiles count down by turning off the LEDs one by one until all the LEDs have been turned off, which means that the mole has escaped. However if the player steps on a lit up tile before it finishes the countdown, the player is considered to have hit the mole and receives one point. The game can either be played in single-player or multi-player mode where the two modes differ slightly. The difference is due to the chance of a bonus tile/mole appearing in the multi-player mode. The players compete for this bonus and the player who wins it, receives a certain amount of points (e.g. 10 points). This tile counts up from 0 to 8 LEDs in red and yellow until a player hits it, but then the red color randomly changes to either blue or green. Then with each hit, the color switches between green and blue until the count up finishes. In the present tests, the tiles are arranged in a rectangle, in 2x3, 2x4, or 4x4 set-ups. Depending on the set-up the amount of tiles each player has to hit changes. In the 2x3 set-up each player has one tile to hit while in 2x4 and 4x4 each player has 2 tiles to hit at each time. When playing, players are most often standing outside the tile platform facing each other in the 2x3 and 2x4 set-ups and stretch their leg inside the platform to hit the lit up tiles. This game-play relies on the reaction of the players and their ability to keep the balance while stretching their leg inside the tile platform. The 4x4 tile set-up requires the players to stand on top of the platform which alters the game-play quite considerably because now size and strength of the player also plays a big role in how they perform in the game.

Adaptivity

Due to the nature of the game, being fast paced and competitive in the multi-player mode, the game was made in such a way that it would adapt the countdown speed of the tiles depending on the number of remaining LEDs lit when a tile was hit. The values used to adapt the countdown speed can be seen in the following table:

Countdown		
LEDs (no.)	LEDs (ms)	Tile (ms)
8	-80	-640
7	-40	-320
6	0	0
⋮	⋮	⋮
3	0	0
2	10	80
1	20	160
0	30	240

Table 1: Countdown speed adaptation values where negative values are an increase in speed and positive a decrease.

In both single- and multi-player mode the game adapts the countdown speed to each individual depending on his performance. This feature possibly allows two players in different physical shape to play a game against each other. The challenge may be to make the game challenging enough to keep each player motivated but at the same time make each of the two players able to win the match. The bonus tile was implemented as a test to see whether it could be used to slow down the faster player.

Tests

User tests were made on two different age groups. One group consisted of children aging 6-8 year old, 3 boys and 3 girls and the other group consisted of adults aging 20-35 year old, 10 males and 10 females.

Single-player

First a single player test was conducted where each player played a 60 second game alone and where the adults played both in 2x3 and 2x4 tile set-ups while the children only played in the 2x3 tile set-up. Comparisons were made between the 10 males and 10 females to determine whether any significant difference was in their performance in the game. Figure 2 shows the performance of males and females in the 2x3 tile set-up, displaying how the countdown time adapts over game time.

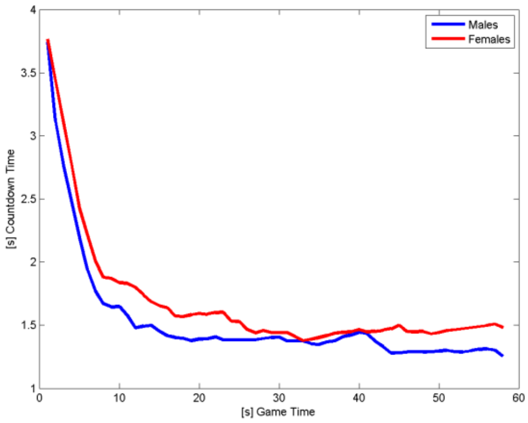

Figure 2: The average values of tile countdown time. A comparison between males and females in 2x3 tile set-up.

The males appear to reach faster countdown time than the females. Comparing the two sets of data consisting of the countdown time at each second of game time, a Mann Whitney U-test returns the P-value 5.6098e-008. At the 0.05 critical alpha level, this concludes that there is a statistically significant difference between the performance of males and females. The game statistics can be seen in the following table.

2x3 – Males vs. Females		
Gender	Tiles hit	Reaction time [s]
Males	82.80	0.446
Females	75.20	0.530
MW-U (P)	0.0881	0.0452

Table 2: Game statistics, average values.

The difference in countdown time observed on Figure 2 is related to the significant difference in reaction speed observed in Table 2.

Similarly a comparison was made between males and females in the 2x4 tile set-up, see figure 3.

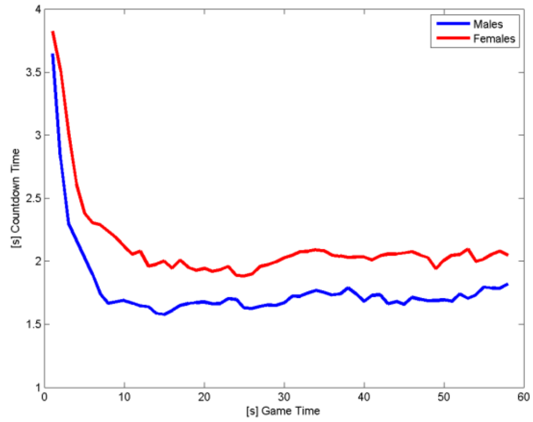

Figure 3: The average values of tile countdown time. A comparison between males and females in 2x4 tile set-up.

For the game on the larger 2x4 tiles platform, the difference between the countdown time of the tiles for the two genders increases from what was observed in the 2x3 tile set-up. A Mann Whitney U-test with the 0.05 critical alpha level was used to determine if the difference could be considered significant. The test returned the P-value 1.6521e-015 so the difference is considered significant.

2x4 – Males vs. Females		
Gender	Tiles hit	Reaction time [s]
Males	127.80	0.612
Females	113.8	0.734
MW-U (P)	0.1117	0.0312

Table 3: Game statistics, average values.

When examined, the game statistics revealed that changing from 2x3 tile set-up to 2x4 tile set-up slowed the reaction time (remember that in this game the user now has two tiles lighting up at a time), and the reaction time difference between the two genders is, as before, statistically significant.

A comparison between adults and children was also made where the averages of all the adults were compared to the averages of all the children, as shown in figure 4.

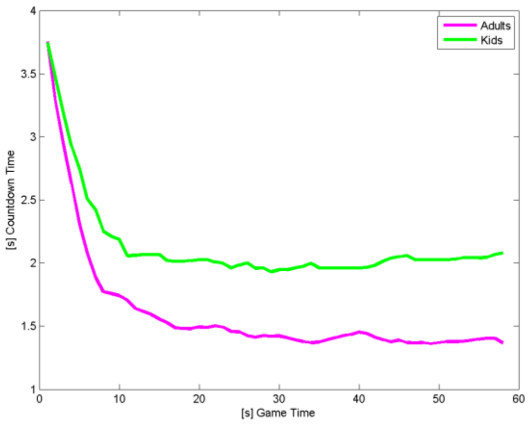

Figure 4: The average values of countdown time. A comparison between adults and children in 2x3 tile set-up.

It can be seen that the adults reached a much faster countdown time on average than the children did. A Mann Whitney U-test returned the P-value 5.4814e-014 so the difference is considered significant.

2x3 – Adults vs. Children		
Group	Tiles hit	Reaction time [s]
Adults	79.00	0.488
Children	61.83	0.684
MW-U (P)	0.0028	0.0038

Table 4: Game statistics, average values.

By examining Table 4 it can be seen that the adults seem to have much faster reactions than the children do. The difference was determined, with the Mann Whitney U-test, to be significant.

Finally for the single-player user tests, a comparison was made between two different tile set-ups, namely 2x3 and 2x4, see figure 5. This comparison was made between the average values of the adults that participated.

It can be observed that the adults reached a faster countdown time in the 2x3 set-up. This difference is explained by the increased number of lit tiles that the players have to hit in the 2x4 set-up.

Game statistics show a significant difference in both tiles hit and reaction time. This is explained as before by that an increase in amount of tiles the players have to hit at each time is increased from one to two.

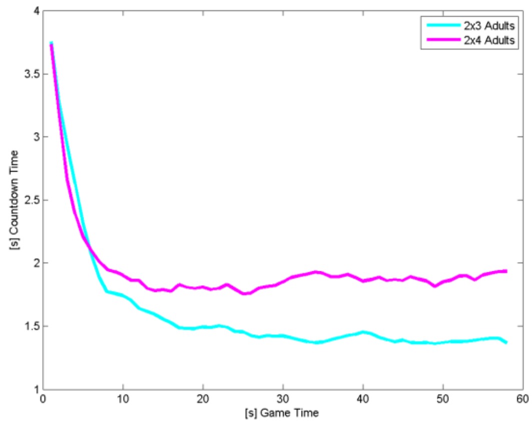

Figure 5: The average values of countdown time. A comparison between adults playing in 2x3 and 2x4 tile set-ups.

2x3 vs. 2x4 – Adults		
Setup	Tiles hit	Reaction time [s]
2x3	79.00	0.488
2x4	117.25	0.673
MW-U (P)	0.0000	0.0000

Table 5: Game statistics, average values.

Multi-player

In the multi-player tests, 16 of the 20 adults were tested. They were split into 4 groups where 2 fast players of each gender were matched against 2 slow player of each gender. The players were categorized as fast or slow depending on how they performed in the single-player test. The same 6 children as before were also tested in 2x3 tile set-up though no performance classification was made.

To see how changing the tile set-up would affect the performance of the adult players, the average values of all adults were put on a single graph for comparison, see figure 6.

When Figure 6 is examined it can be seen that the games adapt to the users at different speeds. The 4x4 tile set-up has by far the slowest game-play. This is due to altered game interaction where the players are now standing on top of the tile set resulting in more disturbances from the other player.

Figure 7 shows the results from the matching of fast and slow players in the 2x4 tile set-up. The other games (2x3 and 4x4) show similar patterns, though with either faster (2x3) or slower (4x4) countdown time. In all games, Mann-Whitney U-tests show (P-values of 1.5085e-009, 3.9221e-013, and 2.7131e-013) a statistically significant difference between the fast and slow players.

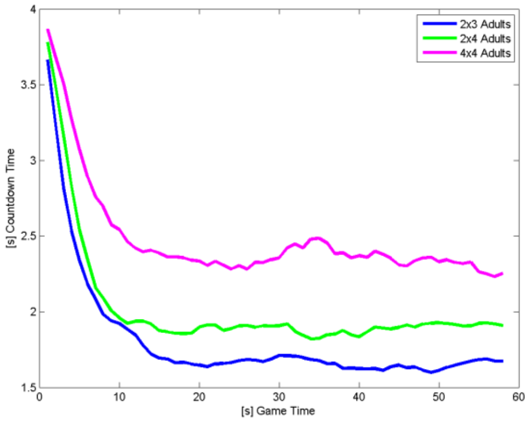

Figure 6: The average values of countdown time. A comparison between adults playing in 2x3, 2x4 and 4x4 tile set-ups.

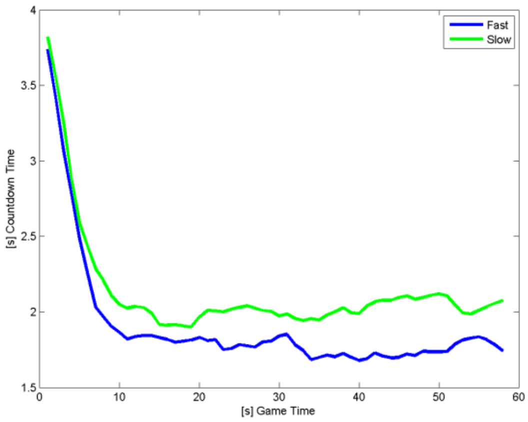

Figure 7: The average values of countdown time. A comparison between fast and slow players playing in 2x4 tile set-up.

2x3 – Fast vs. Slow - Adults			
Group	Tiles hit	Bonus tiles	Reaction time [s]
Fast	59.44	2.13	0.570
Slow	52.50	1.69	0.653
MW-U (P)	0.0258	0.3644	0.0438

2x4 – Fast vs. Slow – Adults			
Group	Tiles hit	Bonus tiles	Reaction time [s]
Fast	73.69	1.94	0.706
Slow	61.94	1.75	0.794
MW-U (P)	0.0039	0.7132	0.0302

4x4 – Fast vs. Slow – Adults			
Group	Tiles hit	Bonus tiles	Reaction time [s]
Fast	61.38	1.31	0.893
Slow	50.13	2.06	1.091
MW-U (P)	0.0066	0.0111	0.0044

Table 6: Game statistics, average values.

For all the game set-ups, the game statistics show a significant difference according to the Mann Whitney U-test both in the amount of tiles hit and the reaction time. In the case of 4x4, there is also a statistically significant difference in bonus tiles hit favoring the slower players.

If the game scoring system is set so that one point is awarded for hitting a regular tile and 3 points for winning a bonus tile, the fast player wins in all three tile set-ups as seen in table 7. On the other hand, if the bonus tile was set to give 15 points, then the slower players would obtain a higher score than faster players in the 4x4 game.

Adults – Scores			
Group	2x3	2x4	4x4
Fast	65.81	79.50	65.31
Slow	57.56	67.19	56.31

Table 7: Adults, average scores in multi-player.

After playing each game, the players answered a questionnaire including the three following questions:

Q1: How was the game ? (1 Boring / 5 Fun)
Q2: How was the speed ? (1 Slow / 5 Fast)
Q3: Was the game difficult ? (1 Not / 5 Very)

The answers were given on a 5-step Lickert Scale. The answers to the questions revealed that both player groups thought the game was entertaining (average 4 on the 1-5 scale) and moderately challenging (speed average 3.5, difficulty average 3). Interestingly, in all cases, the difference in answers between the fast and slow players was not considered statistically significant according the Mann Whitney U-test. Hence, despite the statistically significant differences in reaction speed (and thereby difference in number of tiles hit during each game), the players found the adaptive game equally fun and challenging.

Finally a comparison between adults and children was made to see if there was a difference in how children and adults compete, see figure 8. As can be seen in Table 8, the adults hit significantly more tiles and their reaction time is almost twice as of the children. Interestingly, the amount of bonus tiles hit is similar.

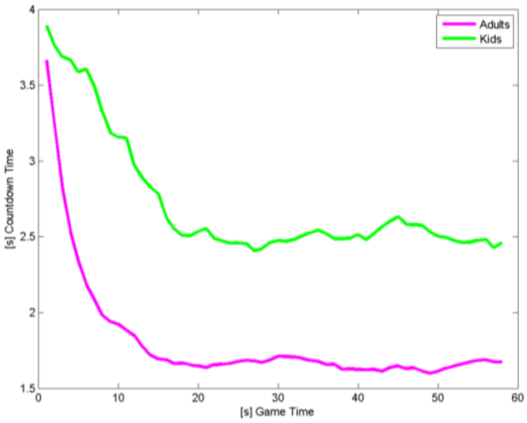

Figure 8: The average values of countdown time. A comparison between adults and children playing the multi-player version in 2x3 tile set-up.

2x3 – Adults vs. Children			
Group	Tiles hit	Bonus tiles	Reaction time [s]
Adults	55.97	1.91	0.611
Children	38.83	1.50	1.046
MW-U (P)	0.0012	0.4996	0.0000

Table 8: Game statistics, average values.

Discussion and Conclusion

With the present work, we have seen how different users have different reaction speed in single and multiplayer physical games. The work shows that there are statistical significant differences between different players and between different game set-ups. Indeed, in the single player game we observed statistical significant differences between male and female players, between adult and children, and between play on a 2x3 tiles platform and a 2x4 tiles platform. A similar change in performance due to different tiles set-ups (2x3, 2x4, and 4x4) was observed with the multiplayer game. Further, the multiplayer games showed that there was statistical significant difference in reaction speed and number of tiles hit between the fast players and the slow players, who were coupled to play against each other. Despite this difference, both fast players and slow players found the games equally fun and challenging.

In our point of view, it is an important result to be able to create physical games which players with different physical abilities can play together with equal fun and challenge. We believed that we obtained this here by the creation of adaptive games that run-time adapts to the reaction speed of individual players. Even in the multiplayer game, the game adapts differently to the two individual players, and thereby they each become challenged at their own particular level.
This can be important for instance in welfare technology for elderly, where we have observed a need for physical training/rehabilitation equipment to easily adapt to the individual elderly [8, 9]. Therefore, in future, we will investigate the adaptive playware as a welfare technology, and adaptive in other games potentially suitable for elderly (e.g. see [10]).

Acknowledgement

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