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Evaluate the Impact of Learning Effect on Children Motion Game Using Eye Tracking Glasses

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Abstract:- Nowadays, motion games play a significant role in training, education, and entertainment fields. Children enjoy feeling that they are moving forward and improving their performance in sports, and the learning effect factor can jeopardize these positive feelings. In this study, we evaluate the impact of learning effects on a new children's motion game called Pikkuli using eye-tracking glasses. Forty-five children (5 to 11 years old), who have never played this game before, participated in this study. The paper evaluates the learning effect factor on children's performance and visual behavior on three motion game challenges (difficulty levels). We collected information regarding time completion, total fixation, average fixation duration, and visible effort by eye-tracking glasses. Results show that difficulty levels of the game can significantly impact children's performance and visual behavior. We also found out that in this children's motion game, the learning effect factor can lead to different production and visual response.

Keywords:- *Motion Games, Eye Tracking, Human-Computer Interaction, Human Centric Design.*

I. INTRODUCTION

Playing games promotes cognitive skills, enhances creativity, problem-solving skills, and even neural processing and efficiency [1]. Games are a critical platform for education, training, and entertainment. Motion plays a crucial role in computer games, so many motion games have developed. In this paper, our focus is on exergames designed for children. We believe that children under 7-8 years have some type of everyday needs for this age range, which have not been typically taken into account in game design. In the video game industry, several factors are supposed to get considered when developing new games. The concept of player progression is one of these factors, while the learning effect is the main factor in the game design industry [2]. The idea of player progression is one of these factors, whereby game difficulty levels play a significant part in player progression. In this paper, we evaluate a newly developed motion game called Pikkuli using Tobii Pro Glasses 2, and we will investigate the learning effect factor by analyzing total time spent, total fixations, fixation duration, and visual effort.

II. RELATED WORK

Children's ability to play games is affected by various factors, such as user background and design factors [3]. Learning effect, familiarity, and usability also play a significant role.

Children develop in several cognitive states. Before the age of 10, children's selective attention is less sophisticated [4]. However, younger than ten years, children may approach a learning situation with a less stringent attitude than older children [4]. Differences in gender may appear as boys' preference for hierarchy and winning, while girls usually play more collaborative games [5]. Usability is considered to be one of the significant criteria to ensure quality [6]. Likeability and enjoyment are two of the primary motivations for children to interact with technology [6]. It is also safe to argue that familiar characters in a game environment might affect a child's motivation to play. Games based on, for example, well-known TV series or comic books, are somewhat simplified. Therefore, designing children's games requires to take into consideration some different factors. So in this paper, as described previously, we study the impact of learning effect on children's performance and visual behavior using glasses eye tracking.

Eye-tracking is a tool that is more accessible today than ever before to researchers and is gaining popularity in usability analysis. Tracking eye movements advance science and technology innovations. [7]. Eye-tracking provides an insight into the allocation of visual attention, i.e., where a test person is looking at all times to the sequence in which the person's eyes are shifting from one location to another [8]. Today's tracking methods are non-invasive, as there is a large variety of optical trackers in the market. Therefore, eye tracking is also suitable for children because it is non-invasive. Eye-tracking provides the number of measures, e.g., pupil size, fixation, saccades, and scan paths. Fixation happens when a person is focusing on a particular target [9, 10]. These measures can provide relevant information about game usability and user behavior.

III. METHODOLOGY

The purpose of this study was to investigate children's performance and visual behavior in the newly developed motion game called Pikkuli. This developed game is the first motion detection game prototypes that have been developed in Turku Game Lab in close cooperation with its industrial partner Sun in Eye Productions. The results of this study are part of the evaluation of the developed prototype with children who never played this game before. However, in this paper, we just focus on evaluating the impact of the learning effect factor on children's performance and visual behavior. The below sections describe more details about the game scenario, data collection, and user metrics.

A. Pikkuli Motion Game

Pikkuli is a children’s animation series that both entertains and educates. The Pikkuli motion game is the first motion game developed to support the Pikkuli animated series, Finnish children's animated series so that it can gain more publicity around the world. The tested match, in this paper, is custom- developed iMotion-based game by Turku Game Lab (TUAS) in Finland. It will be commercially available shortly.

FIGURE 1. SNAPSHOT OF THE INTERFACE OF THE PIKKULI MOTION GAME.

FIGURE 2. A PARTICIPANT, WEARING EYE-TRACKING GLASSES, PLAYS THE GAME ON THE DAY OF THE EXPERIMENT

A simple story lies behind the competition; birds move from branches on the left side of the screen to their nests on the right side of the screen. The player's role is to help these birds to reach their nests safely. Figure 1 shows a snapshot of the game screen. The Pikkuli game is a motion game where the player needs to use their body and their hands in this game to direct the moving birds to the right destinations. Figure 2 shows a child playing the Pikkuli motion game on the day of the experiment.

The game has three levels of difficulty, where the problem lies in continually increasing the number of birds in their nests and their speed movement. Each level has the same time limit and number of players' lives. The games end when the timer runs out, or all number of lives are lost. However, the speed movement of the birds in level two is faster than level one, and the third level is the fastest one.

B. Participants and Eye Tracking Data Collection

Experimental data was collected with short questionnaires (pre and post) and Tobii Pro Glasses 2, wearable eye tracker glasses with a wireless live view function to track user visual behavior. The participants in our user study were children aged from 5 to 11. The parents of the participants were asked to sign a consent form outlining the experiment goals, the study procedure, and the type of collected data.

The participants were interviewed about their gender, age, experiences with video games, familiarity with the character "Pikkuli," and some usability questions about the game interface before starting the game. During the game, eye tracking (Tobii Pro Glasses 2) was used to collect the participant's visual behaviors. Finally, after playing, the participants were interviewed to give their feedback on the game usability, difficulty levels, likeability, and enjoyment.

We managed to recruit 48 children, but only the data of 45 children were used for analysis due to calibration issues with the glasses' eye-tracking. The participants were shown a self-learning video tutorial for 12 seconds. After that, they immediately began to play, starting from easy (first level) to medium (second level), then advanced (third level).

IV. MEASURING LEARNING EFFECT

We categorized the collected data into three forms: (1) the participants’ background and experiences (before playing the game), (2) visual behavior (during the game), and (3) the participants' feedback (after playing the game).

To measure the learning effect while playing the three-level difficulties, we analyzed each level’s: total time spent, total fixations, fixation duration, and visual effort.

A. Time Completion

The participants' game completion performances for the three levels got evaluated with Tobii Pro Glasses 2 by measuring the time taken to play each game level up to the end (the time until all lives consumed for each level). Time completion does not include the time spent to show the collected points between two levels because this is not part of the game.

The analysis of the total times spent on each game level customarily distributed (Shapiro − Wilk; $p < 0.001$). So to analyze the significant differences of multi-level factors, the Kruskal − Wallis test (a nonparametric alternative to ANOVA) was used in place. Then, Wilcoxon signed-rank tests were practically used for pairwise follow-up analysis.

FIGURE 3. GAME COMPLETION TIMES PER GAME DIFFICULTY LEVELS.

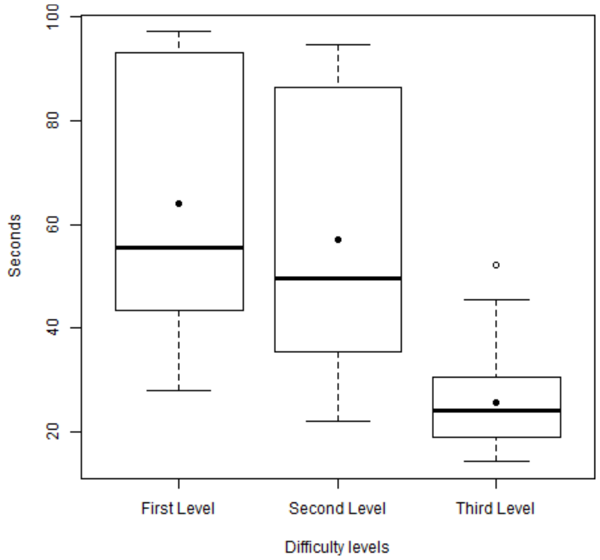
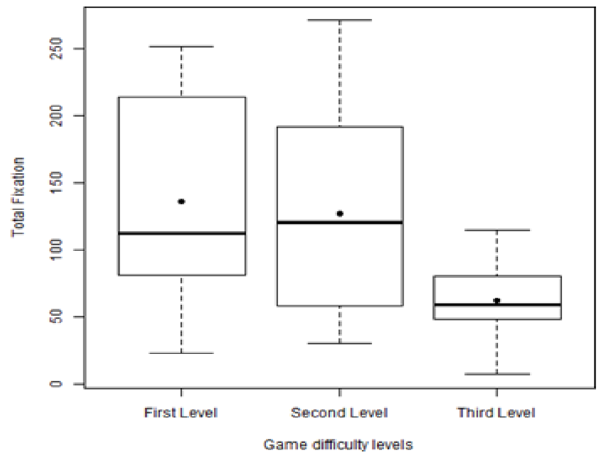


Figure 3 shows the total time spent in gaming in seconds for each level. One outlier point occurred in the third level game; this was a participant who managed to spend more time to play the third level game. The difficulty challenge on the game levels leads to different median amounts of time paid playing the game: 64.12 seconds for level 1, 57.15 seconds for level 2, and 25.7 for level 3. The three levels have a significant impact on time (Kruskal- Wallis; $p<0.0001$). In particular, the participants spent significantly less time managing to complete the third level compared with the first level and the second level (Wilcoxon; $p < 0.0001$). Although the participants managed to play longer on the first level than on the second level, no significant difference was found in the time between the first level and second level (Wilcoxon; $p = 0.086$).

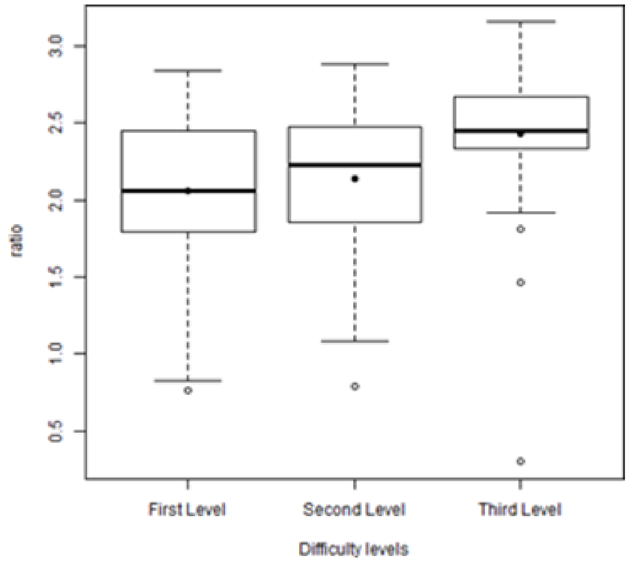
FIGURE 4. TOTAL FIXATIONS SPLIT BY GAME DIFFICULTY LEVELS.



B. *Total Fixation*

Fixations ought to transmit visual signals to the brain [11]. In this game, the eye movements, particularly fixations, are essential to playing the game since the participants necessitate deliver the birds to their correct destination from the left side of the screen to the right. Therefore, we investigated the impact of game difficulty on fixations. Figure 4 shows the total number of fixations for the 45 participants classified by the game difficulty level. The results show substantial differences in the total number of fixations (Kruskal − Wallis; $p < 0.001$). Paired follow-up tests designate that the total number of fixations in the first level and second level are significantly higher than in the third level (Wilcoxon; $p < 0.0001$). This is not surprising due to the significant difference in the total time spent in playing first and second levels, as shown in the previous section.

FIGURE 5. VISUAL EFFORT RATIO, SPLIT BY GAME DIFFICULTY LEVELS.



C. *Measuring Participant Visual Effort*

The game challenge is about assisting the moving birds from the left side of the screen to their nest, correct destination, on the right side of the screen. The game has three difficulty levels, where the number of birds and the speed of their movement speed gradually increases in each level. Therefore, we investigated the participants' visual effort in playing the game on the three difficulty levels with the following formula:

$$\boldsymbol{Visible\ effort} = \frac{\boldsymbol{Total\ number\ of\ fixation}}{\boldsymbol{total\ time\ spent\ on\ playing}}$$

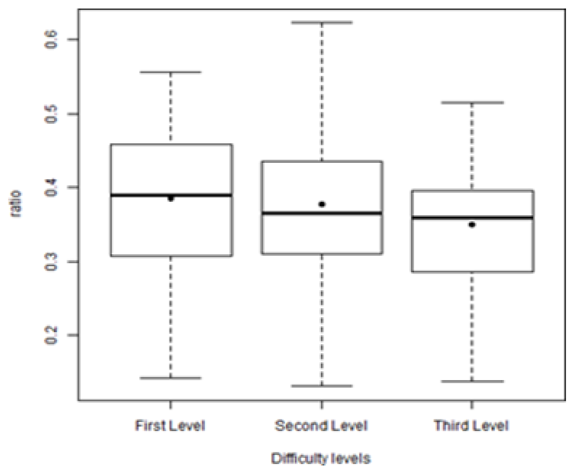
The above method shows the ratio of total fixations during the whole time spent on playing the game. The high ratio indicates more preoccupations with different visual signs, generally known as a more visual effort spent.

The results illustrate that visual effort data are not customarily distributed (Shapiro − Wilk; $p < 0.001$). The results reveal a significant difference in comparing the visible effort spent while playing the three different game levels (Kruskal − Wallis; $p = 0.0001$). Figure 5 presents the participants' visual effort ratio categorized by the difficulty levels. Surprisingly, although participants spent significantly more time on the first and second levels, as previously mentioned. The results show that the participants spent more visual effort on the third level (Wilcoxon; $p>0.0015$) as compared with the first level (Wilcoxon; $p < 0.001$) and second level (Wilcoxon; $p = 0.001$).

D. Fixation duration

Fixation duration is time spent on cognitive processing (gaze points) on a single location. Longer fixation duration directs to relating the interface components [12] and more engaging in some way [8]. In this study, we collected the length of the average fixation for children on each one of the levels of difficulty of the game, see Figure 6. Although children spent less average fixation duration, the more extended play, results show no significant difference in average fixation duration (Kruskal − Wallis; $p = 0.204$). In other words, the fixation duration in children got less influenced by the level of the difficulty.

FIGURE 6. THE AVERAGE FIXATION DURATION FOR THE CHILDREN SPLIT BY DIFFICULTY LEVELS.



V. DISCUSSION

The participants were given training of a 12- second video tutorial to learn how to play the game. Immediately, they started playing the first level, then the second, and finally, the third. In the game mechanism, each next level requires more attention and planning to react to the moving objects (birds), which means that playing becomes more difficult. However, the results show no significant differences in time and fixations between the first and the second level. Still, significant differences were found in the third level in comparison with the first and second levels. One explanation for the lack of substantial differences between the first and second levels in the participant performance is that on the first level, the participants become accustomed to the game and learn the game rules. The participants use these experiences to deal with the challenges of the second level. Thus they perform similarly as on the first level. This indicates that this game gives a good indication for the learning effect factor so that children can have positive feelings to play more.

On the other hand, our analysis indicates that the difficulty levels of the game had a significant effect on completion time and fixations; in particular, completing the third level was significantly shorter and had a considerably lower number of fixations than the first and second levels. One of the main features of the third level is that it requires much faster body movement and quick planning actions concerning the moving objects (birds). One explanation can be that usually, advanced motion difficulty levels need more coarse motor skill challenges [13].

Taking into consideration the results described in the previous two paragraphs, we can conclude that the learning effect factor has expressively no impact on players if the difficulty in the game is quite exceptional. This can result in players losing motivation with no interest in playing again.

Similarly, in this paper, we examined the visual effort that the participants spent on playing the three levels of difficulty. A blatant attempt was measured by dividing the total fixations spent on playing each level by whole time spent on the same level. The results indicate that although participants spent a significantly shorter time playing the third level, they managed to scan more on the third level compared with the first and second levels. This can attribute to the fact that participants understood the concept of the game and tried their best to perform better. However, because of the difficulty in the third level, they could not manage to play longer due to the diminishing number of lives after failing to achieve the game challenge. As a result of this, the game is overdue to losing all the number of lives.

Additionally, evaluation of the learning effect on the game by collecting average fixations duration on the three levels of difficulty was also studied. Although children played the same game three times (with different levels of stress), the result shows that children still require to spend a similar amount of cognitive processing (fixation duration) in playing the three levels. This needs children to pay more careful visual attention (cognitive processing) to gain more scores.

VI. CONCLUSION

We have conducted a user study using eye-tracking to evaluate the learning effect on a newly developed game called Pikkuli for a company called Sun In Eye. Initial analysis shows that eye tracking can provide essential details on user performance and behavior in motion games. Game levels of difficulty are supposed to be designed in such a way that the players can achieve the goals of the game successfully, especially with more time to play the same game. Results show that levels of difficulty can lead to failing the game and losing motivation to play. For instance, in this developed game, Pikkuli, the participants significantly struggled when playing the third level of difficulty due to its prominent frustration and unmanageable for the participants. This can cause the players to lose pleasure for the progress and achievement factors are no longer available unless a challenge. Overall, results considerably show the impact of learning effect on user performance and visual behavior. Users spending more effort on learning effects can lead to less excitement hence less desire to play the game.

In future research, the plan is to analyze the eye-tracking data more in-depth; in particular, we plan to investigate the impact of the players' background on visual behavior. Furthermore, we will quantify the amount of time that participants took viewing the game interface components.

Finally, we will study the usability impact of the player's visual behavior on the Pikkuli game.

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