Differences of Field Dependent/Independent Gamers on Cultural Heritage Playing: Preliminary Findings of an Eye–Tracking Study

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Abstract. Based on a large number of different cognitive theories on information processing procedure, suggesting that individuals have different approaches in the way they forage, retrieve, process, store and recall information, this paper investigates the effect of field dependence/ independence with regards to visual attention of gamers in the context of a cultural heritage game. Gaze data were collected and analysed from fourteen participants, who were classified as field dependent or independent according to Group Embedded Figures Test (GEFT), a cognitive style elicitation instrument. The collected data were analysed quantitatively to examine visual attention in terms of fixation count and fixation impact. The results revealed statistically significant differences in both fixation count and fixation impact towards interactive game elements. Statistically significant differences were also measured for specific types of game elements. Findings are expected to provide insights for designers and researchers aiming to design more user–centric cultural heritage games.

Keywords: Field Dependence/Independence; Cognitive Style; Cultural Heritage; Games; Eye–Tracking; Visual Attention; Game Design

1 Introduction

In the past few years a lot of research on video games in the cultural heritage context has been conducted [2][7][10][17], since they can enrich visitors' experience and contribute towards a much desired learning outcome. To achieve this, game designers aim to include information processing tasks through game mechanisms that guide users to seek and comprehend information and to acquire and recall knowledge. Information processing is closely related to cognitive characteristics, therefore it seems worth investigating the impact of cognitive differences on game playing in cultural heritage contexts. The theoretical background of this work is based on cognitive theories [15][26], suggesting that individuals have different habitual approaches in information seeking, processing and retrieval, which are related to their individual cognitive characteristics such as skills and abilities, e.g. visual attention. High–level cognitive processes, such as cognitive styles, have been the focus of many research endeavours explaining empirically the observed differences in information processing tasks [1][15][23][26]. One of the most well established, credible and validated [3][5] cognitive style is the Field Dependence/Independence style [26]. It is a single dimension model having the field dependence on the one side and the field independence on the other. According to this model, the individuals are classified as field dependent (FD) or field independent (FI). FD individuals tend to prefer a more holistic way when processing information, have difficulties in identifying details from information in complex schemes and perform better on inductive tasks [26]. On the other hand, FI individuals tend to prefer impersonal orientation, prefer a more analytical way when processing information, pay attention to details and easily separate simple elements and structures from the surrounding context [26].

2 Related Work

Several studies [4][18][19][24] have investigated the effect of cognitive styles in various application domains, such as e-learning, industrial engineering and marketing, using eye–tracking tools. Focusing on FD/FI cognitive style, research revealed a correction between the FD/FI style and eye movement and attention patterns, with FD users exemplifying a more disoriented and disorganised eye motion activity and generating a greater number of fixations and FI users following a more oriented and organised scan strategy when performing visual exploration and web search tasks [18][19]. Shinar et al. [24] examined the relationship between field dependence and on–the–road visual search behaviour and revealed that FD individuals require more time to process the available visual information and are less effective in their visual search pattern. Despite that a number of application domains has been researched, to the best of the authors' knowledge no other eye–tracking study has been reported on the gamers' cognitive differences on cultural heritage game playing.

3 Eye–tracking Study

3.1 Methodology

Experimental Design and Procedure We designed an eye–tracking experiment to investigate the effect of cognitive styles on visual attention during a cultural heritage game. To increase the validity of our study we recruited participants who were a) engaged with online gaming activities more than twelve hours per week; b) had no previous experience in playing Time Explorer; and c) had never taken the Group Embedded Figures Test (GEFT) before. During the study session the players were firstly asked to complete a short demographic questionnaire; then they undertook the GEFT test; and finally they played the game. To test the study environment and instruments and make any adjustments, a pilot study was carried out prior to the main study.

Apparatus The eye tracking experiment was performed on Tobii T60 Eye Tracker, integrated into a 17" TFT monitor (96 dpi) at a screen resolution of 1280x1024 pixels. We used the browser Google Chrome v.51 with a window size of 1040x996 pixels. Tobii T60 Eye Tracker has a tracking frequency of 60 Hz and an accuracy of 0.5^o of visual angle. The analysis of the collected gaze data was performed using the software Tobii Pro Studio.

Participants Twenty one undergraduate students were recruited to take part in the eye–tracking study during the spring semester of 2016. However, only fourteen of them produced valid eye–tracking data, two females (14.3%) and twelve males (85.7%). They ranged in age between 18 and 23 years (M = 20.500, SD = 1.852). All the participants met the requirements discussed in Experimental Design and Procedure section.

Group Embedded Figures Test To determine the participants' cognitive styles, the Group Embedded Figures Test (GEFT) [20] was used. The test consisted of three sections, and during each of them, the participants had to identify simple forms within complex patterns in a given time. The first section was introductory. The next two sections were the main ones and they consisted of nine items each; five minutes were allocated to each. The score is calculated by adding the number of simple forms identified correctly in the second and third section, thus the score range is between 0 and 18. During the administration and scoring of the GEFT, the directions about the materials, the test procedure, scoring and time limits described in the scoring template [27] were firmly followed. Participants' average score on GEFT was 11.714 (median = 12, SD = 2.894), distributed normally according to Shapiro–Wilk test ($p = 0.471 > 0.05$). The classification of participants into field dependent (FD) or field independent (FI) is based on a cut–off score, which however is not identified in the original work [20]. However, a number of classification procedures have been developed [8][16] and for the scope of this study the median score was adopted as the cut–off score, i.e. 12. The participants who scored 12 or lower were classified as FD, and those who scored 13 or higher as FI. Eight participants were classified as FD and six as FI. The users' scores on the GEFT test in our sample is comparably similar to general public GEFT test scores as shown in several studies which embraced individuals with different demographics [3][14].

Game The game we selected for this study was Time Explorer; a well-known and multiple award winning game of British Museum, which requires players to perform several information processing tasks through game–play in order to complete their objectives. Time Explorer has four different levels, each related to an ancient civilisation. For the scope of this study, we used Aztec Mexico level. In order to complete the game successfully, the players had to rescue a mystical mosaic mask and deliver it to the tribe priest. To redeem the mask, the players needed to overcome challenges; solve problems; find and decode hidden messages. Hidden items and knowledge artefacts, e.g. bonus facts and objects, were scattered throughout the game, which would not only provide information about each civilization to the players, enhancing their knowledge, but they could also increase their score. In particular, the formula that calculates the final game score is formed by three main parameters: the total level completion time, the total in–game puzzle solution time and the number of hidden facts and objects collected. The hidden elements of the game are divided into two major types: helpful objects and bonus items (objects and facts). The collection of helpful objects is mandatory in order for the player to proceed in the game or complete it, while the collection of bonus items is optional, since they do not provide information crucial to game progress, but they provide general information about the Aztec civilisation.

Measures For our analysis we wanted to know how visual attention on interactive game elements is distributed among players with different cognitive styles. Therefore, we assigned gaze data to areas of interest (AOIs) on the interactive game elements. Twelve AOIs were identified for the Aztec level, representing all the interactive game elements. The collected gaze data are based on fixations, which were detected using the built–in algorithms of Tobii Studio. The algorithms generate a fixation if recorded gaze locations of at least 100ms are close to each other (radius 35 pixels). Fixations assign the entire count or duration to the AOIs that contain the centre point of the fixation, and fixations projected on the foveal area of the eyes may be lost. Hence, we used a technique introduced by Buscher et al. [4], which takes into consideration fixations that are close to the fixation centre using a Gaussian distribution. We used two metrics:

- **Fixation count**: the number of fixations a participant has within an AOI, taking into consideration visits and re–visits to the AOI.
- **Fixation impact**: a modified version of fixation duration, introduced by Buscher et al. [4].

3.2 Results

Fixation Count An independent–samples t–test was run to determine if there were differences in fixation count to any interactive object between FD and FI players. Fixation count for each group was normally distributed, as assessed by Shapiro–Wilk's test (FD: $0.227 > 0.05$ and FI: $0.590 > 0.05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.169 > 0.05$). The FI players had a total greater fixation count (M = 47.167, SD = 17.291) than FD players (M = 24.625, SD = 9.303), a statistically significant difference, M = 22.542, 95% CI [6.973, 38.110], $t(12) = 3.155$, $p = 0.003 < 0.05$. Nonetheless, not all the interactive objects of the game were mandatory for the players in order to proceed in the game, as we discussed previously. Therefore, we investigate whether there are differences in fixation count regarding each type of interactive game elements. An additional independent–samples t–test was run for each element type to determine if there were differences in fixation count between FD and FI players. Regarding the helpful objects, fixation count for each group was normally distributed, as assessed by Shapiro–Wilk's test (FD: $0.184 > 0.05$ and FI: $0.819 > 0.05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.513 > 0.05$). The FI players had greater fixation count to helpful objects (M = 5.167, SD = 3.656) than FD players (M = 2.875, SD = 2.997), but there is no statistically significant difference, M = 2.292, 95% CI [-1.577, 6.160], $t(12) = 1.291$, $p = 0.221 > 0.05$. However, there is a statistically significant difference for both bonus items according to independent–samples t–test. In particular, the FI players had greater fixation count to bonus items (M = 42.500, SD = 13.172) than FD players (M = 20.500, SD = 7.910) a statistically significant difference, M = 22.000, 95% CI [9.727, 34.273], $t(12) = 3.906$, $p = 0.002 < 0.05$. Fixation count for each group and each game element type were normally distributed, as assessed by Shapiro–Wilk's test, and there was homogeneity of variances, as assessed by Levene's test for equality of variances.

Fixation Impact An independent–samples t–test was run to determine if there were differences in fixation impact to any interactive game element between FD and FI players. Fixation impact for each group was normally distributed, as assessed by Shapiro–Wilk's test (FD: $0.651 > 0.05$ and FI: $0.145 > 0.05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.488 > 0.05$). The FI players had a total greater fixation impact (M = 25.422, SD = 8.484) than FD players (M = 16.708, SD = 5.909), a statistically significant difference, M = 8.714, 95% CI [0.364, 17.065], $t(12) = 2.274$, $p = 0.042 < 0.05$. Likewise fixation count, we investigate the effect of cognitive style in the fixation impact of each game element type. Hence, an additional independent–samples t–test was run for each type to determine if there were differences in fixation impact between FD and FI players. Fixation impact for each group was normally distributed, as assessed by Shapiro–Wilk's test (FD: $0.057 > 0.05$ and FI: $0.149 > 0.05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.882 > 0.05$). The FI players had greater fixation impact towards helpful objects (M = 3.283, SD = 2.462) than FD players (M = 2.428, SD = 2.845), but there is no statistically significant difference, M = 0.855, 95% CI [-2.313, 4.022], $t(12) = 0.588$, $p = 0.568 > 0.05$. Regarding the bonus items, fixation impact for each group was normally distributed, as assessed by Shapiro–Wilk's test (FD: $0.250 > 0.05$ and FI: $0.301 > 0.05$), and there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.867 > 0.05$). The FI players had greater fixation impact towards bonus items (M = 22.139, SD = 7.277) than FD players (M = 14.279, SD = 5.890), a statistically significant difference, M = 7.860, 95% CI [-0.206, 15.513], $t(12) = 2.237$, $p = 0.045 < 0.05$.

4 Discussion and Interpretation

Eye–tracking analysis revealed significant differences between the game–playing approaches of FD and FI individuals. There was a significant difference on both fixation count and fixation impact towards the interactive game elements. FI players had greater fixation count and fixation impact than FD players, a finding that was anticipated as FI individuals tend to focus more easily on details and separate them from the background, whereas FD individuals are typically aware of the whole field, paying less attention to details [9][26]. Therefore, the FI players looked more times and for longer time periods at the interactive game elements, and they interacted more times with them [21][22].

Focusing on the different types of the game elements, no significant difference was found on the fixation count and fixation impact towards helpful objects. Since, the collection of such objects was mandatory in order for the players to proceed and complete the game, the fact that no differences between FD and FI players observed was anticipated. However, there was a significant effect regarding the fixation count and fixation impact toward bonus items. FD players observed less times and for shorter time periods the bonus items, as they tend to follow a more intrinsic approach and be less inclined in detecting details [26], having in mind to complete the game faster [22]. On the other hand, FI players tend to develop self–defined goals and be more analytical [26], and thus they observed bonus items more often and for longer time periods.

In both cases, the fact that FI players had greater fixation count and fixation impact towards bonus elements than FD players, would lead them to interact with these elements more often [21][22] and thus the game would provide them more information about Aztec civilisation. Therefore, FI players would more likely get involved in learning activities by acquiring information related to Aztec history, while FD players would process less information. Design wise there is a risk for game designers of unintentionally favouring players with specific cognitive styles. Therefore, cognitive differences should play a role in both the design and the play phase of the games. Our study reinforces the belief that FI/FD users develop different gaming strategies and suggests that research on players cognitive styles could reveal a lot about their interacting behaviour during game play. Hence, designing games that implicitly recognise the users cognitive style and adapts seem to be engraving a new promising path, especially in new emerging environments, such as augmented and virtual reality, where embedding eye-tracking mechanisms is feasible.

In terms of generalisability, we expect that similar effects will derive in different game genres as long as they involve information processing tasks. In cultural heritage contexts, given the large diversity of the visitors in terms of culture and the fact that there is a correlation between the culture and the different cognitive skills and styles [6][13], we believe that adaptive and personalising mechanisms should be proposed, to ensure better visiting experience for all audiences.

5 Conclusion

The aim of this study was to investigate the effects of FD/FI cognitive style on gamers' visual attention when playing a cultural heritage game. A main effect of cognitive differences on the fixation count and fixation impact towards interactive game elements was found. In particular, FI players had greater fixation count and fixation impact towards the total game elements and elements that were not crucial for completing the game. On the other hand, no effect was found regarding the fixation count and fixation impact towards objects that were mandatory to be collected by the players in order to proceed in the game. Our study had limitations such as the rather small sample and the non–varying participants' profiles. However, its distribution was normal towards GEFT scores, reflecting the general public distribution. The participants' age range was also limited, but taking into consideration that high–level cognitive characteristics rarely change throughout adult lifespan [25], the observed main effects of the eye–tracking study would possibly apply for other age groups. In our sample there was an imbalance in terms of gender distribution, which was not reflected to the GEFT scores as they followed a normal distribution. Researchers have argued for and against a correlation between the gender and the FD/FI classification [11][12]; the analysis of our results has not revealed any correlation between the two. Nonetheless more intensive research should be conducted in order to gain a deeper understanding on how cognitive factors are related to players' visual attention in games on a cultural heritage context.

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