# Do Field Dependence–Independence Differences of Game Players Affect Performance and Behaviour in Cultural Heritage Games?

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## ABSTRACT
Stimulated by a large number of different theories on human cognitive processing, suggesting that individuals have different habitual approaches in retrieving, recalling, processing and storing information, this paper investigates the effect of field dependence/independence with regards to game players' performance in the context of a cultural heritage game. Thirty two participants took part in an in-lab study and were classified as field dependent or independent based on a cognitive style elicitation instrument. Quantitative analysis methods were used to examine gaming performance in terms of game completion time, information seeking and items collection. The results revealed statistically significant differences in task completion time and in crucial information retrieval situations. Findings are expected to provide useful insights for practitioners and researchers with the aim to design more user–centric cultural heritage games.

### ACM Classification Keywords
H.1.2. User/Machine Systems : Human factors; Human information processing

### Author Keywords
Cognitive Styles; Field Dependence/Independence; Cultural Heritage; Games; Player Analytics; Game Design

## INTRODUCTION
Immersive technologies and video games are widely used in order to enrich visitors' experience in cultural heritage environments. Therefore, this domain has been the focus of various research endeavours throughout the recent years [9, 14, 18, 33], as technological advances have contributed towards intelligent and sophisticated digital solutions. Numerous cultural heritage games have been developed [4, 28] aiming to engage players in immersive and playful experiences, often combined with learning goals. In the aforementioned context, game designers are usually trying to scaffold informal learning activities embracing information processing tasks, such as information seeking, comprehension, recall and knowledge acquisition, in the game mechanics. Given that the aforementioned information processing tasks are basically human cognitive tasks, it is interesting to investigate the effect of human cognitive differences in information processing on gaming performance during a cultural heritage game.

### Motivation and Theoretical Background
The high–level motivation underlying our work is investigating whether certain game designers' decisions, such as gameplay rules, interaction mechanisms and information structure and presentation, favour specific user groups, who share common information processing attributes, in game contexts embracing human information processing tasks.

The theoretical background of this work is mainly based on theories of individual differences in cognitive styles and abilities [12, 23, 41], suggesting that individuals have preferred ways of seeking, representing, processing and retrieving information, which are related to their individual cognitive skills and abilities, e.g. information process speed and memory load. Several researchers have focused on high–level cognitive processes in order to explain empirically the observed differences in information quest, representation, process and retrieval [24, 35]. Such high–level processes are the cognitive styles and a number of them have been developed and studied over the years [1, 23, 34, 41].

One of the most well established and validated [5, 7] cognitive styles is the Field Dependence/Independence style [41]. It is a single dimension model with the field dependence lying on the one side, and the field independence on the other. The individuals described as field dependent (FD) tend to prefer personal orientation, be holistic, have difficulties in distinguishing details from other information around them and perform better on inductive tasks [41]. On the other hand, the individuals described as field independent (FI) tend to prefer impersonal orientation, be analytical, pay attention to details and tend to easily separate simple elements and structures from the surrounding context [41].


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## RELATED WORK

Video games are closely related to cognitive skills and styles in terms of visual or spatial attention, memory load, verbal representation, etc. [6, 16]. In video gaming contexts the players usually need to solve problems, overcome challenges and interact with the game environment in multiple ways in order to progress and succeed, and thus several cognitive skills are utilised [37, 38]. McDaniel and Kenny in their recent study [27] investigated the impact of FD/FI cognitive style on students' preconceived impressions and enjoyment of video games during a learning activity, and found that there is a difference on the perceived difficulty of playing between FD and FI individuals, with FDs demonstrating a general reluctance towards using games for learning activities. Similar results derived from Naudet et al. [29], who studied the effect of players' cognitive style on a social network game playing in a cultural heritage environment. However, both studies focused on overall gaming experience of the participants, and not on the gaming performance, e.g. game completion time.

## METHOD

### Time Explorer

In order to further elaborate our research motivation, we selected *Time Explorer*[1], a well–known and multiple award winning web based game provided by British Museum, which integrates multiple game mechanisms and genres, such as adventure, action and problem solving tasks, requiring players to perform several information processing tasks through gameplay such as information seeking, comprehension, recall and knowledge acquisition.

The objective of the game is to travel back in time to explore ancient civilisations and recover precious treasured objects. During the game, the players navigate in a room, performing information seeking and retrieval tasks such as quests for helpful items and facts. In order to solve problems to proceed in the game, and answer the final riddle to save the precious treasured object the players are required to reflect on acquired knowledge incorporating information comprehension, recall and acquisition tasks. The aforementioned tasks are reflected on specific gaming performance metrics, which form the overall score. In particular, the score is measured based on the game completion time, the number of items discovered and whether or not the in–game puzzle solved throughout the gameplay, which are the dependent variables of our study.

### Null hypotheses

To provide valuable insights related to our motivation, we formed the following null hypotheses, for which we were suspecting that the main effects would reveal which design aspects of Time Explorer favour specific user types (FD/FI).

- $H0_1$: there is no significant difference regarding the time needed to complete the game between FD and FI players;
- $H0_2$: there is no significant difference regarding the items discovered throughout the game between FD and FI players;
- $H0_3$: there is no significant difference in puzzle discovery throughout the game between FD and FI players.

[1] http://www.britishmuseum.org/games/GreatCourt.swf

### Procedure

The first stage of the study procedure involved the recruitment of the participants, who had to meet a set of minimum requirements. In particular, they should a) be engaged with online gaming activities more than twelve hours per week; b) have no previous experience in playing Time Explorer; and c) have never taken the Group Embedded Figures Test (GEFT) before. After the recruitment, five study sessions were scheduled at times convenient for the participants. The individuals of each session were firstly asked to complete a short questionnaire about demographic information, and then they proceeded to the GEFT sessions, which were facilitated by the researchers and had a total duration of fifteen minutes.

Next, the game session took place in a usability lab. Each participant played an introductory level of the game, Ancient Rome, in order to familiarise with the controls and the overall game environment. The main phase of the game followed, where the players had to rescue a porcelain vase in Imperial China. The time allocated for the game was twenty five minutes in total. At the end, a semi structured interview followed in order to ask questions about participants' behaviour and understand their incentives during the game. Ten minutes were allocated to this phase. Prior to the main study, a pilot study was carried out in order to test the environmental components, the study instruments and the flow and the participants' behaviour, aiming to adjust the study parameters.

### Participants

Participants were recruited from the institution during the spring semester of 2016. In total, thirty two students were recruited, eight female (25%) and twenty four male (75%), aged between eighteen and thirty years old (mean age = 22 years old, SD = 4 years). All participants played single player web based games more than twelve hours per week. Furthermore, the participants were explicitly asked to specify whether they had played Time Explorer before, and no previous experience on the selected game was reported.

### Instruments

#### *Group Embedded Figures Test*

To determine the participants' cognitive styles, the Group Embedded Figures Test (GEFT) [30] 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 included seven items and the time limit was two minutes. Its purpose was to familiarise the participants with the test process, and hence it was not considered in the total score. The next two sections consisted of nine items each and five minutes were allocated to each. The score is calculated by adding the number of simple forms correctly identified 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 [42], were firmly followed.

Participants' average performance on the GEFT was 12.59 (SD = 3.39), distributed normally according to Shapiro–Wilk test ($p = 0.36$). The classification of participants into FD or FI

| Group Statistics | | | | |
|---|---|---|---|---|
| *Group* | *N* | *Mean* | *Std. deviation* | *Std. error mean* |
| FD | 15 | 206.20 | 57.486 | 14.843 |
| FI | 17 | 277.29 | 64.634 | 15.676 |

| Independent Samples Test | | | | |
|---|---|---|---|---|
| *t* | *df* | *Sig. (2-tailed)* | *Mean Difference* | *Std. Error Dif* |
| -3.268 | 30 | .003 | -71.094 | 21.751 |

**Table 1. Independent samples test results.**

is based on a cut–off score, which however is not identified in the original work [30]. A number of classification procedures have been developed [10, 25] and for the scope of this study the mean score was adopted as the cut-off score.

Therefore, the cut–off score was determined to be 12, meaning that the participants who scored 12 or lower were classified as FD, and those who scored from 13 to 18 as FI. Based on the aforementioned classification scheme, fifteen participants were classified as FD and seventeen as FI. It is important to stress that the frequencies of 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, 5, 11, 19, 22, 36].

## ANALYSIS OF RESULTS

### The effect of FD/FI on completion time

To examine whether the hypothesis $H0_1$ is rejected or not, the independent–samples t–test was used. More specifically, this test was used to determine whether there is a difference between the FD and FI individuals regarding the completion time, and whether it is statistically significant. There is only one dependent variable, i.e. completion time, which is measured at the continuous level. There is also only one independent variable which consists of two categorical and independent groups, i.e. FD and FI cognitive styles.

There were no significant outliers in the FD and FI groups as it was visually inspected on the produced box–plots. Next, the Shapiro–Wilk test was used in order to validate that completion times for FD and FI groups were normally distributed ($p > 0.05$). Finally, and since there was homogeneity of variances, as assessed by Levene's test for equality of variances ($p = 0.747$), the t–test with equal variances was run and its results are displayed in Table 1. The completion time of the FD participants was less ($206.20 \pm 57.49$) than the time needed by the FI participants ($277.29 \pm 64.63$) in order to complete the game, a statistically significant difference of 71.094 (95%), $t(30) = 3.268$ and $p = 0.003$.

### The effect of FD/FI on the number of items discovered

To examine whether there is a statistically significant difference regarding the items discovered by the participants during the game, based on their group, the Mann–Whitney U test was selected. In order to meet the assumption related to the study data it should be determined whether the two distributions have the same shape. A visual inspection of the shapes of the

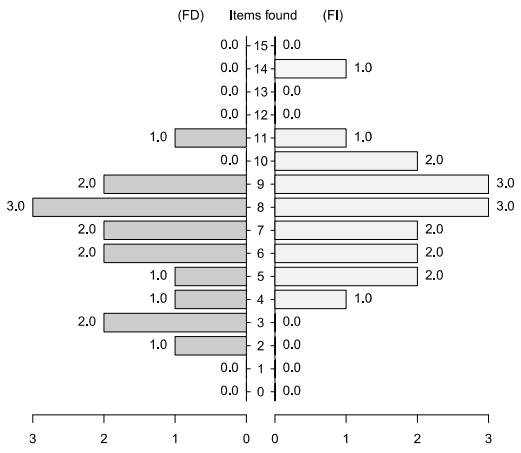


**Figure 1. Number of items discovered by the participants**

distribution illustrated on the histogram of Figure 1, reveals that the shapes are not the same. The Mann-Whitney U test which was run to determine if there were differences in the number of items discovered by the FD participants (mean rank = 6.40, sd = 2.586) and FI participants (mean rank = 8.00, sd = 2.500), revealed that there was no statistically significant difference between the two groups ($U = 86.5$, $z = -1.560$, $p = 0.123$) using an exact sampling distribution for U.

### The effect of FD/FI on whether the puzzle discovered

To examine whether there is a statistically significant difference regarding the discovery of the puzzle which would provide the participants with crucial hints in order to answer the final question and complete the game, Fisher's Exact test was selected. The results of the study revealed that only four (26.7%) FD individuals discovered and solved the puzzle. On the other hand, twelve (70.7%) FI individuals found and solved the puzzle. There was a statistically significant association between cognitive style and the discovery of the in–game puzzle by Fisher's exact test ($p = 0.032$).

### Behavioural patterns of FD/FI players

A few behavioural patterns were identified among the participants of each group. In particular, the two groups followed different approaches in order to complete their tasks. FD individuals tended to seek information in a timely manner and with less moves, whereas FI individuals spent more time when seeking and processing information, as they followed a more analytical approach. Moreover, FD individuals tried more often to correlate acquired knowledge, such as revealed objects, with riddles required to proceed to next game stages, whereas FD individuals followed a more intrinsic approach, being primarily reliant on guesses. Furthermore, FI individuals tended to use the inventory more often, as they wanted to have a clear picture of the gathered items. Also, the fact that most of the FD participants did not access the puzzle stage and found a few hidden items, could be due to their difficulty to perceive objects as separate from the field [24, 41]. The afore

mentioned findings are in line with the results derived from our qualitative analysis [32].

## DISCUSSION AND INTERPRETATIONS

Quantitative analysis uncovered observable differences between the game–playing approaches of FD and FI individuals. The study revealed a statistically significant difference in completion time between FD and FI participants, which is on a par with the findings of studies in other application domains, such as learning and web search [5, 31]. This difference could be attributed to the different approach of problem solving the two groups followed. FI individuals generally require external help to solve a problem [41], which in this case is to finish the game, therefore they were in the lookout for help while playing, such as using the inventory more often or discovering more items. This finding is confirmed in our previous work [32], with FI individuals accessing more often the inventory to find clues on how to proceed, while FD individuals followed a more inherent approach, verifying their intrinsic nature [41]. In addition, FD individuals are generally less inclined to find objects or cues, as they have difficulty in detecting details, which could explain that they found less items than FI participants.

On the other hand, FI individuals tend to develop self–defined goals, while FD individuals require external ones. An example of such behaviour is that the FI participants found more objects than the FD participants while playing. Moreover, most of the FI participants discovered and solved the in–game puzzle, whereas most of the FD players did not. Given that finding hidden objects and solving the puzzle was not a prerequisite for finishing the game, FI participants spent more time trying to find all the objects and solved the puzzle, while they collected less points. This finding is mainly explained by their analytical nature [41]. Despite FI participants discovered more items than the FD, the difference is not statistically significant which can be attributed to the participants' unawareness of whether the items were required in order to progress in the game, but also to the fact that most items were hidden in obvious spots, and thus they were easily distinguishable. In general, FD individuals focused on the external goal, i.e. find the vase, spending less time in exploring the level and concentrated on the cues that allowed them to proceed more quickly.

The analytical nature of the FI individuals enabled them to solve the puzzle that provided critical hints for answering the final question and rescuing the object. Solving the puzzle required information acquired when collecting specific objects of the game, which the FD participants did not detect, as they tended not to pay attention to detail. In addition, the FI participants' engagement in the puzzle solving, could explain the more time they needed to complete the game, in comparison to FD players. Finally, the complexity of the game did not allow for validating other characteristics of the two cognitive style groups such as complex problem solving performance.

### Design Implications and Generalizability

The contribution of the paper entails two important aspects; theory and application. Regarding theory, the study provides evidence that socio-cognitive theories, like FD/FI, can be considered as applicable analysis frameworks in understanding deeper player interactions. Regarding application, the analysis and discussion of results underpinned the value for considering cognitive styles as a human design factor, in both design and run time, in order not to design games that unintentionally favour a specific group, e.g. the Time Explorer designers' decision of non–mandatory discovery of objects and puzzles in order to complete the game favoured FI players in terms of acquired information and FD players in terms of completion time. Given that future studies will further shed light on such effects,they can drive the design of games that adapt to individual cognitive styles by using sophisticated techniques, such as classification tools based on eye tracking mechanisms in AR/VR environments.

Regarding the generalisability of our work, we expect that similar effects will be replicated in the contexts of different game genres, contributing to the study's external validity, as long as the game activity involves in large extend information seeking, retrieval, comprehension, recall and knowledge acquisition tasks. Specifically within the cultural heritage domain, given that user population is culturally diverse, e.g. Time Explorer players span among different cultures, and that users from different nations/cultures have different cognitive processing style abilities [2, 8, 15, 21], we argue that adapting and personalizing design to this aspect may contribute to improvements of cultural heritage gaming experiences for diverse audiences.

## CONCLUSION

The purpose of this study was to investigate the effects of field dependence/independence cognitive styles on gamers' performance and behaviour when playing cultural heritage games. The findings of the study revealed a main effect of cognitive differences on task completion time and the discovery of crucial items. No effect on the exploration of the game environment and the discovery of helpful items was identified.

### Validity of the study and limitations

An important limitation is related to the rather limited number and non–varying user profiles of the sample since undergraduate and postgraduate students were recruited for conducting the study. However, as mentioned previously the sample distribution towards their FD/FI styles reflects the general public distribution. Given that high level cognitive styles of individuals rarely change throughout adult lifespan [13, 40], the observed main effects of this study would possibly apply for other age groups (e.g., 30–40). There is also a gender imbalance in our sample, but despite the fact that there are mixed outcomes in the literature about the gender effect on FD/FI classification [17, 20, 26, 39], our study has not shown a gender effect towards FD/FI distribution within our sample, as the distribution of GEFT scores was normal. Nevertheless, similar research attempts are required in order to acquire a deeper understanding about the effects of human cognitive factors on performance and user behaviour in cultural heritage games, and thus, increase the external validity of this research.

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