

# Examining the Association Between Users Creative Thinking and Field Dependence-Independence Cognitive Style through Eye Movement Components

Efi A. Nisiforou

Multimedia and Graphic Arts  
Cyprus University of Technology  
30 Archbishop Kyprianou Str. 3036, Lemesos  
Cyprus  
efi.nisiforou@cut.ac.cy

## ABSTRACT

This eye tracking study investigated the association between individuals' field dependence - independence cognitive style and level of creative thinking based on users' eye movement behaviour while interacting with a set of visual perceptual tasks. Subjects FD-I cognitive style and creativity were measured with the use of the Hidden Figures Test (HFT) and Torrance Test of Creative Thinking (TTCT). The psychometric methods and the eye tracking-derived data were statistically examined demonstrating a relationship between users' cognitive style, creativity attributes and eye gaze behaviour. This research study adds further to the evidence and theory base of Human-computer interaction for applications in the user-centred design and suggests future directions for research.

## Author Keywords

Field dependence-independence; eye-tracking; eye gaze; visual stimuli; Hidden Figures Test; Torrance Test of Creative Thinking.

## ACM Classification Keywords

H.5.2 User Interfaces User-centered design; I.5.2 Design Methodology (e.g. Feature evaluation and selection, Pattern analysis).

## INTRODUCTION

This study was an investigation towards an on-going project that aims to provide guidelines for the design of adaptive environments by understanding how users of different cognitive types interact with various tasks [1]. The idea that individuals differ in the way they solve or approach tasks

has provided a central underpinning for research in the field of the applied cognitive dimensions. Currently, there is an escalation of studies that examine individuals' cognitive components in correlation to visual perception. In order to accomplish the aforesaid long term vision of the research, there is a need for some premise indicators to be considered. Therefore, the purpose of the current work is to look for any possible connections between the eye gaze pattern and individuals' cognitive characteristics such as featural processing style and creativity.

Creativity involves the capacity to spontaneously shift back and forth between analytic and associative modes of thought according to the situation [2]. These types of thought demonstrate individual differences in how visual information is perceived. One of the most widely used tests to assess associative thinking (divergent or local processing styles) and analytic thinking (convergent or global processing styles) is the Hidden Figures Test [3]. Besides, focusing on specific patterns activates memory that supports divergence or convergence [4]. Thus, a question arises as to whether people who process information in a more analytic way, are more creative than those who look at the whole image/ object embedded in a scene. Finally, the notion that field independent people have been found to be more creative than the field dependents remains vague.

Earlier studies have proposed that the use of ambiguous stimuli may in some way be associated with degrees of creativity [5, 6, 7]. Additionally, tolerance of ambiguity is believed to contribute to the creative process because it enables the exploration of new, uncommon or complex stimuli [8]. These lines of work suggest that the more individuals can tolerate ambiguous objects, the more creative they become.

Thus, the purpose of the designed research is twofold. Firstly it seeks to identify the association between users' Field dependence-independence cognitive style and creative thinking, and secondly to examine individual differences in eye movement patterns during a computer-based visual perceptual task processing between the three different

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cognitive groups of users [i.e. Field Dependent (FD), Field Neutral (FN) and Field Independent (FI)].

Specifically the study seeks to address the following research questions:

- Q1.** Is there any association between users' Field Dependence-Independence cognitive type and their level of creative thinking?
- Q2.** What are the differences between users' cognitive groups (FD, FN, and FI) and eye movement behaviour?

## THEORETICAL BACKGROUND

### Field dependence - independence cognitive style

The field dependence-independence (FD-I) is among the most widely used cognitive style dimensions appearing in the literature [9, 10]. These dimensions are formed based on the individual's reliance on the context to extract particular meaning and describe three contrasting ways of processing information (FD, FN, FI) [1]. Participants' level of field dependency is measured with the use of the Hidden Figures Test [4]. The HFT contains 32 questions divided into two parts. The test presents five simple figures and asks learners to find one of the five simple figures embedded in a more complex pattern. The field dependents find it difficult to identify a simple geometric figure that is embedded in a complex shape while field independent learners can identify the separate parts of a whole. FD learners, take longer to detect a simple figure than FI students, or they may not be able to find it at all [1, 10]. FI individuals, are therefore, more likely to be influenced by internal than external cues and be selective in their information input [1, 2].

### Creative thinking

Creativity has been defined as the process of incorporating seemingly unrelated and irrelevant information to solve problems [12]. Creative thinking is often thought to involve divergent thinking; that is being able to consider a solution in many different ways rather than converging on a single answer [13]. One of the broadest used assessments of creativity is the Torrance Test of Creative Thinking (TTCT) [14, 15]. It is based on widespread analyzes; thus it can be determined that the TTCT is the best creativity test currently exist [16]. The TTCT is available in two versions; the TTCT-Verbal and the TTCT-Figural, each one consists of Form A and B [17]. Both forms are concerned with four principal cognitive processes of creativity: (a) fluency of relevant responses; (b) flexibility as referred to a variety of answers; (c) originality entails considering novelty responses; and (d) elaboration as stated to the number of details used to provide an answer. However, in the scope of this review, only the TTCT-Figural was used.

### Eye tracking and eye movement data

Eye tracking studies try to investigate and understand user behaviour and offer information on issues such as cognitive

activity [18]. The use of eye tracking has long been established in Psychology as a technique for analyzing user attention patterns in information processing tasks [18]. These attention patterns of eye movement data are very informative in revealing evidence about the cognitive processes [17]. A previous study examined the potential of eye tracker as a tool for detecting users' cognitive dimensions with respect to the FD-I classification. The study identified differences between the three cognitive styles and search tasks time completion [1]. Although current studies have provided valuable insights into how different tasks affect a user's eye gaze behaviour, further research needs to examine individual differences in eye movement components in terms of other cognitive features such as creative thinking and featural processing styles.

## METHOD

### Participants

The target audience of the study consisted of thirty one normal vision students with average age 19, 61 years (SD = 1.874) recruited from the school of Psychology at a private University in the U.K.

### Procedure and Materials

Users' interaction and cognitive behaviour were examined with the aid of the eye tracker technology during perceptual processes involved in the interpretation of ambiguous figures. The design of the environment was programmed through the iView SDK software development (kit-interface). A number of twenty (20) ambiguous images (10 images per ambiguous category) were scaled to the same dimension and equalized for intensity. The exploration was conducted in three parts, using the following research tools: a) Hidden Figures Test- HFT; b) Torrance Test of Creative Thinking – TTCT), and, c) eye movement components analysis through eye tracking.

#### *Part A - Hidden Figures Test (HFT)*

Participants' level of field dependence was measured with the use of the Hidden Figures Test and participants had a 24 minutes time limit to complete the test. It consists of 32 questions divided equally into two parts. The test presents five simple figures and asks learners to identify which of the five simple figures is embedded in the complex pattern. Individuals who scored 10 or lower are categorized as FD; those who possess a score from 11 to 17 are classified as FM or FN, and as FI those who score 18 or higher [1].

#### *Part B - Torrance Tests of Creative Thinking (TTCT) (Figural Test Form A)*

The researcher administered the TTCT to the participants as a way to measure their level of visual creativity. The TTCT-Figural contains three non-verbal activities: (a) Picture Construction, (b) Picture Completion and (c) Lines

(repeated figures). Ten minutes were required to complete each activity with a total working time of 30 minutes. The figural test comprises of three activities designed to measure five cognitive characteristics (fluency, originality, abstractness of titles, resistance to premature closure and elaboration) and thirteen creative strengths.

*Part C – Eye movements' gaze analysis* using the iViewX model of the eye-tracking device.

Students were asked to perform perceptual visual tasks while viewing ambiguous figures (images with more than one meaning). Their task was to press keyboard buttons every time they see the picture changing into something else, coupled with eye gaze recordings.

## RESULTS AND DISCUSSION

### Field Dependence-Independence cognitive style

Eye tracking metrics revealed statistically significant differences between the three different cognitive groups of learners and their level of creative thinking. The findings of the study are discussed in terms of the association between field dependent, field neutral and field independent cognitive groups and the level of creativity during a visual search task process. As previously mentioned, the Hidden Figure Test (HFT) was used to define users' FD-I current cognitive type (e.g. FD, FN and FI). Participants' score on the test was calculated as the difference between the numbers of questions answered correctly minus the number answered incorrectly. The participants were classified into their cognitive type as follows: 16 field dependent, 8 field neutral and, 7 field independent. The testing activity involved in the HFT is a reliable and widely used approach for determining the FD-I cognitive dimension.

### Level of creative thinking

The results from the Torrance Test of Creative Thinking (TTCT) indicated participants' level of creative thinking. The scoring scales measure the five norm-referenced totals (Fluency, Originality, Elaboration, Abstractness of Titles and Resistance to Premature Closure) and the 13 criterion-referenced scores, which compose the Creative Strength total. The cut off scores procedure of the three levels of creativity (Low, Moderate, and High) was based on previous studies measurements taking into account the standard deviation and mean of the Creativity Index [2]. Participants were classified as 6 Low creative thinkers, 21 moderate creative users, and 3 high creative thinkers.

### Eye movement comparisons of FD, FN, and FI users

Figure 1 demonstrates the scan paths of the field dependent, field neutral, and field independent subjects as a result of their interaction in one of the thirty visual stimuli of the experiment. The eye tracking scan paths reflect the users' eye gaze patterns while performing the perceptual visual tasks. It was hypothesized that individuals FD-I cognitive

style will affect their degree of creative thinking. Specifically, it was assumed that the FI will produce a higher level of creativity, contrary to the FN and FD users who might exemplify a moderate and a lower creativity level respectively.

These eye gaze patterns demonstrate that the field dependents produce a greater number of fixations and saccades, showing disoriented eye movement behaviour. In contrast, the field independents' and field neutrals' eye gaze activity exemplified a more oriented navigation, resulting in less number of fixations and saccades.



**Figure 1. Example of the ambiguous figure displayed in the experiment demonstrating FD, FN and FI users scan paths (from left to right), My Wife and Mother-in-Law © W. E. Hill**

### One-way Anova

A one-way ANOVA was conducted to examine the association between the field dependence-independence cognitive style and users' level of creative thinking on the visual stimuli employed. There was a significant correlation of the level of field dependency on creative thinking at the  $p < .05$  level for the three cognitive groups  $F(2, 28) = 4.21$ ,  $p = .025$ . Post hoc comparisons using the LSD test indicated that the mean score for the field dependence cognitive group ( $M = 0.13$ ,  $SD = 0.23$ ) was significantly different from the field independence group ( $M = 0.68$ ,  $SD = 0.24$ ). Moreover, the field neutral users' ( $M = 0.13$ ,  $SD = 0.23$ ) were significantly different from the field independents. Overall, these results suggest that individuals' level of field dependency affects their level of creative thinking. Specifically, the field dependent individuals exemplify lower levels of creative thinking, whereas, the field independents were classified as higher creative thinkers. The field neutral group showed a moderate creativity level compared to the FI group. However, it should be noted that there were no statistically significant differences between the field dependence and field neutral cognitive groups ( $p = .58$ ).

Thereby, why does looking at the whole suggest more creativity than looking at the specific? These findings in turn are greatly accentuated by the capacity to shift between associative and analytic thinking as a medium to be creative. The different processing modes are typical of creative thinking and can be explained based on Gabora's

cognitive theory of memory activation [2]. This approach is related to what we know about the different ways individuals' process and perceive visual stimuli.

## CONCLUSION

The eye tracking technique was employed to examine the association between the Field Dependence-Independence cognitive style and creativity during perceptual processes involved in the interpretation of ambiguous figures. This paper moved one step beyond creativity and cognition studies by adding an eye gaze behaviour empirical study. The findings yielded that the field independence group of individuals; who allocated less number of fixations in the visual stimuli of the experiment, resulted in higher levels of creative thinking than when related to the field dependence group. Besides, the field neutral group showed a moderate creativity level compared to the FI group. This finding proposes that paying attention to stimulus features rather than the ensemble suggest more creativity. Therefore, a contribution to Creativity and Cognition can be made by better understanding that certain types of people (as measured by the HFT) are probably more creative (as measured by the TTCT).

Currently, further research is under progress that will take the above study on its next phase combining behavioural and electrophysiological methods. The forthcoming work aims to investigate the mechanisms that underlie the association between FD-I cognitive style, eye gaze patterns, and creative thinking. As a final point, this work will contribute to the long term vision for the design of personalized environments that can reflect users' cognitive needs and characteristics.

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