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Doctoral Dissertation

ASSESSING LEARNERS' DIFFERENCES IN FIELD DEPENDENCE-INDEPENDENCE COGNITIVE ABILITY USING MULTI-METRIC METHODS

Efi Nisiforou

Limassol 2016

CYPRUS UNIVERSITY OF TECHNOLOGY
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PhD Dissertation

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ASD:	Autism Spectrum Disorders
ADHD:	Attention deficit hyperactivity disorder
BCI	Brain Computer Interface
CI:	Creativity Index
CERI:	Centre for Educational Research and Innovation
EEG:	Electroencephalography or Electroencephalographic
EM:	Eye Movements
ERP:	Event Related Potentials
ET:	Eye-tracking or Eye-tracker
FDI:	Field Dependent – Independent cognitive dimension
FD:	Field Dependent or Field Dependence
FI:	Field Independent or Field Independence
FN/ FM:	Field Neutral or Field Mixed
GBL:	Game based Learning
HFT:	Hidden Figures Test
HCI:	Human Computer Interaction
MBE:	Mind Brain and Education
MOOCs:	Massive Open Online Courses
OECD:	Organisation for Economic Co-operation and Development
PLE:	Personalized Learning Environments
RT1, RT2:	Reaction Time 1, Reaction Time 2
TEL:	Technology Enhanced Learning
TTCT:	Torrance Test of Creative Thinking

ABSTRACT

The notion that users' characteristics such as cognitive ability have an effect on visual information processing is fast emerging. Henceforth, understanding how cutting-edge technologies can detect these cognitive abilities leads to solutions that improve users' online experiences. Complex cognitive processes function in the way people perceive visual information, while various neural pathways are involved. This PhD thesis investigated cognitive and creative processes to provide feedback towards the improvement of future Human-Computer Interaction (HCI), Technology-Enhanced Learning (TEL) and Personalised Learning Environments (PLEs). Taking the concept of interdisciplinary study as a fundamental principle, this research stands at the crossroads of rich bi-directional and reciprocal interactions between the disciplines of HCI (User Experience), Neuroscience, Psychology and Education. Field Dependence-Independence (FD-I) is an important dimension of cognitive abilities through which individuals process information, classified through the conventional psychometric method Hidden Figures Test (HFT). Formed based on individual's reliance on the context to extract specific meaning, it encompasses three distinct approaches: Field-Dependence (FD), Field-Independence (FI) and Field-Neutral or Mixed (FN/FM). Field-Dependent learners find it difficult to identify a simple geometric figure embedded in a complex image; Field-Independents can identify the separate parts of a whole; and Field-Neutrals behave as FD or FI according to the learning situation. The Torrance Test of Creative Thinking (TTCT) was employed to measure individuals' level of creativity. A total sample of one hundred and twenty-nine (n=129) students were sourced across the experiments and was recruited from public universities in Cyprus and the United Kingdom. A multi-metric method approach was employed and combined valid and reliable existing psychometric methods with biometric (ET) and neurometric techniques (EEG) in order to comprehend aspects of the visual processing system, involving: a) psychometric tests to measure learners' cognitive abilities and creativity, b) eye movement analysis through eye-tracking (ET) metrics, and c) brain signals via electroencephalography (EEG) measurements. The empirical and experimental methods used are mainly quantitative estimations that provide continuous, objective measurements of human-system interactions. Eye movements were recorded during a set of visual tasks with the aid of the SMI iViewX eye-tracker device; and brain activation was measured with the use of the mBrainTraining Smarting EEG device. The findings highlighted the effectiveness of eye-tracking and EEG as potential techniques in detecting users' cognitive ability during visual processing. The psychometric, biometric and neurometric methods were statistically examined, demonstrating a relationship between users' FD-I cognitive ability, creativity, eye gaze behaviour and brain signals. The psychophysiological data revealed individual differences in users' FD-I visuospatial attention, saccadic and fixation eye movements, creativity, and reaction time during the visual search tasks. Differences have also been identified among the FD-I visuospatial groups in the Occipital and Frontal brain regions. Hence, as technologies continue to develop, it is imperative to understand how to design interfaces and instructional materials that support the specific needs and preferences of learners (i.e. individual information-processing and/or disembedding capabilities). Therefore, this work has revealed a number of research contributions for adaptive and personalised learning systems. The proposed method of assessing and evaluating FD-I and creativity using psychophysiological signals is one of the main contributions of this project. On the basis of the new method employed, this research attempted to map out the complex phenomenon of individual differences in Field Dependence-Independence cognitive processing with psychophysiological traits (creativity, eye movements and brain activity). This work has publicised, for the first time to our knowledge, apparent proof that the FD-I construct affects users' eye movements as a valid enmeshed contributory determinant. Eventually, the findings aimed to suggest a set of principles based on the eye-movement behaviours and brain signals (EEG) derived during the process of experiments. Consequently, concepts have been encapsulated based on different disciplines in a novel research setting in the HCI community, contributing with knowledge on how user differences manifest themselves during certain visual tasks. Finally, limitations and implications for future directions of research and practice are addressed.

Keywords: Field Dependence/Independence; Hidden Figures Test; cognitive abilities; higher education; learners; eye-tracking; eye movements; fixation and saccades; visual stimuli; Creativity; Torrance Test of Creative Thinking; EEG/ERP; brain activation.

DECLARATION

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or professional qualification of this or any other university or other institution.

(Efi A. Nisiforou, 2016)

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To my Parents, Andreas and Anastasia,

1. CHAPTER ONE

INTRODUCTION

This introductory chapter refers to the motivation that underpins the current Ph.D. thesis by briefly considering the theoretical background of the study whilst denoting the problem and purpose of the research. The chapter then leads to the specific research questions that guided this research. Concise definitions of the key concepts and methodology of the study are provided. Ultimately, this chapter presents the structure and the outline of the thesis.

1.1. Theoretical background

In the era of global technological revolution, the design and development of adaptive and personalised learning environments has become imperative. Meanwhile, the visual interface of online environments constitutes a complex area (Souto, 2013; Blashki, 2013) hence there are many aspects to be considered when designing and developing the interfaces of online environments. One essential element in the design of digital environments is the visual appeal (Orth & Wirtz, 2014). Therefore, understanding the linkage between a user's interaction with the visual element of an interface, and a user's ability to interact with a system, requires the utmost attention. The information on user interaction will provide insights for the implications of designing interfaces that will scaffold learners' online experience in the cognitive demands of a task (e.g. search performance, reaction time, task completion time, task context) by targeting their cognitive needs and characteristics. Cognitive style data is currently being integrated into adaptive systems for the development of personalised user models (Mehigan, Barr, Kehoe & Pitt, 2011). Thus, tailoring individualised learning based on learners' variations in the cognitive repertoire attracts researchers' and practitioners' attention. In particular, the use of eye movement input has lately been attracting more attention with the increasing demand for user interfaces and adaptive environments based on users' cognitive behaviour.

Previous studies have used eye movements indirectly to gather useful information regarding users' cognitive features (Toker, Conati, Steichen & Carenini, 2013). Since eye movement behaviour can reflect individuals' complex mental state, the investigation of what the eye patterns may further infer still remains a challenge (Sugano, Ozaki, Kasai, Ogaki & Sato, 2014). Cognitive styles defined by the information processing habits represent the learner's typical mode of reading, perceiving, thinking, problem-solving and remembering (Messick, 1985). According to Cronbach (1977), the Field Dependence-Independence (FD-I) cognitive style is not a distinctive style but is rather a deficiency in ability which contributes to learning and performance by affecting what and how people learn (Witkin, Dyk, Faterson, Goodenough & Karp, 1963; Witkin, Moore, Goodenough & Cox, 1977; Ragan, Back, Stansell, Ausburn & Ausburn, 1979). The term refers to an individual's ability to extract relevant information from a complex visual scene, in which some people find it much easier than others to identify parts of a figure as being separate from a whole (Galotti, 2013). In particular, Field Dependent people, who are more influenced by external cues, see the information more globally (Clark & Roof, 1988; Marendaz, 1985; Tinajero, Catelo, Guisande & Páramo, 2011), whereas Field Independents, who are affected by internal cues, are more able to analyse the information and restructure it according to their needs (Guisande, Páramo, Tinajero & Almeida, 2007; Riding & Cheema, 1991; Tinajero et al., 2011; Witkin et. al., 1963). Earlier studies have proposed that the use of ambiguous stimuli is somehow correlated with degrees of creativity (Urban, 2003; Wiseman, Watt, Gilhooly & Georgiou, 2011; Dove & Jones, 2014). These lines of indication suggest that the more individuals can tolerate ambiguous objects, the more creative they become.

Based on the aforementioned ambiguous phenomena, the thesis endeavours to determine the connection between the Field Dependence-Independence cognitive style and creativity. The goal is to open the unobservable black box of individual differences in psycho-physiological measures related to brain activity and eye movements.

The next sections attempt to identify and describe the research gap in the current literature and the purpose of the study. A detailed review of the theoretical keystones is set out in Chapter 2, which is the Literature Review.

1.2. Rationale

The European Commission (IP/15/5568) has recently turned its academic lens to identifying concrete traits that mark innovative digital and open learning environments. Society is shifting from the 'one-size-fits-all' model of teaching and learning to personalised learning. Personalised learning (PL) consists of a major educational topic which has been defined in various ways, but the most fundamental principle is set as putting the learner at the heart of the educational system (Leadbeater, 2008a,b). "Personalisation" refers to the instruction that is paced to learning needs, tailored to learning preferences, and to the specific interests of different learners (Bailey, Schneider & Vander Ark, 2013 pg.3). The EDUCAUSE Learning Initiative (ELI) defines personalised learning "as a tool to help educators design student-centred instructional models" (EDUCAUSE Learning Initiative, 2014). Considering that traditional classrooms are increasingly characterised by the diversity of learners' backgrounds, individual cognitive and learning needs, these are promising developments for improving personalisation for the support of every individual learner. The challenge, therefore, is how best to move from a 'teaching objectives 'model (where the focus is on the teacher) to a 'learning objectives 'model (where the focus is on the learner).

Despite the rapid progress towards realising the 'made to order' learning vision with adaptive technology, key elements are still being ignored or overlooked and should be addressed. First and foremost, one missing element concerns how learners process, build and store knowledge, while a second key element is the lack of instructional issues oriented on learners' needs and abilities. Recognising, accommodating and measuring individual learning differences from a whole-person perspective still remains a challenge.

Thus far, developments have been driving towards technological achievements rather than an investigation of the core learner-centric issues. This perspective lacks the real evidence that would allow us to tap into individual differences in key cognitive and creative factors that could accelerate learning. As an end point, existing studies employ questionnaires regarding Personalised Learning Environments (PLE) systems to identify users' learning styles. The results obtained from these questionnaire sessions are then applied manually to systems to adapt the learning content to suit the individual user needs. However, the results obtained are inconclusive or even contradictory since most online instructional courses are instruction-oriented rather than learner-oriented. One reason might be that the most common measure that has been used to assess learning cognitive abilities has included self-reporting methods (e.g. questionnaires) rather than a combination of self-reporting, eye-related and brain-related measures. The combination and mutual analysis of these psychometric, biometric and neurometric indicators is an implied gap and can clearly be considered more objective when compared to the self-reporting methods (O'Brien, Gwizdka, Lopatovska, & Mostafa, 2015). Consequently, present studies should attempt to move away from heavy reliance on questionnaires in order to make realistic progress in this area (Slater, 2004).

The multidisciplinary research experimentations on smart learning environments of the European Commission [(Horizon 2020 – ICT, EC/8631/2013)] builds on advances on neuroscience, pedagogical and learning theories, educational psychology, artificial intelligence. Henceforth, these advances focus on adaptive learning technologies for the personalisation of learning experiences, adaptive interfaces, including Brain Computer Interfaces accommodating personalisation to respond to an individual's needs.

As Antonenko, van Gog and Fred Paas (2014) suggested, real, interdisciplinary research including neuroscience, psychology and education domains can conduct experimental research and produce innovative designs that will allow researchers to update and develop new instructional theories and principles. Nevertheless, a downside of PLE as a term causes a certain amount of confusion, since several plans focused on the instruction and not on the learner (Bray & McClaskey, 2012). Additionally, many online instructional courses lack adequate support for differences in individual learning habits how people learn differently, and as a result they end up being more informational than instructional.

Adaptive systems, however, adjust the learning process by offering each learner specific learning materials based on their learning needs, oriented to how the learner processes and receives the information. An essential component of future adaptive learning strategies should allow for the brain’s incredible ability to unleash the potential of each and every student to achieve their fullest potential. Brain-based insights can provide design guidelines for supportive learning resources, solutions and environments that adapt to how people learn best. This suggests the need to further understand how the brain works, since education is becoming more and more personalised (Martinez, 2013).

Nowadays, personalised learning is still subject to new rules. Instructional designers, researchers, developers and educators should create a learning ecology with the learner at its centre. Therefore, the aim of adaptive and personalised systems should support the cognitive and creative processes, for the benefit of every individual learner, through the use of new technologies. This can be achieved by empirically examining a user's cognitive workload and creative process through a triangulation of methods using subjective and objective measurements. The next section explores the scope of the study.

1.3. Thesis purpose

In light of the aforementioned gaps in the literature, there is an imminent need to understand how users of different cognitive abilities interact and manifest their abilities during visual tasks. Hence, the way users of diverse cognitive abilities perceive visual information constitutes basic knowledge for modelling Human-Computer Interactions. Complex cognitive processes function in the way people perceive visual information, and various neural pathways are involved. Considering the complex functionality of the neural system, this thesis aims to empirically study individual differences in the FD-I cognitive ability of normal population in terms of psychophysiological and neurophysiological features as classified through the conventional psychometric method HFT. This complementary psychometric test requests participants to dissemble figures; a similar process followed by a person when dissembling an ambiguous image which requires recognition of the hidden meanings embedded in the figure.

While previous studies relied on subjective ratings (e.g. questionnaires) for measuring learners' cognitive style, this study assesses users' cognitive ability using subjective and objective methods by the innovative combination of psychometric, biometric (eye-tracking - ET) and neurometric (electroencephalography - EEG) techniques. A visual environment is developed, based on the current literature and relevant theories, to investigate users' experience and interaction. The proposed method builds upon the triangulation of psychometric (Hidden Figures Test), biometric (eye-tracking) and neurometric devices (EEG) for the measurement of different physiological and neurophysiological data. Consequently, identifying individuals' differences and abilities based on the way they perceive and utilise information will ultimately facilitate and accelerate their learning, based on tailored instructional activities. Henceforward, analysing cognitive ability during the development of a system is the first step for personalised tuition to support improved learning outcomes at an individual level. The subsequent section addresses the aim and objectives of this research.

1.4. Aim and Objectives

The generic research aim of the thesis is to conduct interdisciplinary, empirical investigations within a normal population to assess individual differences in the FD-I cognitive ability in terms of psychophysiological and neurophysiological features during visual search task performance. The following research objectives have been set to answer the main aim of the thesis which is conceptualised into testable research questions in the experimental chapters of this thesis.

1. Investigate the potential of the biometric and neurometric methods (eye-tracking and EEG respectively) as objective methods of assessing Field Dependence-Independence cognitive ability (either independently or complementary).

2. Identify individual differences in Field-Dependence/ Independence cognitive ability with respect to physiological and neuropsychological features such as eye movements (eye-tracker) and the neural underpinnings of brain activation (EEG).

3. Introduce new, complementary attributes/aspects in the Field-Dependence/ Independence cognitive ability in terms of eye movements, creativity and brain regions.

4. Construct a new approach (tool) of assessing users' (a) FD-I cognitive styles and (b) creativity through ambiguous figures.

5. Propose user-centred design principles based on the corresponding set of physiological and neurophysiological differences in FD-I cognitive ability.

The subsequent sections sketch the methodology, definitions of key terms and outline of the Ph.D. thesis.

1.5. Methodology

The thesis will use a triangular technique which is defined as "the use of two or more methods of data collection in the study of some aspect of human behaviour" (Cohen, Manion & Morrison, 2009, p. 141). This innovative setting will track and grasp the user's behaviour in real time by investigating gaze activity and human brain (both individually and combined) during visual search tasks. This information will provide a deep understanding of the complexity and individuality of the Field-Dependence Independence cognitive processing by following a multi-method approach. This multi-metric method approach will employ two valid and reliable behavioural psychometric methods; the Hidden Figures Test (HFT), and Torrance Test of Creative Thinking (TTCT) with biometric and neurometric techniques, namely eye-tracking (ET) and electroencephalography (EEG) under a novel experimental research context that has never been applied before (see **Figure 1.1**)

Eye-tracking offers the advantage of investigating how visual scenes are explored most naturally by humans (i.e. through saccadic eye movements), and offers information on cognitive activity and the visual process itself. EEG, on the other hand, is one of the most famous neuro-physiological and non-invasive techniques used to study neurocognitive processes by directly measuring neural (electrical) activity inside the brain or close to the surface of the scalp (Andreassi, 2007; Cohen, 2011; Cohen, 2014). While performing the visual tasks, users' eye-movements will be unobtrusively measured with the aid of the eye-tracking biometric technique. Experiments have always played an important role in Human-Computer Interaction (Purchase, 2012).

Eye-tracking technology can be used to drive real-time Electroencephalography (EEG) recordings. EEG has recently started to become a popular research tool in educational research to collect and analyse cognitive load data for the purpose of testing the usability of learning materials and refining their design (Antonenko, Paas, Grabner & Van Gog, 2010).

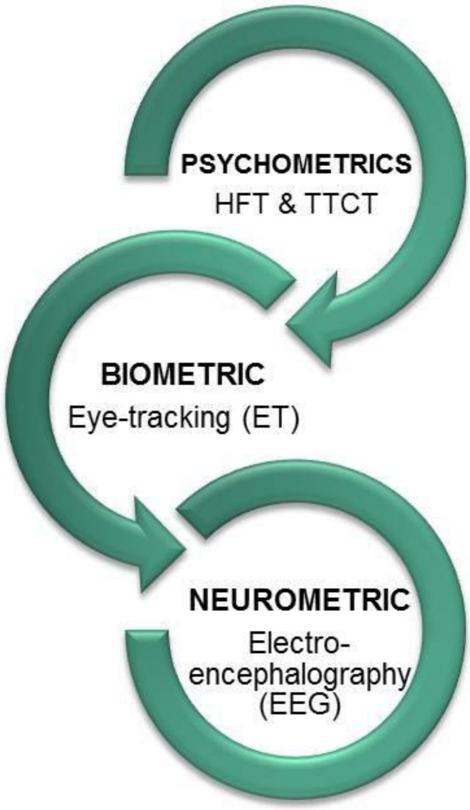


Figure 1.1 Multi-metric method approach used in the thesis which combined psychometric, biometric and neurometric methods.

1.6. Definition of key concepts

The following terms will be used throughout the project and are presented in alphabetical order:

Ambiguous images (or reversible/ bistable/ perceptual figures): Sometimes known as optical illusion images which exploit graphical similarities and other properties of visual system interpretation between two or more distinct image forms.

Cognitive abilities: the capacity to perform higher mental processes of reasoning, remembering, understanding, and problem solving (e.g. attention, perception, memory).

Eye movements (EM): Integral and essential part of our visual perception. Cognitive processing demands are reflected by over ten types of eye movements, such as fixations and saccades (see also *Fixations* and *Saccades*).

Field Dependence: FD learners are influenced by the context of a field. They cannot identify the separate parts of a whole.

Field Independence: FI learners break a field into parts. They see the separate parts of a whole.

Field Neutral or Mixed: Those who fall between FD and FI. They sometimes behave as FD and sometimes as FI according to the learning situation.

Fixations: points at which the eyes are static and focused on a visual stimulus (see also *Eye Movements*).

Saccades: points at which the eyes are moving between visual stimuli (see also *Eye Movements*).

Visual Creativity: The ability to generate useful and new ideas or solutions to a visible problem such as images, and the mental procedure that permits people to think of new and useful ideas.

1.7. Thesis outline

The overall outline as well as the organisational pattern of this thesis is discussed in this section. The work consists of eight chapters, of which five involve the experimental part of the dissertation (see **Figure 1.3**). The research part reported in this thesis is distributed in five studies (as illustrated in **Figure 1.2**) and falls under the auspices of Chapters 3, 4, 5, 6 and 7. Each study contributes and leads to the development of the next study. Study 1 examines individuals' level of Field Dependency on the performance on the Hidden Figures Test (HFT). It also compares the scores with the eye-tracking derived data in order to reveal the potential of eye-tracking as an alternative method of measuring individuals' FD-I cognitive style. Subsequently, Study 2 investigates the association between Field Dependence-Independence cognitive style and eye movements with the use of the eye-tracking technique. In Study 3 a correlation between users' level of creativity as measured by the TTCT-Part I Figural and the FD-I movements is presented. Creativity is introduced here as an added concept. Therefore, instead of examining eye gaze and creativity in a substitute experiment, their separate pair association and correlation will be examined through Study 4. Study 4 examines the link between the FD-I cognitive style, eye movements and creativity with the use of the two psychometric tests (HFT and TTCT) with the aid of the biometric eye-tracking technique. The final study combines the psychometric (HFT and TTCT), biometric (eye-tracking) and neurometric (EEG) measures to examine the association between FD-I cognitive type, Creativity, Eye Movement and Brain regions activation.

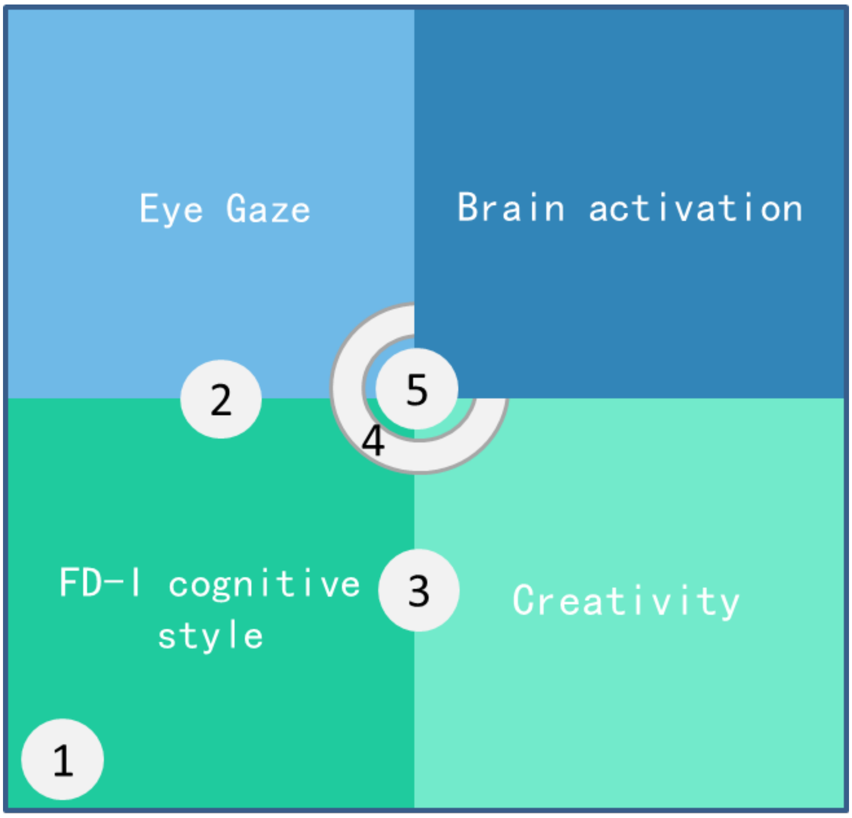


Figure 1.2 Illustration of the five studies reported in the thesis.

Lastly, the outline of the thesis is organised as follows:

Chapter One is the introductory chapter which describes the general overview and briefly considers the theoretical background to the study. It then confers the problem of the research, noting the purpose, and emphasises the aim and the research objectives that underpin the current thesis. Brief definitions of the main key concepts, methodology, and major contributions of the study are sketched out. The outline and content of the thesis is also stated therein.

Chapter Two presents a comprehensive discussion of the theoretical roots of the main key terms which emerged from a detailed summative review of the literature focusing on the interdisciplinary areas of the thesis: HCI, Educational Neuroscience, Cognitive Psychology and Technology. The literature review, theories and explanations that conceptualise the specific concepts that frame the study are presented in this chapter. Specifically, the typologies of Field Dependence-Independence cognitive ability is introduced, followed by a brief presentation on creativity, eye movements, brain activation areas and the processing of visual stimuli such as the ambiguous figures. Finally, the link between the key terms is illustrated and thoroughly explained.

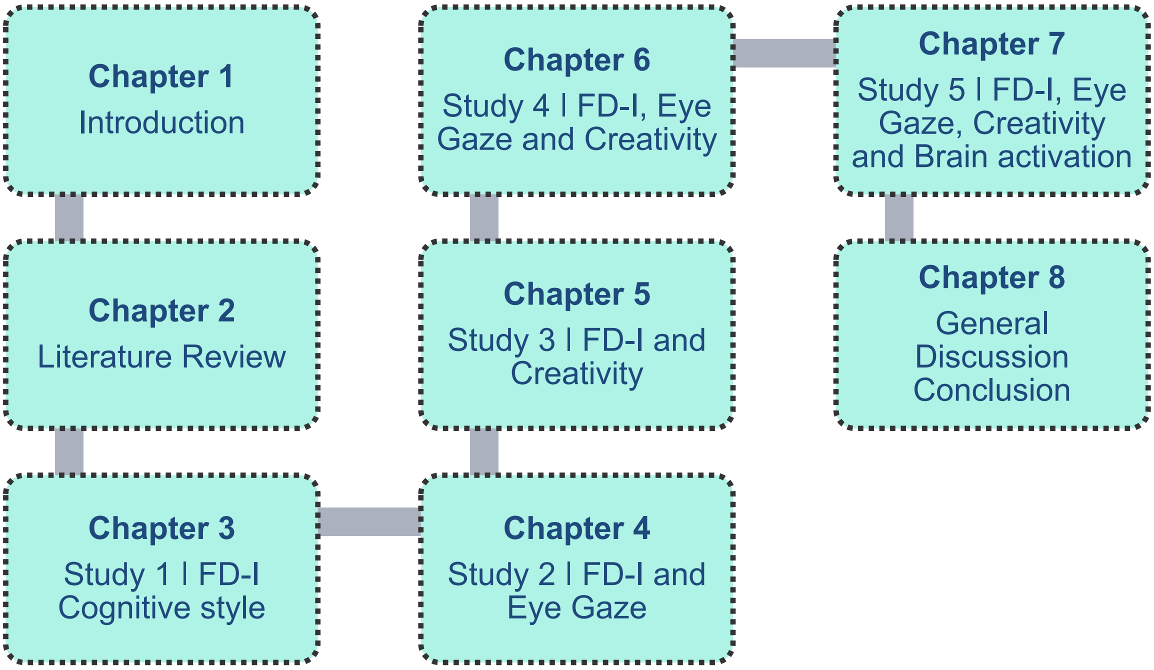


Figure 1.3 Flowchart of the Ph.D. thesis Chapters.

Chapter Three explores how Field Dependence-Independence can be assessed and measured during users' interaction within a complex visual scene. It states the research design and the methods that have been followed to address the research questions of Study 1. These are presented along with the population of the study, analysis and presentation of the data, discussion of the findings and summary. The results of this study have been published in the *Proceedings of the ICEM conference* (see Nisiforou & Laghos, 2012), in the *Proceedings of the EC-TEL conference* (see Nisiforou, 2013), and in the *Educational Media International Journal* (see Nisiforou & Laghos, 2013).

Chapter Four presents the user-experience (UX) study conducted to examine the association between the FD-I cognitive style and eye movements with the use of the eye-tracking technique and the Hidden Figures Test (HFT) psychometric method. The methods, along with the findings, discussion and summary, accompany this chapter. Findings of this study have been published in *Interacting with Computers Journal* (see Nisiforou & Laghos, 2015). Creativity was then added as a concept and instead of having Eye Gaze and Creativity experiment their separate pair association and correlation was examined through study 4.

Chapter Five discusses the results of the study which examined the link between FD-I cognitive style and creativity with the aid of the eye-tracking technique and the two psychometric tests: the Hidden Figures Test and the Torrance Test of Creative Thinking (TTCT). The research design and the methods employed are presented alongside the results, discussion and summary. Results of this study have been submitted for publication in a peer - reviewed Journal.

Chapter Six describes an eye-tracking study designed to examine the relationship between FD-I cognitive style, eye movements and creativity. The methods employed are the same as in the previous chapter. As a final point, the findings, discussion and summary sections are provided. Findings of this study have been published in *Proceedings of the ACM Creativity & Cognition conference* (see Nisiforou, 2015).

Chapter Seven presents the final study of the thesis and describes an experimental design which involves the use of different measurement techniques. The novel approach combines psychometric, biometric and neurometric methods with the synchronisation of the eye-tracker and electroencephalography techniques (EEG). This study is complementary to behavioural methods, as it enables researchers to pinpoint the physiological and neurophysiological differences of individuals while performing cognitive and creative processing tasks. Results of this study have been submitted for publication in a peer - reviewed Journal.

Chapter eight draws upon a summary of the main findings, implications of the study and contribution of the current thesis. Ideas for future directions are also outlined. To consolidate the answer of the research aims and objectives, this chapter synthesises the overall findings, which follows the research implications for researchers and practitioners. Detailed contributions to the theory and the body of knowledge are also discussed. As directed by the present research findings and background, several future directions of research are suggested. Finally, the limitations of this research are discussed.

2. CHAPTER TWO

LITERATURE REVIEW

Chapter Two presents a comprehensive discussion of the theoretical roots of the key terms which emerged from a detailed narrative review of the literature focusing on the interdisciplinary areas of the thesis: Human-Computer Interaction (HCI), Education, Neuroscience and Psychology. The literature review and theories conceptualising the specific concepts that frame the study are presented in this chapter. Specifically, the basic definitions and terminologies, recent advances in the fields and finally the typologies of Field Dependence-Independence cognitive ability are introduced. These are followed by a presentation on creativity, ambiguous figures, biometric and neurometric methods such as eye-tracking and electroencephalography, and the psychophysiological data - namely eye movements and brain activation areas. Finally, the link between the key terms is illustrated and thoroughly explained.

2.1 Cognitive abilities and learning styles

The field of individual differences in cognitive and learning style is complex and has received criticism for contested and overlapping definitions, lack of validity, clarity, stability, insufficient measurement and lack of experimental control (Peterson, Rayner & Armstrong, 2009). Denig (2004) states that learning styles describe the way in which students approach, acquire, internalizes, organize and remember new materials, which can be measured using learning styles inventories. Generally, learning styles refer to the way people learn while cognitive styles declare the way individuals think and process information (Graf, 2007).

Decades of research on both perceptual and problem solving tasks indicate that individuals differ in the way they perceive, gather and process information (Hao, Wang, Yang, Wei, Qiu & Zhang, 2013). Field dependence – independence (FD-I) ability/style has been subject of much research for over 30 years and it is relatively a well-established construct for identifying individuals' visuospatial processing ability or perceptual (Üstünel, Uçar, Civelek & Umut, 2015). The FD-I cognitive styles designated by Witkin, Moore, Goodenough and Cox (1977), are associated with individuals' perception and are identified at the visual perception style of processing (Tinajero & Paramo, 1997, Taylor, 2012). Perceptual style refers to the particular approach people perceive environmental stimuli, and is considered by the differentiation according to local and global processing (Witkin & Goodenough, 1981; Puig, Puigcerver, Aznar-Casanova & Supèr, 2013). The FD-I construct refers to several phenomena, one of which is that some people find it much easier than other to identify parts of a figure as being separate from a whole (Galotti, 2013). Hao et al (2013) found that the FD-I cognitive styles are related to visuospatial processing mostly by important structural and functional alterations in posterior visual-spatial and medial frontal regions.

The current study focuses on learners' online visual behaviour, therefore the FD-I visuospatial cognitive ability has been selected as the most appropriate construct for identifying individuals visuospatial behaviour as measured by the Hidden Figures Test (HFT).

2.2 Cognition and Field Dependence-Independence cognitive ability

"Cognition represents the software of the human brain. It represents the programmes, or in cognitive terms, the concepts, scripts, structures, and processes of thinking. Using this metaphor, individual differences can be taken as indicating that different persons have different programmes available to them" (Runco, 2014, p. 19). Additionally, cognition refers to the ability of the human mind to acquire and manage information (Spanoudis & Kyza, 2009) and comprises various mental processes such as attention, memory, perception, problem-solving and learning (Solso, MacLin, & MacLin, 2005). Individuals may choose to approach the same task in a variety of ways, depending on distinctions in abilities and style (Galotti, 2013). Cognitive style describes the characteristic way of functioning shown by individuals in their perceptual and thinking behaviour during the decision-making process (Graf & Liu, 2008). Since the perception of complexity is correlated with the variety in the visual stimulus a visual pattern may also look complex if its parts are difficult to identify and separate from each other (DaSilva, Courboulay, & Estraillier, 2011).

Field Dependence-Independence (FD-I) is among the most broadly studied of the variety of cognitive abilities or style dimensions appearing in the literature and especially in the educational technology domain (Dragon, 2009). Field Dependence-Independence cognitive dimension was designated by Witkin and Acsh (1948a, 1948b) in the laboratory of research regarding perception (Tinajero & Paramo, 1998). Witkin indicated that "perception may be considered articulated, in contrast to global, if the person is able to perceive items as discrete from their background when the field is structured (analysis,) and to impose structure on a field and so perceive it as organised, when the field has relatively little inherent structure (structuring)" (Witkin, 1969, pp. 688-689). The term refers to several phenomena, one of which is that some people find it much easier than others to identify parts of a figure as being separate from a whole (Galotti, 2013). Individuals are classified as Field Dependent (FD), Field Independent (FI), and Field Mixed (FM) or Field Neutral. As stated in Witkin, Moore, Goodenough and Cox (1977) the Field Dependents and Field Independents can respond to the different kinds of learning and teaching methods, and can describe different ways of processing information. Individuals who are located towards the FD style face difficulties in distinguishing incoming information from its contextual surroundings. This group of people are more likely to be influenced by external cues, thus process visual information more globally and are non-selective in their data uptake (Clark & Roof, 1988; Marendaz, 1985; Guisande, Páramo, Tinajero, & Almeida, 2007; Tinajero, Catelo, Guisande & Paramo, 2011; Taylor, 2012). On the other hand, Field Independents are more likely to be determined by internal than external cues, and are able to analyse the information and restructure it according to their needs (Guisande et al., 2007; Riding & Cheema, 1991; Tinajero et al., 2011; Zhang, 2004; Witkin, Dyk, Faterson, Goodenough, & Karp, 1963). Therefore, they are selective in their information input and global in their behaviour (Zhang, 2004; Guisande et al., 2007). Finally, those who sometimes behave as FD and sometimes as FI depending on the learning situation are known as Field Neutral or Field Mixed. The key difference between the three cognitive groups of learners relies on visual perceptiveness (Graf & Liu, 2008).

Further, FD people can explain individual performance differences on a broad variety of visual perception tasks, and capture the relative influence of whole visual fields (Witkin, 1950). Mainly, they can separate a part from the complex whole in which that part was embedded. Field Dependents also experience greater difficulty in focusing on and processing objects embedded in a context (Orth & Crouch, 2014). People who are more Field Dependent face difficulties in perceiving a part separately from the complex whole in which was embedded (Goodenough, 1987).

Field Dependent captures the degree to which perception is affected by the dominant structure of a visual field (Witkin, 1950). As a consequence, they find it more difficult to distinguish between relevant and irrelevant information and thereferoe, connect/ apply novel information with prior knowledge (Arthur & Day, 1991). In contrast, FI learners are capable of retrieving items from memory and appear to have greater cognitive disembedding skills, thus encountering fewer problems in discriminating relevant from irrelevant information (Goodenough, 1987). Conversely, people who are more Field Independent have better disembedding skills and meet fewer problems when discriminating relevant from irrelevant information.

The concept of Field Dependence/ Independence was developed by Witkin (1950), and it is used to classify individuals as Field Dependent or Field Independent. It is concerned with the strategy used to separate parts of aspects from the whole in which they occur. The approach a person employs when faced with a complex task depends on the characteristics of the individual (Aykin & Aykin, 1991).

Moreover, other studies have indicated that some personality features such as social, interpersonal and humanities appear as part of FD-I cognitive ability characteristics (Saracho, 2003). Scientists have stated that subjects who were either left-handed or ambidextrous were more Field Dependent than right-handed subjects (Musser, 1998; Pizzamiglio, 1974; Silverman, Adevai, & McGough; 1966).

Psychometric assessments such as the Hidden Figures Test (HFT), Body Adjustment Test, Rod and Frame Test and the Embedded Figures Test (EFT), have been designed to measure cognitive styles and specifically the Field Dependent-independent (Riding & Cheema, 1991; Arthour, Doverspike & Bell, 2004). Nebelkopf and Dreyer (1970) investigated the relationship between analysis and structuring as stylistic modes of perceptual functioning by using the Children's Embedded Figure Test (CEFT) and Ambiguous Picture Test (APT). The results indicated a strong relationship between the two tests which means that the perceptual structuring is an additional attribute of the Field Dependent-Independent (FD-I) dimension of perceptual or visuospatial style. Subsequent to the concerns of this research work and due to the complex and unclear yet Field Dependence-Independence concept, the terms "cognitive dimension", "cognitive style", "cognitive type", "cognitive ability", "visuospatial processing style" and "perceptual ability" are used interchangeably and are treated as synonyms.

Other studies found that some personality features such as social and interpersonal appear as part of FD-I dimensions characteristics (Saracho, 2003). Field Dependent students are better achievers in humanities' science, are receptive to criticism, have a holistic approach to learning, and are more influenced by their environment. Conversely, Field Independent students are more successful in basic sciences (Ahmadzade & Shojae, 2011). Previous studies have mentioned that Field Dependent learners respond better as part of a group since they are directed by others and need more structured work from their teachers. Furthermore, they require more guidance in problem-solving tasks. On the other hand, Field Independent people prefer to learn more individually and have an inner direction, as they want to discover their own learning capabilities and learning approaches (Ridings & Chema, 1991). Thus, those who are Field Dependent appear to be more extroverted and able to access social information as they can handle their interpersonal skills better, whereas Field Independent learners are introverted and known as being socially isolated, but display good analytical skills by extracting detail from its surrounding context (Witkin et al., 1977; Riding & Chema, 1991; Saracho, 2003). Besides, they show greater disembedding ability in perceptual functioning and better cognitive restructuring (Zhang, 2004; Guisande, Páramo, Tinajero, & Almeida, 2007; Vacas et al., 2011). Moreover, FI young learners, aged between 13 and 16, performed better than their FD classmates in all of the subjects on the school curriculum (Tinajero & Paramo, 1997). A study by Nisiforou and Laghos (2013) showed that the groups of Field Dependent, Field Neutral and Field Independent participants differ in terms of task-time completion. More precisely, FI individuals were significantly faster in time completion during a visual problem solving task than the FD learners, whereas FN individuals outperformed those who were Field Dependent. Furthermore, previous research indicated that FIs are more creative than FDs (Hecht & Reiner 2007; Rastogi, 1987; Noppe, 1985). The link between Field Dependence-Independence and Creativity still remains vague and requires further investigation.

Nevertheless, it is worth mentioning that the differences between the two dimensions do not imply one is better than the other. On the contrary, these differences are inherent to the way each unique brain processes and perceives information. Students possessing one of these styles-abilities carry their own weaknesses and strengths (Ahmadzade & Shojae, 2011).

2.3 Creativity

Creativity has been defined in different ways and exploited in a number of viewpoints. In simple terms creativity is the production of effective novelty that can be seen as the springboard for innovation (Cropley, Cropley, Kaufman & Runco, 2010). Creativity therefore reflects the capacity to solve problems in novel ways, and to produce works which are appropriate and socially valued (Razumnikova, 2007). Novelty and usefulness are often referred to as the standard definition of creativity, which was first introduced by Stein (1953). According to Runco and Jaeger (2012), creativity is the "novel work that is acceptable as tenable or useful or satisfying by a group".

Henceforth, creativity is defined in two ways. Firstly, creativity refers to the production of useful and new ideas or solutions (Amabile, 1983a, b; Amabile, Conti, Coon, Lazenby & Herron, 1996; Burleson & Selker, 2002; Gaspersz, 2005; Sternberg, 1988; Woodman, Sawyer & Griffin, 1993). Secondly, it describes the mental procedure that permits people to think of new and useful ideas (Gaspersz, 2005; Mayer, 1999; Klijn & Tomic, 2010). Withal, creativity is the process of incorporating seemingly unrelated and irrelevant information to solve problems (Runco, 2004). However, researchers have failed to decide on a definition though there have been numerous studies absorbed on creativity (Davis, 2004; Plucker, Beghetto, & Dow, 2004; Fugate, Zentall & Gentry, 2013).

Creativity involves the capacity to spontaneously shift back and forth between analytic and associative modes of thought according to the situation (Gabora, 2010). These types of thought demonstrate individual differences on how visual information is perceived. Henceforth, focusing on specific patterns activates memory that supports divergent or convergent thinking (Gabora, 2000). Guildford argued that creativity can be considered as the district ion between convergent and divergent modes of thinking (Guildford, 1950). In addition, creative thinking is often thought to involve divergent thinking (Guilford, 1959); that is being able to consider a solution in lots of different ways rather than converging on a single answer (Medin, Ross, & Markman, 2001). More precisely, divergent thinking is the capacity to access memory to derive multiple, unique answers to open-ended questions, and thus refers to intuitive and associative thought, and thinking that necessitates flexibility. In contrast, convergent thinking is related to IQ tests, which means that it refers to the capacity to come up with one right answer for each question (Malhora, Bana & Malhora, 2013).

One of the broadest psychometric instruments used to measure creativity is the Torrance Test of Creative Thinking (TTCT), developed by Torrance in 1966. The Scholastic Testing Service, Inc., holds the copyright of the TTCT. It is composed of verbal and figural subtests and it is the most well-known and widely used tool for measuring creativity (Baer, 1993; Kim, 2006; Jo, Lee & Lee, 2014). Based on widespread analyses the TTCT forecasts creative attainment better than any other divergent-thinking tests or creativity measurement, thus it can be determined as the best creativity test which is currently available (Razumnikova, 2013).

Earlier work has demonstrated the impact of different cognitive styles on idea generation and creativity (Miron, Erez & Naveh, 2004). Field Dependence-Independence consists of one of these cognitive perceptual phenomena that has been related to creativity (Goodenough, 1976). As was formerly stated, the FD-I refers to an individual's ability to extract relevant information from a complex visual scene. In particular, previous research associated creativity with the degree of field dependency and found that FI people are more creative than FD individuals (Hecht & Reiner 2007; Rastogi, 1987; Noppe, 1985). Henceforth, creative people could be considered Field Independent, in that they can extract useful information from a complex visual background without being distracted or overwhelmed by extraneous and irrelevant external cues, as Field Dependents would be. Hence, FI individuals could do well on tasks that examine the ease or difficulty of finding a simple figure embedded within a distracting complex pattern such as those involved in the Hidden Figures Test (Witkin et al., 1963). The activity involved in this psychometric test has been described above and it is recognised as perceptual disembedding. Participants are requested to apply their disembedding capabilities or their visuospatial abilities (i.e. seeing embedded shapes) on the complex figures; a similar process followed when dissembling an ambiguous image which requires recognition of the hidden meanings embedded in the figure.

Using perceptual disembedding tests some studies have treated FD-I as a continuous variable, while others have specified cut-off scores for two (Field Dependent and Field Independent) or occasionally three levels of FD-I. Those investigations utilising three levels of the FD-I cognitive dimension include a middle 'Field Neutral' or 'Field Mixed' level (Graf, 2000).

Along the same lines, Martinsen and Kaufmann (1999) examined the link between FD-I cognitive ability and creativity and claimed that Field Dependent individuals are less creative than Field Independents. Previous studies have suggested that the use of ambiguous stimuli may in some way be associated with degrees of creativity (Urban, 2003; Wiseman, Watt, Gilhooly, & Georgiou, 2011; Dove & Jones, 2014; Nisiforou, 2015). These lines of indications suggest that the more individuals can tolerate ambiguous objects, the more creative they become. Hitherto, the notion that Field Independent people are more creative than Field Dependents remains vague.

2.4 Ambiguous figures

When viewing an image there is only one percept to observe (stable perception) (Intaite, Noreika, Šoliunas & Falter, 2013). Their physical properties remain unchanged; however multiple interpretations can be perceived (Wimmer & Doherty, 2011). Ambiguous figures are recognised as reversible figures, multistable stimuli, bistable images, or perceptual figures and constitute visual stimuli that can elicit more than one possible interpretation (meaning or configuration). More precisely, bistable stimulus is when an ambiguous stimulus causes exactly two percepts (objects of perception processes) to alternative in awareness and thus the observer's perception will alternate virtually exclusively between only two interpretations. These kind of images have been of historical importance for theories of visual perception and continue to be an extensively used research tool for studies in the psychological field, but rarely in conjunction with the field of HCI and Education for the design of PLE environments. Nowadays, with the development of new technologies these images form an important research tool that provides empirical support for theories on visual perception and remain widely in use, finding new roles as research methods in novel technologies such as brain imaging (Wimmer & Doherty, 2011).

Moreover, it has been frequently stated that creative ideas seem to happen unexpectedly, after a period of stalemate (Metcalfe & Weibe, 1987; Ohlsson, 1992) and that the phenomenology of having a creative idea is related to that of suddenly seeing an ambiguous picture in a novel way (Schooler & Melcher, 1995; Wiseman, et al., 2011). Furthermore, disambiguation is the ability to interpret ambiguous information in a sensible way, and it is considered one of the fundamental components of the creativity process (Ishizu, 2013). Disambiguation processing is also known as perceptual bistability, perceptual ambiguity, perceptual reversal, and ambiguous reversal - terminologies which are treated as synonyms for the requirements of this thesis.

2.4.1 Perception and ambiguous perceptual phenomena

Perception is an active process in which different levels of analysis interact to define what we perceive and understand (Medin et al., 2001). Visual perception is the ability to interpret information from visible light, and the outcome is known as vision. The visual system is part of the nervous system which allows organisms to see. The best studied visual area in the brain is the primary visual cortex, which is located in the posterior pole of the occipital cortex (Wu, 2011). Visual perception encompasses complex cognitive processes involved in other forms of conceptualisation and learning (Workman, 2004).

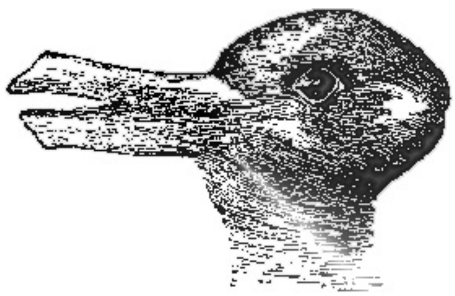
During the last decade many scientists have studied the phenomena of multistable or bistable visual perception, using the electroencephalography (EEG) biometric method (e.g. Mathes, Pomper, Wallla & Eroglou, 2010; Ehm, Bach & Kornmeier, 2011). Multistable visual awareness states two phenomena, in which one invariant stimulus form is apparent in at least two different, reciprocally exclusive ways. Viewers consciously perceive spontaneous alternations between the two images. Multistability is represented by classical ambiguous figures such as the well-known Necker cube, Rubin's vase/faces or Jastrow's duck/rabbit figure. Multistable stimuli offer the opportunity to examine visual perception, since they induce spontaneous alternations between different perceptual explanations of the same stimulus (Strüber & Herrmann, 2002). Researchers have defined two dissimilar aspects of how our awareness attends to items present in the environment. Selective attention includes interacting neural processes including top-down and bottom-up mechanisms (Mast & Jäncke, 2007). The perception of the ambiguous figures seems to be affected by top-down and bottom-up processes independently (Intaitė, Noreika, Soliunas, & Falter, 2013).

Recent studies have used ambiguous stimuli as a measure of complex visual processing (Mitroff, Sobel & Gopnik, 2006). Bottom-up and top-down processes refer to whether processing is driven by lower order or higher order information (Long & Toppino, 2004). Ambiguous pictorial figures offer valuable insights into these two types of processes (Rock & Mitchener, 1992; Wimmer & Doherty, 2011). Reciprocally, these processes are involved in figural perceptual switching (Long, Toppino, & Kostenbauder, 1983; Leopold & Logothetis, 1999; Long & Toppino, 2004; Wimmer & Doherty, 2011; Kornmeier & Bach, 2012) and can affect perception concurrently (Intaite, et al., 2013). Specifically, bottom-up is a passive perceptual (automatic) process that is controlled by incoming data and is stimulus driven. Reversing of ambiguous figures occurs automatically on seeing the figure. For top-down processes, processing is influenced by active higher-order levels of cognitive processes controlled by previous experience. In relation to ambiguous visual stimuli, the perceptual reversal phenomenon requires cognitive effort from the viewer. Moreover, individuals experience changes in their multistable perception while viewing ambiguous pictures and exhibit differences in their switching patterns (Leopolod & Logothetis, 1999). As a result, a spontaneous switching back and forth between the different visual interpretations of these images occurs. Thus, ambiguous figures provide specific insight into the interplay of bottom-up and top-down perceptual processes, leading to specific perceptual switching patterns within individuals. These switching patterns are related to other cognitive features such as creativity (Wiseman, Watt, Gilhooly & Georgiou, 2011; Doherty & Mair, 2012).

These figures, which are based on top-down knowledge, fall into three distinct categories, wherein reversal is of content, perspective, or figure and ground (Long & Toppino, 2004). These categories of ambiguous figures can be briefly described as follows:

1. *Content ambiguous figures*

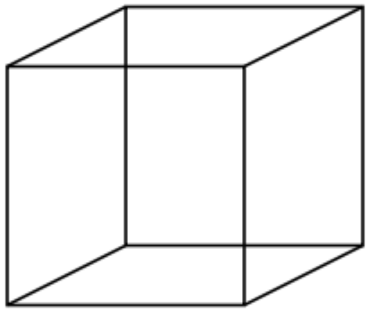
Content reversal stimuli represent images for which the reversals (interpretations of meanings) are due to the content of the image and not due to figure/ground or perspective (Wemmer, 2013). For instance:

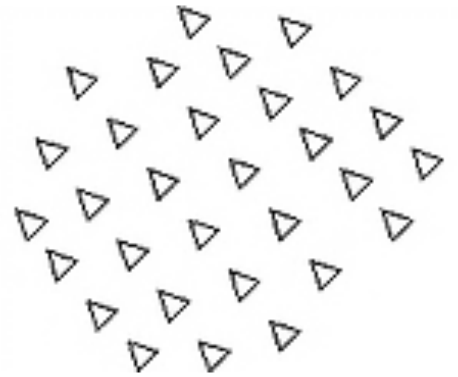


(a) wife/mother-in-law (Boring, 1930), (b) duck/rabbit (Jastrow, 1900)

2. *Perspective ambiguous figures*

Perspective reversing images are categorised by the ambiguity of a two-dimensional drawing with relation to its three-dimensional interpretation. These figures are frequently symmetric and low in semantic content (Wemmer, 2013). Examples:





(a) Necker cube (Necker, 1832), (b) ambiguous triangles (Attneave, 1968)

3. *Figure/ground ambiguous images*

Wemmer (2013) suggests that figure-ground perception is a perceptual grouping, as a result of the difference between the background and the figure. Such as:

(a) vase/faces (Rubin, 1958), (b) the Maltese cross (Köhler, 1940)

One of the categories of illusions that Gregory (1996) referred to is the illusion that is formed based on the top-down knowledge. Top-down mechanism influences perception that is how things are perceived (Medin et al., 2001).

Theories of ambiguous picture reversal can be categorised as top down or bottom up. Reversal is controlled by knowledge, prior experience, and active cognitive processes, including the intentions of the viewer (Wimmer & Doherty, 2011).

According to Rock and colleagues, there were three prerequisites for seeing the reversal of an image (Rock, Hall & Davis, 1994). First the individual had to understand the nature of the ambiguous images, second to know the particular interpretations, and third to aim to observe reversal (Girgus, Rock, & Egatz, 1977; Rock & Mitchener, 1992; Rock, Hall, & Davis, 1994 cited in Wimmer & Doherty, 2011).

2.4.2 Creativity and ambiguous figures

Further, earlier studies have proposed that the use of ambiguous stimuli may in some way be associated with degrees of creativity (Urban, 2003; Wiseman et al., 2011; Dove & Jones, 2014; Ambrose, Cohen & Tannenbaum, 2003). Additionally, tolerance of ambiguity is believed to contribute to the creative process because it enables the exploration of new, uncommon or complex stimuli (Ambrose et al., 2003). These lines of work suggest that the more individuals can tolerate ambiguous objects, the more creative they become (Nisiforou, 2015).

Ambiguous figures require learners to apply their disembedding capabilities as the HFT. Consequently, stored knowledge is used to aid the recognition of objects (Braisby & Gellatly, 2012). Two of the most significant proponents of the constructivist approach are Rock (1997) and Gregory (1980). Gregory suggested that individuals attempt to recognise objects by generating a series of perceptual hypotheses about what that object might be (Braisby & Gellatly, 2012). Rock's and Gregory's ambiguous figures provided important insights into the role that knowledge plays in perception (e.g., Gregory, 1966, 1997a,b; Rock & Mitchener, 1992). Moreover, it has frequently been stated that creative ideas seem to happen unexpectedly, after a period of stalemate (Metcalfe & Weibe, 1987; Ohlsson, 1992) and that the phenomenology of having a creative idea is related to that of suddenly seeing an ambiguous picture in a novel way (Schooler & Melcher, 1995; Wiseman et al., 2011).

Creativity has been defined as the process of incorporating seemingly unrelated information to solve problems (Runco, 2004). Incidents from a previous study found a relationship between self-reported perception of ambiguous figures and creative ability by using subjective ratings for both variables (Wiseman et al., 2011). The participants were informed that the stimulus used was an ambiguous figure and that could be seen either as a duck or a rabbit. The results demonstrated a link between creativity and ambiguous figure reversal. One year later Doherty and Mair (2012) replicated the results of Wiseman's et al. (2011) study using quantifiable measures instead of subjective measurements. The participants were naïve when presented with the ambiguous figures. In this case, three ambiguous figures were used instead of one, and participants' creativity was measured with the Wallach and Kogan's (1965) pattern meanings test. The relationship between ambiguous figures reversal, creativity and academic preference as an added variable were studied, and the results revealed that creativity and ability to reverse are indeed related. Moreover, the findings yielded significant correlations between creativity scores, frequency of reversals and time to first reversal. Specifically, the relationship between reversal frequency and creativity was significant, exemplifying that the more creative participants could reverse each stimulus more frequently than those who were less creative. Although studies have proposed the relation between creativity and ambiguous figures, this provides some impetus for further investigation since it is still unclear whether creativity allows reversal per se. Therefore, the current study will examine whether creativity indexed by the Torrance Test of Creative Thinking (TTCT) predicts the time it takes and ability to reverse per se.

Due to frequent associations between the concepts of ambiguity and creativity that this study seeks to examine, the notion of ambiguity in visual representation is of particular interest. There are several lines of work that suggest the use of ambiguous stimuli may in some way be associated with high degrees of creativity. A high tolerance of ambiguity is a feature that has been shown to be prevalent in creative people (Dove & Jones, 2014). Moreover, tolerance for ambiguity is a personality trait that refers to the way in which an individual tends to perceive, interpret and react to ambiguous situations or stimuli (Furnham & Avison, 1997; Barbot, Tan, Randi, Santa-Donato & Grigorenko, 2012). Earlier studies have proposed that creative activity requires the tolerance of ambiguity (Sternberg & Lubart, 1995; Zenasni, Besancon & Lubart, 2008; Botella et al., 2013; Rietzschel, Slijkhuis & Van Yperen, 2014). Authors have suggested that the more individuals can tolerate ambiguous objects, the more creative they become (Barron & Harrington, 1981; Sternberg & Lubart, 1995; Urban, 2003). Based on Urban's (2003) components model of creativity, tolerance of ambiguity is believed to contribute to the creative process because it enables the exploration of new, uncommon or complex stimuli (Zenasni, Besançon & Lubart, 2008). Specifically they found that adolescents' creativity was predicted by their ambiguity tolerance.

In addition, there are individual differences in how visual information is perceived (global versus local). One of the most widely-used tests to assess visuospatial tendency indicative of spatial orienting or global-local processing styles is the Hidden Figures Test (HFT) 'indexed by' Ekstrom, French, Harman and Dermen (1976, Weissman & Woldorff, 2005). It contains 32 questions divided into two parts. The test presents five simple figures and asks learners to find one of the 5 simple figures embedded in a more complex pattern. Participants are classified as Field Dependent (FD), Field Independent (FI) and Field-Mixed (FM) or Field-Neutral (FN). As focusing on specific features allows reversal (Tsal & Kolbet, 1985) the question arises as to whether those with a featural processing style are more capable of reversing per se and reversing earlier, than those with a global processing. Therefore, we compare performance on the HFT and ambiguous figure revesal.

Findings of previous studies have shown how eye movements are associated with ambiguous figures reversal. According to Boring (1930), Necker believed that eye movements played a crucial role in producing figural reversals. Past behavioural studies have found that focusing on specific segments of an image can cause changes to interpretations of ambiguous images (Ellis & Stark, 1978; Tsal & Kolbert, 1985; Peterson & Gibson, 1991). The study conducted by Ellis and Stark (1978) examined fixation durations on ambiguous figures. Their findings yielded participants longer fixation durations which were reported by a button-press. In addition, Tsal and Kolbert (1985) asked participants to decide which side of the figure favoured which interpretation (rabbit or duck interpretation) as a medium to identify the distinctive features of the two alternative interpretations of the duck/rabbit figure. Georgiades and Harris (1997) used the wife/mother-in-law ambiguous figure and found that changes in visual attention between different features (e.g. selective removal of certain features and the position of the fixation point) cause the perceptual alternations of the figure. A more recent study by Gleitman, January, Nappa and Trueswell (2007) found that shifting to specific parts of an image was associated with the perceived front area of an ambiguous figure. Salverda, Brown and Tanenhaus (2011) found that participants direct their fixations to those parts of an object that were behaviourally most relevant (e.g., the spout of a tea kettle). Their findings suggest that changes in the initial locus of visual attention, induced by shifting the initial gaze position of the subjects to different parts of the stimulus, would have a causal effect on the subsequent perceived object identity. The same year, researchers investigated how patterns of viewing behaviour precede the conscious recognition of ambiguous stimuli (Kietzman, Geuter & Konig, 2011). The findings exemplified that different percepts (and perceptual switches) are preceded by significant and percept-aligned differences in viewing behaviour. Finally, a more recent study reported that the dominance of perceptual reversal in ambiguous figures can be affected by different variables such as shifting patterns of eye movements and/or covert visual attention (Toppino, 2003; Chen & Scholl, 2014).

Mitroff, Sobel and Gopnik (2006) mentioned that different focal regions or areas within an ambiguous figure favour different interpretations of the stimulus. Fixation at different focal areas has been demonstrated to promote different perceptual interpretations with a variety of reversible figures. Evidence shows that small eye movements made during fixation are correlated with perceptual ability and that eye movements can induce perceptual alternations and may resolve perceptual ambiguity (Laubrock, Engent & Kliegi, 2008). Although bottom-up signals following small eye movements have been suggested to be responsible for perceptual alternations, this is an unresolved research problem (Kanai, Moradi, Shimojo, & Verstraten, 2005). For an initial reversal, naïve observers’ were selected as the most appropriate population to participate in the experiment (Rock et al., 1994; Oh, 2011). Moreover, the current study extends the work of Wiseman et al (2011) and Doherty and Mair (2012) by displaying 20 ambiguous stimuli instead of one (Duck/rabbit) and three (Necker cube, Vase/Figure and Dick/rabbit). In the light of the gaps in the literature, the goal of this study is to examine whether higher featural processing style and creativity may underlie reversal per se.

2.5 HCI, Cognitive Characteristics and FD-I

Human-Computer Interaction (HCI) is an important part of systems design and focuses on all aspects of the interaction between human and computer systems, together with the user interface and the processes underlying the construct of interactions. The term HCI is commonly used interchangeably with terms such as Cognitive Ergonomics, Man-Machine Interaction or Interfacing, Human-Machine Interaction and Computer and Human Interaction (Falzon, 1990). The burgeoning interdisciplinary field of HCI involves contributions from areas such as computer science, cognitive psychology, social science and ergonomics, human factors, and engineering (Booth, 2014).

The quality of a system depends on how it is represented and employed by its users. Therefore, enormous amounts of attention have been paid to better design interfaces of HCI. The new direction of research is to replace common regular methods of interaction with intelligent, adaptive, multimodal, natural methods (Karray, Alemzadeh, Saleh & Arab, 2008). Recent developments in HCI have allowed the user to interact with the computer in novel ways beyond the traditional boundaries of the keyboard and mouse. New input devices such as trackballs, joysticks, datagloves, and touch screens have become commonplace. The advances made in last decade in HCI have almost allowed for this new technology to become available, accessible and/or affordable to everyone.

Individuals' cognitive characteristics and visual complex environments have been gaining ground in recent literature. With the rapid and constant advancement of technology, a new method of presenting information that leads to visually complex online environments is constantly being introduced. Westerman (1997) stated that instructional designers should understand the interaction between user characteristics and interface styles. There are significant individual differences in computer-based performance which have more impact on the performance level than differences in system designs and training methods (Egan, 1988). Adaptation in Human-Computer Interaction (HCI) is directed at adjustment to individual differences. In their early consideration of adaptivity, Browne, Norman and Riches (1990) provided one of the first classifications of candidate dimensions of user differences that may impact computer usage, including diversities in cognitive styles (i.e., Field Dependence/ Independence, Impulsivity /Reflectivity etc.), (Nakić & Granić, 2009) and a number of other personality and cognitive characteristics. As reported in section 2.2, cognitive style describes the tendencies of the modes in which students approach, acquire, organise, process and interpret information (Miron et al., 2004) and how these interpretations are used to guide their actions (Hayes & Allinson, 1998). The cognitive style-ability of Field Dependence-Independence (FD-I) refers to several phenomena, one of which mentions that few people find it easier to identify parts of a figure as being separate from a whole (Galotti, 2013).

In line with this thinking, Van Der Veer (1989) argued that it is essential to closely match user interface with the characteristics of the user, so that the system will be able to offer users a choice of interaction formats in a way that reflects their individual behaviour. Additionally, previous studies stress the need of considering individual characteristics' interactions that take place at the user interface and adapt systems based on users' differences in cognitive style and HCI (see Jennings, Benyon, & Murray, 1991; Benyon, 1993). Moreover adaptive educational systems in the Technology Enhanced Learning (TEL) and Personalised Learning Environments (PLE) arena provide a forward-thinking form of learning setting that takes into account the needs of individual students (Kelly & Tangney, 2006). Therefore, cognitive psychological theories and methods should be further applied to HCI interaction to interpret users' individual needs and cognitive traits.

According to Dillon and Watson (1996) psychological measures of individual differences are needed to raise potentials for generalisation of HCI outcomes. Since the perception of complexity is correlated with the variety in the visual stimulus, a visual pattern may also look complex if its parts are difficult to identify and separate from each other (DaSilva, Courboulay, & Estraillier, 2011).

Much of the research on FD-I cognitive dimension has focused on examining the effects of FD-I on learners' computer performance (Hercegfi, 2011). A study by Ford, Miller, and Moss (2005) demonstrated individual cognitive style differences in web searching tasks. In addition, Józsa and Hámornik (2012) stressed the necessity for further studies to use new grouping variables such as cognitive style as a mean to identify users' information seeking behaviour. The growing number of online learning environments is instructive and calls on instructional designers to understand cognitive individual differences during navigation processing. The ability to capture process differences in learners has been cited as one of the major uses of computer-based assessment (Baker & Mayer, 1999). Additionally, it is mentioned that hypermedia evaluation needs to take into account both structure and content, thus field dependency needs to be considered since some users quickly distinguish structure from content (Paterson, Winschiers-Theophilus, Dunne, Schinzel & Underhill, 2011). Moreover, research confirms that response readiness forms a user visual characteristic component and constitutes one of the critical usability issues that can influence users' response to visual stimuli (Lim, Ryu & Kim, 2014). Based on this suggestion, a recent study argued that the amount of usability difficulties evaluators attend to varies across evaluators' Field Dependence psychological construct (Clemmensen, Hertzum, Hornb, Shi & Yammiyavar, 2009).

2.5.1 Eye-tracker technology and eye-tracking technique

Eye-tracking is the process of measuring the motion of the eye relative to the head and inferring the point of gaze – the location on the stimulus object that the subject is looking at. A detailed review of eye-tracking methods and measures is given by Holmqvist et al. (2011). The use of the eye-tracker has long been established in Psychology as a technique for analysing user attention patterns in information processing tasks, whereas in education this happens to a lesser extent (Tuch, Bargas-Avila, Opwis, & Wilhelm, 2009; Steichen, Carenini, & Conati, 2013). An eye-tracker is a biometric measuring device that allows researchers to collect objective behavioural data and analyse user attention patterns in information processing tasks (Rayner, 1995). These attention patterns of eye movement data are suggested to reveal evidence about the cognitive processes (Rayner, 1998). The eye-tracker records the movement of a person's eyes when exposed to visual stimuli. These stimuli can range from fixed images, to videos or web pages. One of the main goals of eye-tracker studies was to comprehend the human visual system as well as the visual process itself. Such measures offer information on issues such as cognitive activity (Boksem, Meijman, & Lorist, 2005).

The history of eye-tracker devices for measuring eye movement dates back to the late 80s, when they were mostly custom-built, mechanical, and uncomfortable. In recent years, eye-trackers have become commercially available, non-intrusive, adequately accurate and robust for widespread adaptation. A variety of eye-trackers are available from companies such as Tobii, SR research and SMI systems which offer non-intrusive measurement of observers gaze in a variety of situations (Hermens, Flin & Ahmed, 2013). The eye-tracker functionality relies on the use of an infrared camera directed towards the eyes of the participant, and on image processing techniques enabling the extraction of the position of the pupil with the use of a calibration procedure. The calibration calculates the location looked at by the participant by measuring the position of the retina reflection and the pupil positions of the participant of the position fixated on the screen for any eye position within a fixed range (Acunzo, 2013).

Nowadays the rapid changes in technology and the increased use of the internet have changed the way in which information about users is collected, stored, accessed and distributed. These changes require people to disclose personal information online (Shih, Hsu, Yen, & Lin, 2012) and assist the development of personalised learning environments based on individuals' needs. Eye-tracking is a technique used in a variety of fields such as vision, cognitive science, psychology, human-computer interaction, marketing research and medical research to provide useful information. Eye-tracking is mostly used in the applications for visual search (Greene & Rayner, 2001), marketing/advertising (Rayner, Rotello, Stewart, Keir & Duffy, 2001), neuroscience (Snodderly, Kagan & Gur, 2001), Psychology (Rayner, 1998) and Human Computer Interaction (HCI) (Goldberg, Stimson, Lewnstein, Scott & Wichansky, 2002); Jacob, 1990). The eye-tracking technique is the measurement of eye movement/activity and gaze and has been typically approved to examine human visual attention based on the eye-mind assumption (Just & Carpenter, 1980). Eye-tracking and usability evaluation studies try to investigate and understand user behaviour with an increasing interest in web page behaviour and visual images interaction (Jacob, 1995; Rayner, 1998). Research in this field has also examined the impact of individual user differences on reading and search tasks (Witkin et al., 1977). Specific areas include web usability, advertising, reading studies and evaluation of image quality, and all could be include in the initiatory question as to how we look at an image (Babcock, Pelz, & Fairchild, 2003;

Cowen, Ball, & Delin, 2002; Gintautas, & Ramanauskas, 2004; Goldberg et al., 2002; Hyönä, Radach & Deubel, 2003; Ninassi, 2006; Zhu, Fujimura, & Ji, 2002).

The use of eye-tracking as a method of measuring users' cognitive dimension during visual processing provides a twofold benefit. Firstly it provides insight on how cognitive type affects user perception and ability to interact on different learning stimuli, and secondly it gives information on how this can become valuable in finding ways to improve subjects' online experience. It therefore demonstrates the significance in designing interfaces that reflect user's cognitive type.

The eye-tracking-derived data is analysed using data mining techniques, such as scan path clustering, gaze plots (scan path) and attention maps (heat maps) (Goldberg & Helfman, 2014). This method captures the fundamental eye-tracking metrics such as the saccadic and fixaton eye gaze movements. These features can be analysed to give a viewer's attention patterns and are built by calculating statistics upon namely the number of fixations and saccades. (i.e. keeping gaze on one area on the screen) and saccades (i.e. quick movement of gaze from one fixation point to another) (Toker, Conati, Steichen & Carenini, 2013)

Eye-tracking has become practical for the research of visual user interfaces, with Yammoto and Kuto (1992; Grier, Kortum, & Miller, 2007; Zaphiris, & Kurniawan, 2007) performing some of the first experiments in this field. Eye-tracking measures also aid the enhancement of usability, as they can give information on issues such as cognitive activity (Boksem et al., 2005). Numerous measures from eye-tracking data have been used in several disciplines to understand situation awareness, expertise level, learning ability and the mental state of the human subjects. A number of application domains have utilised eye-tracking to derive insights into human behaviour. Research in various areas such as visual search and information processing (Glöckner & Herbold, 2011; Toker et al., 2013), multimedia learning (van Gog & Scheiter, 2010), and human-computer interactions (Drewes, 2010) have reported insights using eye-tracking. Future studies may apply eye-tracking techniques to explore the cognitive process of online learning and examine the potential and limitation of its applications in future online assessment and learning systems. What is more, eye-tracking techniques are recommended to deeply explore the cognitive process during e-learning, and to be applied to future online assessment systems (Tsai, Hou, Liu & Yang, 2012).

2.5.2 Eye movements (EMs)

Among many methods available for eye movement monitoring (Holmqvist et al., 2011), the eye-tracking technique allows the experimenter to capture visual behaviour, both in simplified settings and real-world situations. With these systems, gaze direction is derived from the position of the pupil centre and usually also one or more corneal light reflexes within video images of the infrared-illuminated eyes. The dominant method of eye-tracking relies on video-based measurement of eye movements. Eye movements (EM) are considered to offer a real-time window into cognition based on the “eye mind”. They make up an integral and essential part of our visual perception, driven by characteristics of the visual world and processes in a person's mind (Rayner, 1998). Study of eye movement is being employed in HCI research and arguably allows one to study attention shifts in their most “natural" form. Humans explore their visual environment through saccadic eye movements. Eye gaze recording methods produce important information on our understanding of visual perception (Deutsch, Schrammel & Tscheligi, 2011). Henceforth, understanding how this information and cognitive overload affects user perception and web interaction can lead to solutions that improve users’ web experience (Michailidou, 2009; Khan & Sekharaiah, 2013).

To control input, the visual system is equipped with a toolbox of different eye movements. Visual exploration ‘consists of the succession of saccades that depend on both external visual or “bottom-up” stimuli and cognitive “top-down” control’ (Liman & Zangemeister, 2012, p.1). The set of gaze data collected from an experiment can be analysed using various statistical and computational measures computed from the eye-tracking data. There are over 10 types of EMs, of which the most salient and frequent types are segmented into two distinct patterns: fixations and saccades. Fixations are produced by cause of users’ EM stops in order to focus on a certain area, and the extremely fast movements between these fixations are called saccades. Particularly, fixations are the short, rapid movements where the eye is able to process information, while the hold of a fixation on a location for a few hundred milliseconds generates a saccade to a new location. Typically, about two or three saccades are generated each second. Longer fixations are associated with greater visual and/or cognitive complexity. An increased number of fixations can be interpreted as having a negative impact on search efficiency (Goldberg & Helfman, 2014; Renshaw, Finlay, Tyfa & Ward, 2003). Both the task performed by an individual and the content of an explored scene influence eye movements. Yarbus (1967) showed how, given the same scene, different tasks lead to different parts of the scene being explored. Inversely, it has been observed that visual features in a scene constitute a predictor of fixation location during scene exploration. When the eye fixates, during this stop the brain starts to process the visual information received from the eyes (Rayner, 1998).

Moreover, computational models have been developed in order to predict the location of fixations, most of them relying on local features (the most well-known of being the saliency-based model by Itti & Koch, 2000) although some incorporate more global features (see e.g. Torralba et al., 2006). While it appears that humans preferentially fixate on objects (Nuthmann & Henderson, 2010), there is still debate as to what extent semantic information drives eye movements in scenes. Researchers in HCI and data visualisation use eye-tracking technology to examine tendencies and dissimilarities in user attention patterns and decision processing (Toker et al., 2013). Although the available studies so far provide valuable insights on how different tasks and/or activities affect a user's gaze behaviours, they have traditionally neglected cognitive individual differences among study participants. It is known from the seminal studies of Yarbus (1967), and more recent laboratory based work (e.g. Castelhano, Mack, & Henderson, 2009), that eye movements are highly task dependent and are linked to our cognitive goals. Nevertheless, research is yet to uncover the eye movement repertoires associated with higher level cognitive tasks that are encountered on a day-to-day basis (Gidlöf, Wallin, Dewhurst & Holmqvist, 2013). Past work has empirically determined relationships between eye gaze and individual user differences in attention-related tasks (Kruschke, Kappenman, & Hetrick, 2005; Toker et al., 2013). Earlier work has examined the potential of the eye-tracker as a tool for detecting users' cognitive dimensions with respect to the FD-I classification and identified differences between the three cognitive styles and task time completion with the FI outperforming the FD and FN students (Nisiforou & Laghos, 2013). Research by Tang, Topczewski, Topczewski and Pienta (2012) has "focused on a single, domain-specific user trait (task-domain expertise), showing that domain experts and novices display different gaze behaviours" (Toker et al., 2013, p.2). Eye-tracking and usability evaluation studies also seek to understand user behaviour (Jacob, 1995; Rayner, 1998). An eye-tracking study conducted by Toker et al. (2013) investigated the relationship between user characteristics and attention patterns. Their results showed that users' cognitive abilities, such as perceptual speed and verbal working memory, have a significant impact on gaze behaviour with respect to task difficulty and user visualisation type (Toker et al., 2013).

The eye-tracking method has become practical for studies of visual user interfaces (Grier, Kortum & Miller, 2007) and usability studies. A study conducted by Michailidou, Harper, and Bechhofer (2008) found that visually complex pages generate users' disoriented navigation, while visually simple pages produce the opposite perspective (Michailidou, Harper & Bechhofer, 2008). Tsianos, Germanakos, Lekkas, Mourlas, and Samaras (2009) demonstrated that users' cognitive and emotional characteristics have a significant impact on the personalisation and adaptation process of online environments that increase user usability and satisfaction during the navigation and learning procedure. Recent research has identified individual differences in task processing with respect to the level of Field Dependency and visually complex webpages. The results revealed that task completion time is significantly different in medium and complex pages between the FD and FI users, while regarding the simple pages their information processing remained the same (Nisiforou, Michailidou & Laghos, 2014).

Moreover, van Gog and Scheiter (2010) claimed that the findings of their study can contribute to multimedia research by using eye-tracking to examine how diverse design interventions (e.g., spoken vs. written text) affect processing of complex visual presentations. Visual perception depends on the stimulus and the user's characteristics (Lavie & Tractinsky, 2004). Additionally, cognitive measures such as perceptual speed and visual memory have been shown to affect a user's ability to complete a task effectively (Conati & Maclaren, 2008). Even though data mining methods can quickly identify clusters of similar attention patterns during visual tasks, (Goldberg & Helfman, 2014), it is currently unstudied how user gaze behaviour relates to user cognitive type.

Research has shown that the movement of the eye contains specific events (Duchowski, 2007; Majaranta & Raih, 2002). For example, when reading the eye temporarily stops at a word and remains still for a period of time. This pause in eye movement is called fixation, and is necessary to stabilise the image of the word on the retina. Fixations typically last between tens of milliseconds up to several seconds. The eye also rapidly moves from word to word during reading, i.e. from one fixation to another. Such a rapid movement is called a saccade. Eye movement is measured in visual degrees which can be translated into spatial coordinates (mm or pixels on a computer screen) of the stimulus object based on viewing distance (Groot, Ortega & Beltran, 1994). The subsequent sections will discuss the basic definitions and terminologies, and previous and recent advances in the Neuroscience field which consists of one of the four interdisciplinary domains of the thesis. These are followed by a presentation on the neurometric methods such as the electroencephalography, and the psychophysiological data in terms of neurophysiology, namely brain activation areas.

2.6 Brain anatomy: Cerebral cortex and brain regions

The human body has a line of symmetry running from the top of the head to the feet. The brain is also divided into two major parts, the left and right hemispheres. Most people have two quite functional cerebral hemispheres that continually interact to process information and achieve cognitive functions. Some define the difference in function between the two cerebral hemispheres of the forebrain by category: the left and the right hemispheres. The left hemisphere is the analytical one, found to be more adept at analysing the local element, whereas the right hemisphere is the synthetic one which is biased to analyse the local element (Sergent, 1982; Robertson, Lamb & Knight, 1988; Ivry & Lebby, 1993; Carlson, 2013). One significant principle of the two hemispheres is that each side of the brain controls most activities of the opposite side of the body. That means that the right side of the brain controls and obtains sensory information from the left side of the body, whereas the left side of the brain monitors and controls the right side of the body (Breedlove & Watson, 2013). The right hemisphere has been shown to play a key role in spatial abilities and face recognition while the left hemisphere hosts crucial networks involved in language, mathematics and logic. The two hemispheres communicate though a band of up to 250 million nerve fibres. Hence, even though there are some activities that appear to be dominant in one hemisphere, both hemispheres contribute to overall brain activity, there are subsystems linking the two hemispheres (OECD, 2007). Studies conducted with both normal and brain-injured subjects suggest that the left hemisphere prevails over spoken language functions while the right hemisphere primarily preponderates the visual-spatial functions of right-handed individuals (Languis, Sanders & Tipps, 1980; Waldron & Ross, 2012). According to Ivry and Lebby (1993) the partition of function between the two hemispheres tends to be based on the tasks or types of material: language is allotted to the left hemisphere, spatial analysis to the right hemisphere (Ivry & Lebby, 1993; Beeman & Chiarello, 2013).

Each hemisphere is further divided into lobes; each lobe can be approximately associated with certain functions. In addition, each hemisphere of the cortex has four anatomically independent lobes, namely the Frontal, Parietal, Occipital and Temporal lobes (see **Figure 2.1**). Colloquially, in order to understand the complex human brain a brief explanation of each lobe follows: The Frontal lobe is involved in planning and action and it is important for movement and high-level cognition (Breedlove & Watson, 2013; p.39). The Parietal lobe plays an important role in sensation and spatial processing and receives sensory information from the body and participates in spatial cognition. The Occipital lobe is essentail in vision. Particularly it obtains and process information from the eyes, giving rise to the sense of vision. Temporal lobe is involved in audition, memory and object recognition. Besides, auditory information is directed to the nearby temporal lobes, which are also particular associated with the sense of smell and with aspects of learning and memory (OECD, 2007). In addition to the occipital lobes, posterior portions of the parietal lobes and temporal lobes are also involved in visual perception.

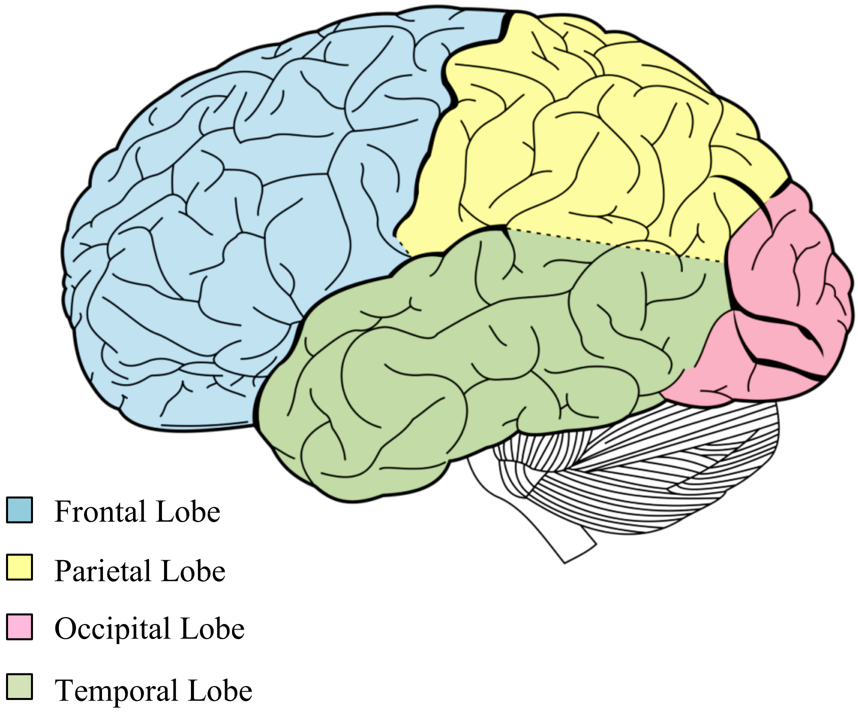


Figure 2.1 The four lobes of the cerebral cortex, Source. Odile Pavot for the OECD (2007, p. 40)

2.7 Psycho-physiological measures

There is a broad range of psycho-physiological measures that have been explored and linked to psychological and neurophysiological (or physiological) and specifically cognitive, processes and states (Fritz, Begel, Müller, Yigit-Elliott & Züger, 2014). Some of the most commonly used measures can be categorised into eye-related, brain-related or skin-related measures. Previous studies used measures of fixation and saccades in their overview of eye-tracking research in HCI and usability, and others found that a higher number of saccades is believed to be an indicator of a participant’s difficulty in extracting information from a display (Jacob & Karn, 2003; Simola, SalojäRvi & Kojo, 2008).

2.7.1 Electroencephalography technique

Electroencephalography (EEG) it is the most widely known neurometric technique for the recording of brain activity. It is a powerful and insightful high-temporal-resolution brain-imaging technique for studying neurocognitive processes by directly measuring neural activity using sensors on the scalp (Cohen, 2011; Cohen, 2014). EEG is a non-invasive and relatively inexpensive brain imaging method which provides a precise measure of neurophysiological function during different cognitive tasks and conditions. By utilising the EEG we are able to discern the activities of specific areas of the brain and the relationships between them.

Various EEG components such as event-related potentials (ERPs) have been used to non-invasively study visual processing in response to stimulus presentation (Clark, Fan, & Hillyard, 1995; Hillyard, Vogel, & Luck, 1998). An event-related potential (ERP) is the measured brain response that is the direct result of a specific cognitive, sensory, or motor event. More precisely, it is the electroencephalographic activity which is time locked to the event of interest occurring in response to a stimulus by a stimulus response (Dien, Spencer, & Donchin, 2003). The ERPs are scalp recorded electrophysiological responses that are related to an internal cognitive event (Celesia & Brigell, 1992). Further, the ERP waveform consists of a series of positive and negative wave components that are identified by their time of occurrence and polarity. "The unit of measurement of EEG is volts. The microvolt recorded form an electrode is actually the change in the measured electrical potential between that electrode and a reference electrode placed somewhere else on the head" (Cohen 2014, p. 17). One component particularly important in visual processing is the P3, a time-locked deflection which appears 300 – 400 ms after stimulus presentation (Sutton, Braren, Zubin, & John, 1965). For example, the P3 (or P300) component occurs as a positive wave that peaks at or near 300 ms after a stimulus event. Components are sometimes also designated simply according to their serial order, so that the P300 component might also be called the P3 component, meaning the third positive wave following the stimulus (Dien, Spencer, & Donchin, 2003; Bressler & Ding, 2006).

EEG has started to become a popular research tool in education for collecting and analysing the cognitive load data for the purpose of testing the effectiveness and refining the design of learning materials (Antonenko, Paas, Grabner,, & Van Gog, 2010). In a study by Tsianos, Germanakos, Lekkas, Mourlas and Samaras (2009), eye-tracking metrics revealed statistically significant differences between different types of learners, wherein imagers focus on visual content, verbalisers on text, and intermediates place in between the two. Visual perception depends both on the stimulus and the individual's characteristics (Porteous, 1996; Lavie & Tractinsky, 2004). Antonenko and Niederhauser (2010) studied the hypertext with EEG, whereas Gerlic and Jausovec (1999) used it on multimedia learning materials. Moreover, researchers such as Liu, Shi, Zhao and Yang (2008) used EEG to find the biological origin of individual differences in intelligence. Nevertheless, literature from the Educational and Neuroscience domains are rare since the "emersion" of the Educational Neuroscience field is as yet quite unexplored, and it could be considered an area which has been somewhat neglected by researchers.

With electroencephalogram methodologies (EEG), a sample size of between 30 and 40 participants is needed to achieve a statistical threshold (Sands, 2009) and depends on each procedure. For a typical experiment, it is recommended that at least ten participants is a sufficient number of subjects. With electroencephalogram methodologies (EEG), a sample size of between 30 and 40 participants is needed to achieve a statistical threshold (Sands, 2009). Typical EEG experiments have between 16 and 20 participants per group or condition of interest (Light et al., 2010). A previous doctoral study examining cognitive processing via EEG used a sample of 20 subjects (Tzimas, 2010). Earlier studies have selected a range sample from 10 to 60 subjects, depending on the cognitive processing under investigation (Benedeck, Bergner, Könen, Fink, & Neubauer, 2011; Gevins, Smith, McEvoy, & Yu, 1997; Liu et al., 2008; Neubauer & Fink, 2003) with the use of ambiguous images and EEG metrics (Ehm, Bach, & Kornmeier, 2011).

2.7.2 Neurophysiological differences between FD-I subjects

Researchers' created the cognitive style because of individual differences in brain physiology (functioning). Cognitive style is the way individuals remember, think and perceive information, and also refers to how they use such information to solve problems (Riding & Rayner, 1998; Mampadi, Chen, Ghinea & Chen, 2011). One of the most important cognitive features which appears to be deeply embedded in individuals' minds is Field Dependence-Independence, as described thoroughly in Section 2.2.

During the past decades, studies examining the cognitive style of Field Dependence-Independence have associated this construct with the degree of brain hemispheric lateralisation. Witkin et al. (1977) demonstrated much evidence that the brains of Field Dependent and Field Independent subjects have neurophysiological differences. According to Pizzamiglio (1974), Silverman, Adevai, and McGough (1966), the left-handed subjects and the ambidextrous subjects were more Field Dependent than the right-handed subjects (Musser, 1998). Some researchers have recommended that Field Independent subjects display greater left hemisphere lateralisation for verbal processes and greater right hemisphere lateralisation for visuospatial processes. Moreover, Oltman, Ehrlichman and Cox (1977) argued that male and female Field-Independent adults display a stronger left visual field (right hemisphere) bias for a right-hemisphere task (composite faces) (Berlin, 2012). Zoccolotti and Oltman (1978) used tasks including both hemispheres of the brain. They found that Field Independent subjects displayed a quicker reaction time to letters in the right visual field (left hemisphere) and to faces in the left visual field (right hemisphere), while Field Dependent subjects exhibited no substantial hemisphere difference for either task. Bloom-Feshback (1980) correlated Field Independence with a measure of spatial ability (right hemisphere) and with the left ear (right hemisphere) advantage on a dichotic linguistic listening task. The results of a relatively recent study suggest a greater right-hemisphere lateralisation, as well as greater integration or overlap of essential functions for Field-Independent subjects (Berlin, 2012). A more recent study investigated the neural correlates of individual differences in FDI cognitive styles by analysing the correlations between the Embedded Figures Test (EFT) score and structural neuroimaging data. The results revealed differences in the superior local processing ability and cognitive inhibition and suggested that these occurred due to individual differences in FDI cognitive styles (Hao et al., 2013).

2.7.3 Neurocognitive research and ambiguous figures

Ambiguous images reverse from one interpretation to the other. They have physical properties which remain the same; however, many interpretations can be perceived. Long and Toppino (2004) mention that “they offer a unique window to the involvement and interplay of critical underlying processes in the visual system” (p. 748).

Top-down selection theory suggests that attention-related frontal-parietal areas are responsible for initiating perceptual alterations by sending top-down signals to direct activity in the visual cortex towards either one representation or the other (Leopold & Logothetis, 1999).

According to Rock and colleagues, there are three requisites in order to reverse. The individual must firstly understand the nature of the ambiguous images, secondly know the particular interpretations, and thirdly the intention to observe reversal (Rock & Mitchener, 1992; Rock, Hall, & Davis, 1994; Wimmer & Doherty, 2011). The neural processes underlying spontaneous perceptual reversals remain elusive (Long & Toppino, 2004). The perceptual reversal of ambiguous images is associated with a transient increase of anterior right hemispheric gamma oscillatory activity (BaSar-Eroglu, Strüber, Schürmann, Stadler, & BaSar, 1996; Strüber, Basar-Eroglu, Miener, & Stadler, 2001; Mathes, Struber, Stadler, & Basar-Eroglu, 2006). The pattern of increased and decreased gamma activity in the inter-stimulus interval preceding those ambiguous stimuli that were indicated as reversed is the most interesting result of the Ehm, Bach and Kornmeier (2011) study. They investigated the electroencephalogram frequency modulations of the accompanying change-related rebinding processes. Moreover they found that in endogenous reversals, preceded by the gamma modulation may indicate an unstable brain state, ready to switch (reverse in ambiguous). The lack of a suitable time reference for the not directly accessible reversal instant remains a main problem in endogenous perceptual reversals (Keil, Muller, Ray, Gruber, & Elbert, 1999; Kornmeier & Bach, 2004; Strüber & Herrmann, 2002).

A transient right-hemispheric gamma modulation preceding endogenous rotating by at least 200 ms was the most noticeable whereas with exogenously induced reversals of unambiguous stimulus variants, no such modulation occurred. Moreover, the post onset components were delayed for ambiguous compared to unambiguous stimuli. From estimates based on binding-related suggestions, the time course of oscillatory motion differed in some respects (Ehm, Bach & Kornmeier, 2011).

A high number of EEG studies reported endogenous perceptual reversals accompanying the right-hemispheric activity. Britz, Landis and Michel, (2009) reported right-hemispheric EEG correlates anticipating spontaneous perceptual reversals. Evidence from EEG studies (Johnson, 1986; Müller, Federspiel, Falgatter & Strik, 1999) shows that the alpha and gamma frequency bands seem to be functionally related to perceptual (or figure) reversals (Strüber & Herrmann, 2002).

The term bottom-up (exogenous) essentially means that the perceiver starts with minor bits of information from the environment and combines them in various ways to create a percept, whereas top-down (endogenous) processes are those directed by expectations derived from context or past learning or both (Galotti, 2013). One of the categories of illusions that Gregory (1996) referred to is the illusion that is formed based on the top-down knowledge.

Recent human electroencephalographic (EEG) work for the study of perceptual binding (Christoforou, Constantinidou, Shoshilou, & Simos, 2013) has reported gamma band modulations during ambiguous perception (Ehm, Bach & Kornmeier 2011; Hipp et al. 2011) and decreased alpha power around the time of perceptual switch for other bistable images (Ehm et al., 2011). In this work, the researchers coordinated perceptual reversal with stimulus start, which served as a time reference for averaging. A number of EEG studies reported that endogenous perceptual reversals accompany the right-hemispheric activity. Several of them provide sufficient temporal resolution to trace this activity prior to endogenous rotating (Ehm et al., 2011).

Earlier studies found that user cognitive abilities such as perceptual speed and visual/verbal memory have a significant impact on user gaze behaviour and user performance in terms of task difficulty within a given visualisation (Toker et al., 2013).

The neural processes underlying spontaneous perceptual reversals remain elusive (see Blake & Logothetis, 2002; Long & Toppino, 2004). A better understanding of how the perceptual system changes spontaneously between two different representations of the same visual object could also understand the binding problem: How does the brain integrate separately analysed features into a coherent object representation (e.g., Livingstone & Hubel, 1988; Treisman & Gormican, 1988; Uhlhaas et al., 2009).

The finding of stronger signals for ambiguous stimuli is opposed to previous studies which found neural activity to be weaker in bistable images compared to the normed figures (Pitts, Martínez & Hillyard, 2010; Moreno-Bote, Rinzel, & Rubin, 2007). A recent study claims that frontal and parietal brain regions seem to be involved in perceptual switching (Knapen, Brascamp, Pearson, van Ee & Blake, 2011). Results of an earlier piece of research yielded that changing percept's of ambiguous figures are associated with neural activity in the early visual cortical areas and posterior parts of the brain (Parkkonen, Andersson, Hämäläinen & Hari).

2.7.4 Neuroimaging studies and creativity

Researchers studied EEG patterns of subjects during convergent and divergent thinking tasks (Razoumnikova, 2000). A study by Mölle et al, (1996) found that divergent thinking is considered to be the general process that underlies creative production (Mölle et al., 1996). Neurological studies used EEG measures as determinants for creativity (Bekhtereva, Danko, Starchenko, Pakhomov & Medvedev, 2001; Mölle et al., 1996). These studies assign a significant role to the Frontal lobes, especially in the right hemisphere (Klijn & Tomic, 2010). On the one hand, some have claimed that creative problem solving is driven by processing in the right hemisphere (Miller et al., 1996, 1998, 2000; Murai et al., 1998). Previous thinkers and recent studies indicate the importance of processing in both hemispheres (Aziz-Zadeh et al., 2009; Lindell, 2011) in supporting the creative process. A study by Mihov, Denzler and Förster (2010) shows that global thinking style, context-dependent thinking style and figural processes are characteristics of right hemisphere dominance. Moreover, EEG studies of artistic creativity support a role of the right prefrontal cortex, illustrating a significant synchronicity in the right hemisphere during visual perception and visual memory (Bhattacharya & Petsche, 2002; Zadeh, Liew & Dandekar, 2013). However, Aziz-Zadeh, Liew and Dandekar (2013) show that creative processing recruits both hemispheres. The finding of activity in both hemispheres during creative tasks might rely on the fact that the left hemisphere is needed to complete the task, whereas the right hemisphere is recruited to provide creative processing (Zadeh et al., 2013). A study by Chamberlain, McManus, Brunswick, Rankin, Riley and Kanai (2014) observed art students versus non-art students during the completion of drawing tasks, and found that the artist group demonstrated more grey matter density in the region of the brain called "precuneus" located in the parietal lobe during the artistic training, while in the right medial frontal gyrus and the left anterior cerebellum, an increase in grey matter density was observed in relation to observational drawing capacity. This area is involved in many skills, but could be associated with the control of the mind's eye with respect to visual creativity.

The majority of these studies examine verbal ability and creativity (Miller et al., 1996, 1998, 2000; Murai et al., 1998). The gaps in international literature regarding how neural activity and brain functionality underlie learning still exist, as neuroscience applications in educational research are just being realised. Continued interdisciplinary collaboration has the potential to further advance understanding of the mental processes and structures associated with creative thought and behaviour. Thus, future studies should shed light on the benefits of collaboration between user experience researchers, creativity, cognitive and educational neuroscientists. Finally, the goal of the creative approach is to provide a thorough analysis of creative behaviour in the laboratory approach by using the experimental methods of cognitive science, including the development of a variety of experimental paradigms (Finke, Ward & Smith, 1992; Smith, Ward & Finke, 1995; Ward, Smith & Finke, 1999; Shah, Smith, & Vargas-Hernandez, 2003).

Ultimately, the previous and recent advances stand as a street with rich bi-directional and reciprocal interactions between the four disciplines combined in this thesis: HCI, Educational Neuroscience and Psychology. This evidence provides the opportunity to examine individuals' cognitive and creative processes by investigating the plausible link between the FD-I cognitive ability-style, creativity and the psychophysiological measures such as eye movements and brain activation. The next five Chapters involve the research part of the dissertation.

3. CHAPTER THREE

STUDY 1 – FIELD DEPENDENCE-INDEPENDENCE COGNITIVE ABILITY

3.1. Overview

Study 1 focuses on the Field Dependence–Independence cognitive ability. In particular this eye-tracking study examines how users of different cognitive styles (Field Dependent, Field Neutral and Field Independent) interact on a set of visually complex stimuli in order to solve specific tasks. The evaluation of the tools' usability in assessing users' level of Field Dependency was also the aim of the proposed study. Additionally, it investigated the relationship between the Hidden Figures Test (HFT) scores and the eye-tracking metrics. If the two tools were associated, a fertile ground for the application of eye-tracking as an alternative method in assessing users' FD-I differences in online behaviour should be revealed.

3.2. Objectives and Research Questions

The objective of Experiment 1 was to explore the potential of the eye-tracker in assessing the learners' Field Dependence-Independence cognitive a as an alternative method of objective measurement. Therefore the below research questions (RQ) are addressed:

RQ 3.1 What is the correlation between the eye-tracking biometric technique and the Hidden Figures Test psychometric method of assessing users' FD-I visuospatial attention?

RQ 3.2 What are the differences between users FD- I cognitive style and visual search performance with regard to response time and visual search behaviour?

3.3. Method

3.3.1. Participants

A total number of sixteen university students were drawn from the department of multimedia and graphic arts of a public university in Cyprus and volunteered to take part in this User Experience study. Subjects provided written consent and reported normal, or corrected-to-normal, vision. The participants' ages range from 17 to 30 years including a variety of higher education levels ranging from undergraduates up to doctorate students. The particular group of students was chosen as it is considered to be the future workforce, having an extensive training on multimedia devices and knowledge for the design of innovative learning environments.

3.3.2. Experimental Design

Each student participated in the Psychometric Hidden Figures Test Phase and Experimental Phase (Embedded shapes tasks, and Hidden faces tasks), counterbalanced in a Latin-Square sequence design (Mitchell & Kolley, 2013). The design of the online environment material and tasks of the User Experience (UX) study was inspired by the Hidden Figures Test. The user interface presented offered visual-based learning object information. The purpose being was to ensure that the interaction with the screen is completely visual as per the objective of the study.

3.3.3. Materials and Procedure

Six images were used for the experimental phase of the study. A set of four complex images were designed for the Embedded shapes tasks, and four for the Hidden faces task. No specific time limit was set for the completion of the experimental tasks in order to track users' real-time performance, behaviour and experience, and to gain insights into the complex nature of cognitive and perceptual concepts.

The experiment was conducted in two phases on an individual basis and took place in the eye-tracker laboratory room. The HFT was administered prior to the beginning of the experiment.

3.3.3.1. Psychometric Test Phase

The participants were initially categorized by their FD-I cognitive style (Field Dependent, Field Neutral and Field Independent) on their performance in the Hidden Figures Test (HFT) (Ekstrom et al., 1976). The HFT is a psychometric tool that measures the level of an individual's Field Dependency. It consists of 32 questions divided equally into two parts, and scores ranged from 1 to 32 (with a maximum of 32 points achievable). The test presents five complex patterns in each of which is embedded a simple figure. Users who achieved a score of 10 or below were defined as FD, while those defined as FI scored 16 or higher. The FN scored between 11 and 15. A subject's score on the test was calculated as the number of responses marked correctly minus the number marked incorrectly. The completion of the test took 24 minutes, 12 minutes per part (Ekstrom et al., 1976). The testing activity involved in the HFT is a reliable and widely-used approach for determining FD-I cognitive dimension. Reliability of the internal consistency of the psychometric test has been validated using Cronbach's alpha coefficient, which is a widely-used index of test reliability. The closer the score is to +1.00, the higher the reliability. In this research study the Cronbach's alpha for the HFT was 0.862 (Cronbach, 1977). The increased value of alpha indicates that items in the psychometric test are correlated to each other.

3.3.3.2. Experimental Phase

Subjects were then assigned to the experiment, placed in front of an eye-tracker and asked to complete two tasks. Instructions were provided prior to the conduction of the actual experiment. Gaze activity was recorded with the use of the eye-tracking system. Calibration was performed on a standard nine-point calibration displayed on the monitor prior to the start of the experiment. The user self-paced experience study was designed in order to collect participants' accurate response times and visual search performance in the online solving tasks. The aim was to categorise participants into the relevant group of Field Independence based on their gaze behaviour. The online environment of the UX study included the following tasks, which appeared in a random order for counterbalancing purposes:

(a) Embedded shapes tasks

The embedded shapes were four complex web-based line drawings inspired by the HFT. Each shape was displayed on the screen and subjects had to identify one of the lettered shapes, each of which was embedded in a more complex pattern (see **Figure 3.1**) and indicate their response with a mouse click. When the participant made the identification, this caused the subsequent appearance of the next stimulus on screen. If the participant could not provide a response, he/she could ask to proceed with the following stimulus. Only one stimulus was visible each time, and no time limit was set in order to allow users a number of attempts, therefore revealing their real response time and visual search performance.

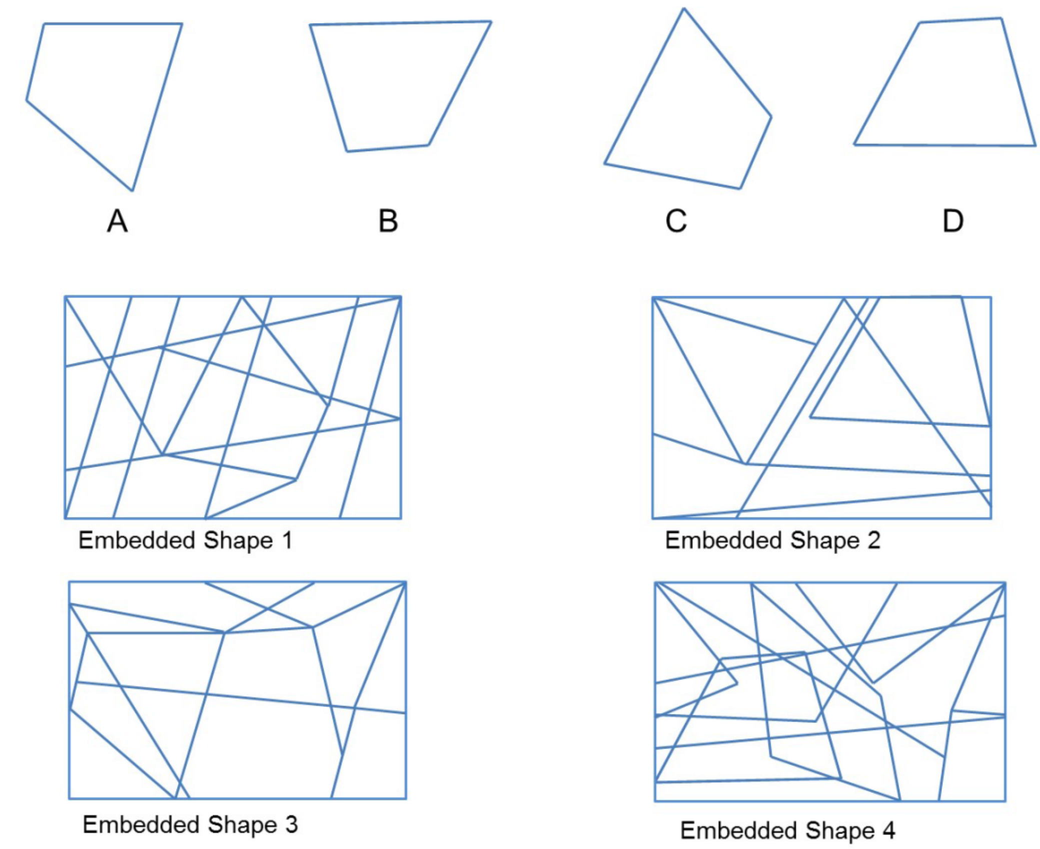


Figure 3.1 The visual stimuli of the embedded shapes tasks displayed in the UX eye-tracker.

(b) Hidden faces tasks

Subjects were requested to detect the hidden face in each of the four pictures and indicate their response with a mouse click (see **Figure 3.2**). The procedure was the same as in the previous task (see Embedded shapes tasks p. 77).

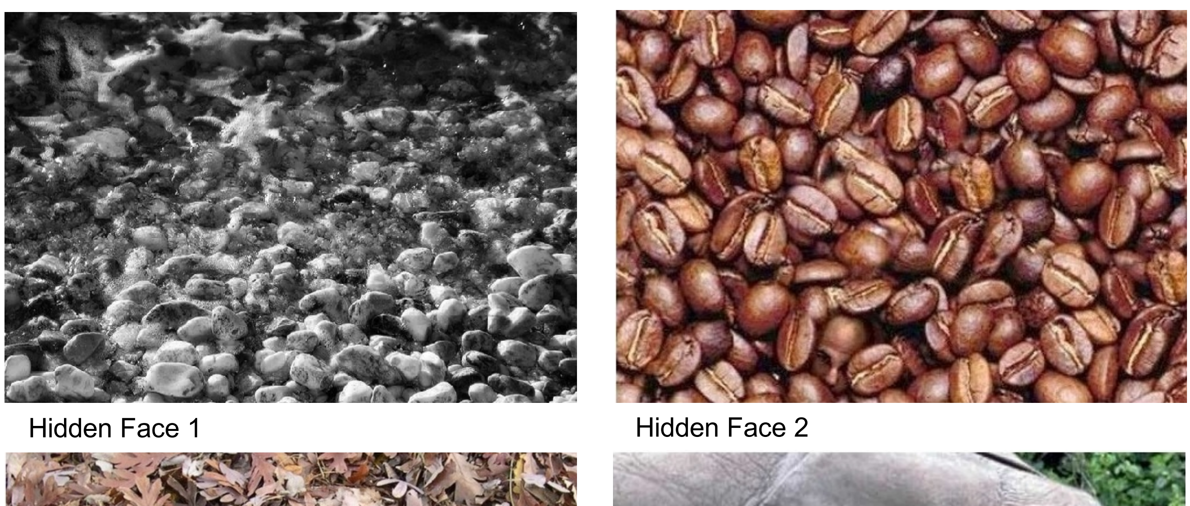


Figure 3.2 The visual stimuli of the Hidden faces tasks displayed in the UX eye-tracker study.

3.4. Data Analysis

The eye-tracker-derived data was analysed with the aid of the Be Gaze 3.1 Software and primarily focused on heat map and scan path analysis. The data was then statistically analysed with the use of the statistical package SPSS version 20.0.0.

3.5. Results

3.5.1. Hidden Figures Test

Participants' level of Field Dependency was measured with the use of the Hidden Figures Test (Chen & Macredie, 2004; Angeli, 2013, Nisiforou & Laghos, 2013, Nisiforou & Laghos, 2015). Participants had a 24-minute time limit to complete the entire test (Ekstrom, French, Harman, & Dermen, 1976).

The test presents five simple figures and requests learners to find out which of the five is embedded – with the same size and orientation - in each of the 32 complex patterns (see **Figure 3.3**). The Field Dependency cut-off scores were decided by taking into consideration how other researchers had determined the cut-off scores in their studies (Daniels & Moore, 2000; French, Ekstrom & Price, 1963). Therefore, individuals who scored 10 or below were categorised as Field Dependent (FD), those who ranked from 11 to 17 were classified as FM or FN, and those who achieved a score of 18 or higher as FI. This classification revealed five Field Dependent (FD) participants, five Field Independents (FI) and six Field Neutrals (FN).

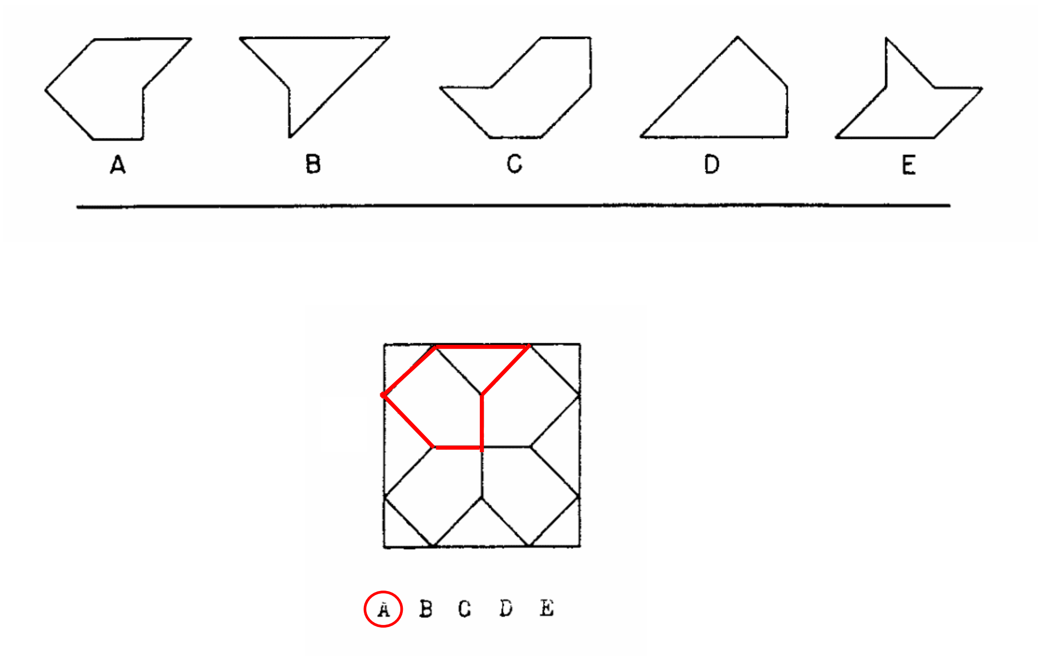


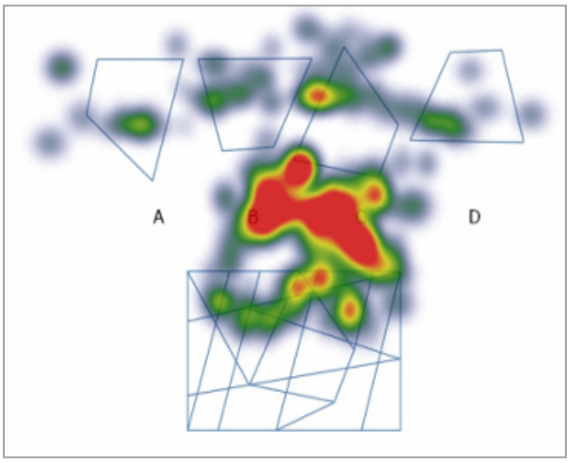
Figure 3.3 Example of the HFT Hidden Figures Test task (Ekstrom et al., 1976). The task is to determine which one of the five simpler figures is embedded in the more complex figure. The correct respond is the circled letter "A".

3.5.2. Eye-tracking and Behavioural analysis

3.5.2.1. Embedded shapes task

Figure 3.4 shows the heat maps of the Field Dependent Learner (FDL's) and Field Independent Learner (FIL's). The heat map analysis demonstrates the FD participant's incorrect response since the gaze activity reflects the inefficient recognition of the shape embedded within the complex pattern. This is demonstrated by the green heat maps which overlay all possible answers without actually providing the correct response, which is lettered shape C. On the other hand, FI fixations were clustered in the embedded shape indicating the correct response (Nisiforou & Laghos, 2012).

Fixations were displayed as heat maps, which were created based on the total time participants looked at all stimuli. Red spots indicate higher levels of fixation, with yellow and green indicating decreasing amounts of fixations. Areas without color were not fixated upon. The most accurate performers are displayed in **Figure 3.5** (left column), while the weakest performance (right column).



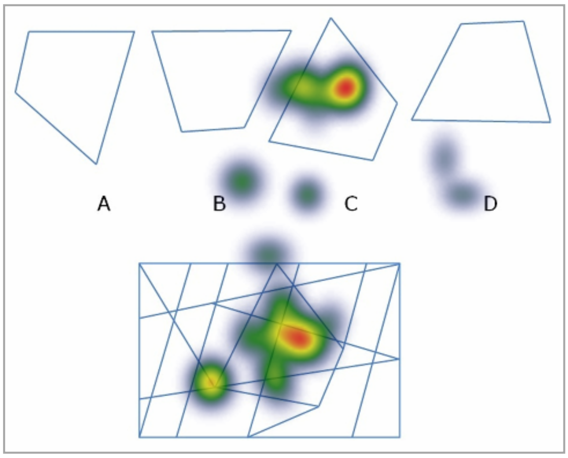


Figure 3.4 Heat map reflecting the FD and FI learner (from left to right)

Note. The red gradient represents a standard gaze heatmap and the green gradient represents an arousal physiological heatmap based on pupil size.

3.5.2.2. Hidden Faces task

Figure 3.5 shows a comparison of a set of heat maps demonstrating the differences between Field Independent (left column images) and Field Dependent (right column images) users. The FD often could not detect the hidden face or, if they could, needed more time to find it, whereas the FI gaze activity demonstrates that the hidden face could be identified.

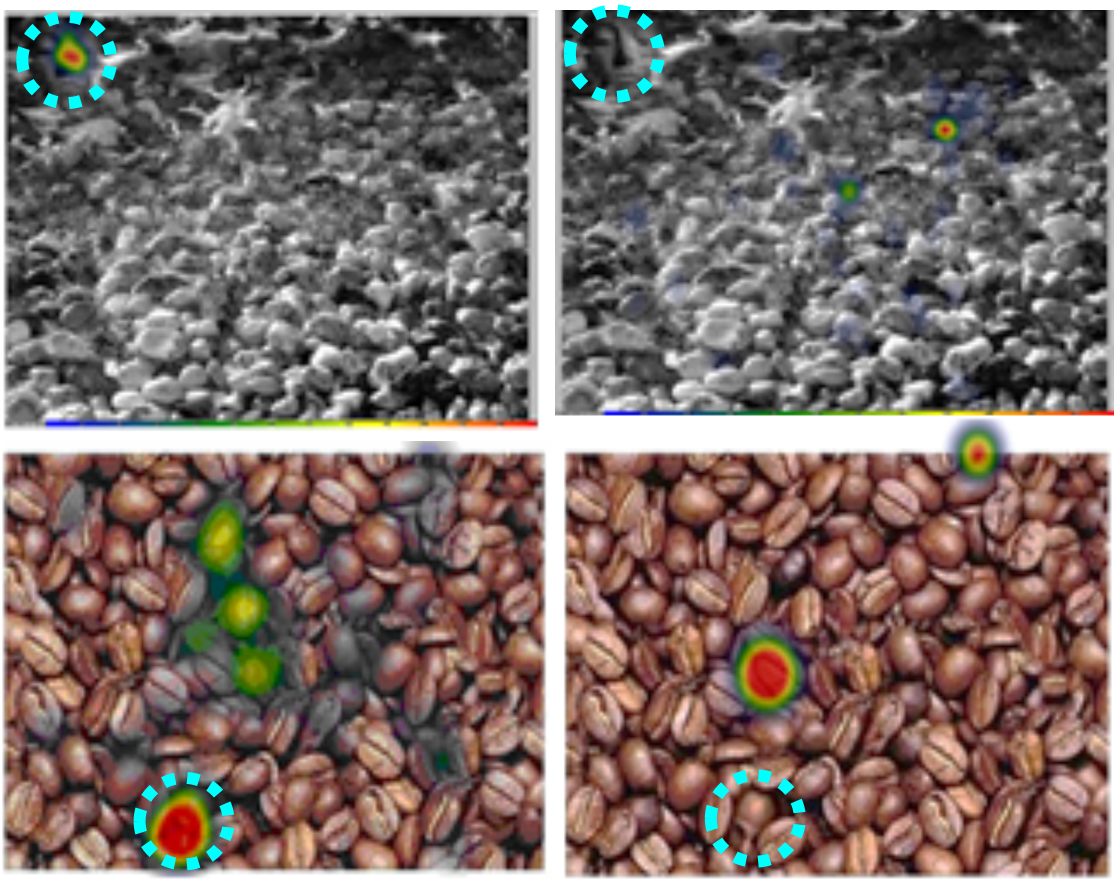


Figure 3.5 Eye Gaze analysis (Heat map) of FI (left) vs FD (right) users

3.5.3. Task response time (RT) and learners' cognitive type

Participants' performance on the visual search tasks was compared in order to understand how users of different cognitive styles (Field Dependent, Field Independent and Field Neutral) interact on a set of visually complex stimuli. Therefore, their response time was compared and a wide variation was found between the subjects of the three different cognitive groups. The term 'task response time' refers to the users' task-time completion regardless of whether the correct result was provided. Specifically, **Table 3.1** illustrates the total mean average of the FD students was nearly five times greater than the total mean average of the FI learners.

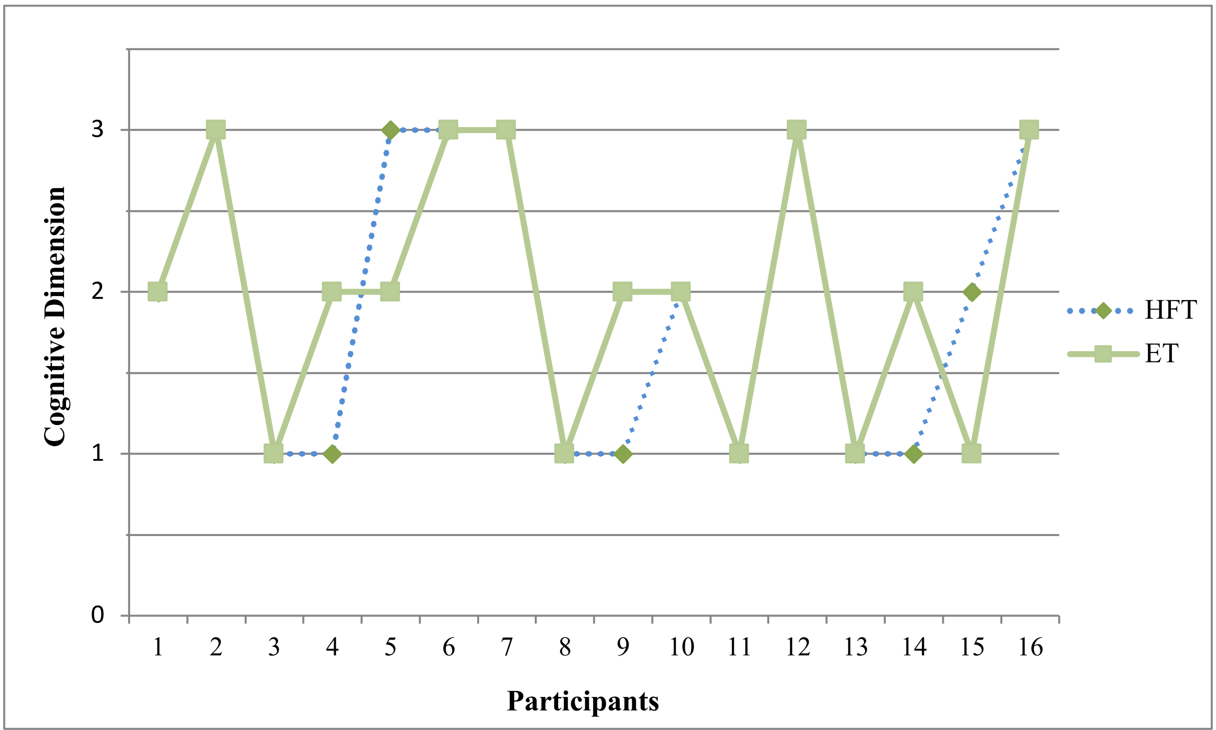
Table 3.1 Task response time and mean average time per participant in their performance of the experimental phase of the study.

Cognitive Style Group	Response Time in Seconds				
	Embedded shapes				
Field Dependent	*Shape 1*	*Shape 2*	*Shape 3*	*Shape 4*	Mean Average
P03	19.626	16.719	12.464	20.629	17.360
P08	40.231	18.785	4.970	22.997	21.746
P11	1:17.190	1:26.570	15.212	17.596	49.142
P13	21.783	23.139	1:26.570	31.677	40.792
P15	1:13.916	34.859	8.625	22.119	34.880
			Total Mean Average		32.784
Field Independent					
P02	5.562	11.670	5.641	8:303	7.794
P06	17.430	10.269	4.734	7.699	10.033
P07	10.685	10:021	6.087	13.163	9.989
P12	4.591	4.354	4.090	12.184	6.305
P16	11.551	16.660	7.048	15.227	12.622
			Total Mean Average		9.349
Field Neutral					
P01	23.300	1:33.04	6.214	16.383	34.734
P04	19.625	16.710	20.629	12.464	17.357
P05	39.871	9.092	11.243	19.142	19.837
P09	13.684	36.330	10.142	6.295	16.613
P10	29.667	9.981	18.312	14.980	18.235
P14	40.231	26.382	7.807	14.750	22.293
			Total Mean Average		21.512

Consequently, FD learners in general needed more time to complete the tasks than did the FI and FN. Additionally FN learners occasionally behave as FD or FI according to the learning situation. This behaviour was confirmed since the total mean average of the FN learners falls between the total mean average of the FD and FI groups.

3.5.4. Comparison of the two phases: Hidden Figures Test and Experimental Eye-tracker metrics

By cross tabulating the outcomes of the HFT (the scores as a result of participants' performance on the HFT) and the experiment using the eye-tracking technique (categorising participants into their FF-I cognitive group based on their response time on the visual tasks of the experiment phase) clearly it can be seen that the patterns in HFT and ET lines are very similar (see **Graph 3.1**). These results suggest that there is a correlation between the two different tools. In order to verify this outcome a chi-square was performed to examine and demonstrate whether a statistically significant relationship exists between the two tools (see **Table 3.2**).



Graph 3.1 Cognitive abilities as defined by HFT and ET.

Note. (Y) Axis – Cognitive dimensions 1= FD, 2= FN and 3= FI

3.5.5. Statistical analyses

3.5.5.1. Chi-square Test

A chi-square test was conducted to examine whether there was a relationship between HFT and ET outcomes. The results revealed that the results of the HFT correlated with those revealed from the eye-tracking metrics, χ^2 (4, N = 16) = 16.65, p = .002, Cramér's V= .721. Towards validating the fact that there is a promising field in detecting users' FD-I dimension through the use of eye-tracking technology and HFT, a statistical analysis has been carried out in order to cross tabulate the results. It is obvious that there is a significant correlation between the results derived from the two tools. This is verified by a chi-square test (the nonparametric test giving the same results as the descriptive statistics) that was performed to examine the association between the two tools. The data demonstrated in **Table 3.2** gives a chi-square test statistic, and the results are presented in a tabular form based on the two research tools. The statistic Pearson Chi-square correlation, X^2=16.653 and $p = 0.002<0.05$ shows that the relation between the two variables is statistically significant. Therefore, the variables in Hidden Figure Test and Eye-tracker are correlated.

Table 3.2 Chi-Square values based on HFT and ET

Variables	N	χ^2	df	Sig. (2-tailed)
Hidden Figure Test	16	16.653	4	0.002*
Eye-tracker	16			

* The mean difference is significant at the 0.05 level.

In furtherance of improved data interpretation, and in order to be better able to measure the degree of association between the two nominal variables, Phi and Cramer's V were applied. The calculation of Phi and Cramer's V symmetric measures tests gauge the strength and direction of the relationship between two categorical variables, HFT and ET, and are based on the chi-square statistic itself. Phi and Cramer's V values fall between 0 and 1. Cramer’s V is the most popular of the chi-square based measures of nominal association, whereas Phi is a chi-square based measure of association. When reading **Table 3.3** we are interested in the results of the Cramer’s V correction. This selection was based on the criterion that both variables are categorical and at a nominal level is possessed of more than two categories. Values closer to 1 indicate that a strong or high association between the two variables exists, whereas values closer to 0 show that there is a weak or low association between the variables. We can see here that the value of Cramer’s V is = 0.721 and the level of significance, $p = 0.002 < 0.01$. Therefore, it can be stated that statistically significant associations between the Hidden Figures Test scores and the eye-tracker metrics do exist, showing a strong relationship in strength.

Table 3.3 Phi and Cramer’s V symmetric measures of HFT and ET variables

Nominal by Nominal	Value	Sig. p-value
Phi	1.020	0.002*
Cramer’s V	0.721	

* The mean difference is significant at the 0.01 level.

3.5.5.2. One-way ANOVA Test

A one-way ANOVA was used to test for differences in the performance of the three cognitive groups in the two experimental tasks with respect to the response time on the visual search tasks (see **Table 3.4**). The RT mean average differed significantly across the three categories, $F(2, 13) = 4.48$, $p = .033$. Post-hoc analysis using Tukey’s HSD criterion indicated that the FD group (M = 6.60, SD = 50, 55) produced significantly higher time means than the FI group (M = 9.35, SD = 2.41) $p = .029$. This indicates that the two groups are significantly different. Comparisons between the FN group (M = 3.63, SD = 24. 95) and the other two groups were not statistically significant at $p < .05$. Therefore, based on the statistically significant results, the two cognitive groups FD and FI are not correlated in terms of the RT on the visual search tasks. An emergent result is that FN learners show no difference from the two other groups. A possible assumption might rely on the fact that this group of individuals falls in the middle of the continuum, sometimes acting as either FD or FI, thus enabling them to adapt to their learning situation as needed. As a consequence, they might slightly differ from the two ends of the FD-I cognitive type.

Table 3.4 Descriptive statistics and one-way ANOVA between the three cognitive groups and response time on the experimental tasks of the study

	M	SD	F	df	Sig. p value
FD	6.88	50.55			
FN	2.90	24.95			
FI	9.35	2.41			
Between Groups			4.48	2	.033*
Within Groups				13	

* The mean difference is significant at the 0.05 level.

3.6. Discussion

Experiment 1 confirmed that eye-tracking can be used as an alternative tool to assess and categorise individuals in their Field Dependence-Independence cognitive type (Nisiforou & Laghos, 2013). The chi-square analysis revealed that results from the Hidden Figures Test and the eye-tracking derived data was significantly correlated. These findings are consistent with Nisiforou and Laghos (2012) and Nisiforou and Michailidou (2013) in which the HFT validated the data retrieved from the eye-tracker metrics. Additionally, the results suggest a new method of assessing users' FD-I cognitive type based on their response time on a set of visual search tasks. During the first task of the experimental phase – embedded shapes – the performance of FI subjects was significantly faster and more accurate compared to the FD group. In line with these results, Tinajero and Paramo (1997) found that Field Independent students generally performed better than Field Dependent students. Isaak-Ploegman and Chinien (2009) mentioned in their study that Field Independent learners outperform Field-Dependent learners in terms of their scores on the HFT. Similar preliminary results were reported in an earlier work by Nisiforou and Laghos (2012) in which a large variation in task response time appeared among the subjects of the three different cognitive groups. In line with the results, a previous work by Burnett (2010) hypothesised that FI learners will outperform FD learners in terms of time taken to respond correctly to the problem-solving task. Other studies stated that FI individuals face less difficulty in separating the most essential information from its context than do the FD subjects (Riding & Cheema, 1991; Zhang, 2004; Guisande et al. 2007).

3.7. Summary

However, caveats need to be noted and are subject, primarily, to one limitation. Due to the small sample size it is unlikely that the results can be generalised from the findings. Therefore, this experiment could be viewed as the pilot study of the thesis from which essential foundations might be built to guide the development of the dissertation. It is understood that an increased number of subjects is needed, but the initial data demonstrates an interesting observation that will reinforce this field with a promising new methodology. Study 3 was conducted to assess the potential of eye-tracking technology for gathering user data to allow the detection of FD-I cognitive style in visual environments. User eye movement data potentially provided sufficient data to efficiently measure a learner's style based on the FD-I classification. The findings showed a statistically significant correlation between users' visual attention and visual stimuli, demonstrating the necessity for emerging solutions that will reflect the user's cognitive characteristics and can conversely improve users' Web experience through the design of advanced interfaces. The findings of Experiment 1 contributed on both theoretical and practical levels to those experiments described in the upcoming sections of the thesis, as to the enhancement of the understanding of the relations between human attention (eye-movement behaviour) and cognitive abilities (visual attention on the basis of the FD-I style).

4. CHAPTER FOUR

STUDY 2 - FIELD DEPENDENCE-INDEPENDENCE AND EYE MOVEMENTS

4.1. Overview

The experiment in Study 1 employed the eye-tracker technology to elucidate implicit understandings on users' Field Dependence-Independence cognitive style. The results created a promising fertile ground for the application of eye-tracking as a new method of assessing users' individual differences in FD-I cognitive style. These lines of evidence give some indications for further elaboration and generated the need for alternative and objective methods of measuring users' cognitive style. Second, there is evidence that the eye-tracking metrics and the Hidden Figures Test scores are significantly correlated. Third, there are individual differences in the performance and interaction on visual tasks in terms of search behaviour and task-response time. Therefore, it is plausible that a link between learners' online task performance and cognitive behaviour exists.

Chapter Four describes the Experiment conducted as part of Study 2 which employed eye-tracking as the biometric technique to capture the real-time eye gaze information of a user, in relation to the FD-I cognitive type. The eye-tracking study investigated the association between adults' cognitive style and eye movement (EM) patterns while interacting with a set of visual tasks. This was the first attempt to investigate this association and intended to identify whether users' differences in FD-I cognitive style can be manifested in eye-gaze patterns, and how cognitive style influences eye gaze behaviour. The outcome of the study provides an additional novelty element towards the completion of the thesis puzzle of significance.

4.2. Research Questions

An important question as to whether eye gaze components such as the number of fixations and the number of saccades can suggest users' Field Dependence-Independence cognitive style led to the development of the current study. Therefore, the experiment in Study 2 was designed to contribute towards the exploration of the following research questions (RQs'):

RQ 4.1 How does users' Field Dependence - Independence cognitive type affects their eye movement behaviour during visual search tasks?

RQ 4.2 What are the differences between users' FD-I cognitive style and eye movement (EM) behaviour in visual search tasks?

4.3. Method

In this user experience study, visual images were displayed on a monitor and participants' performance was measured with the aid of the eye-tracking technology as a method of identifying individuals' eye movement differences with respect to the FD-I cognitive style classification.

4.3.1. Participants

Study population was recruited from a public university in Cyprus. A total of fifty-four students (aged 18 - 35) participated voluntarily in the experiment. The participants were initially categorised into their current FD-I cognitive occupation (Field Dependent, Field Neutral and Field Independent) according to their performance on the Hidden Figures Test (HFT) (Ekstrom et al., 1976).

4.3.2. Materials and procedure

The stimuli were the same as those used in the Embedded Shapes tasks of the experiment (see Embedded Shapes tasks p. 77). The experiment was conducted in two phases on an individual basis and took place in the eye-tracker laboratory room. The HFT was administered prior to the beginning of the experiment.

The experiment was conducted in two phases: Hidden Figures Test Phase and the Experimental Phase.

4.3.1.1. Hidden Figures Test Phase

This phase of the experiment was the same as in the experiment of Study 1 (see Psychometric Test Phase of the Study 1 experiment, p. 76). In this research study, the Cronbach's alpha coefficient test reliability for the HFT was 0.880.

4.3.1.2. Experimental Phase

Users were placed in front of an eye-tracker and were engaged in a visual exploration task. The environment of this phase, as stated in the previous chapter, was inspired by the HFT, and four complex shapes were designed to serve as the stimuli of the experiment (see **Figure 3.1** in Chapter 3, p. 52). While reviewing the embedded shapes, users' eye activity was recorded with the use of the eye-tracking system. No time limit was set for this task, as to elucidate continuous, objective measurements of human-system interactions.

4.4. Data analysis

Participants' eye gaze data in their performance on the four visual stimuli tasks was analysed with the aid of the BeGaze analysis software provided by SMI. For the analysis participants' visual behaviour was measured, analysed and evaluated, subject to the number of fixations, number of saccades, scan path and heat maps eye-gaze analysis for each stimulus. Consequently, the total number of fixations of each cognitive-style group was computed on every stimulus, and the average total number of all four stimuli was calculated. The same procedure was followed for the number of saccades.

The eye-tracking-derived metrics were statistically analysed with the use of the SPSS software. One-way ANOVA (post-hoc analysis using Fisher's LSD criterion) tests were conducted as a medium to examine the effect of the Field Dependent-Independent cognitive style on users' eye movement behaviour in relation to fixations and saccades.

4.5. Results

In this section, the results are discussed with respect to the research questions of the study for each cognitive group. It was hypothesised that Field Dependent learners would yield a more disoriented and disorganised eye pattern while performing the visually Embedded Shapes tasks, and hence produce greater numbers of fixations and saccades. On the other hand, Field Independent learners would generate a lower number of fixations and saccades, and as a result of their interaction with the stimuli, a more organised behaviour would occur. These findings contributed towards the exploration of the thesis's research objectives as defined in the first Chapter/Introduction.

4.5.1. Field Dependence-Independence cognitive ability

The innovative findings of the study are discussed in terms of the association between FD, FN and FI users and the number of fixations and saccades they generate during a search task process. As previously mentioned, the Hidden Figure Test (HFT) was used to define users' FD-I current cognitive type (e.g. Field Dependent, Field Neutral/Mixed and Field Independent). Participants' score on the test were calculated as the difference between the numbers of questions answered correctly minus the number answered incorrectly. Taking into account how other researchers determined the cut-off scores of the test in their studies (e.g. French, Ekstrom & Price, 1963; Chen & Macredie, 2004; Angeli, 2013) the participants were classified into their cognitive type. In line with this classification framework, participants were classified as follows: 24 Field Dependent, 16 Field Neutral and, 14 Field Independent.

4.5.2. Eye Movement (EM) Features

Eye-tracking data was analysed using data mining techniques, such as scan path clustering (Goldberg, 2014). An eye-tracker captures gaze data in terms of fixations (i.e. keeping the gaze on one area on the screen) and saccades (i.e. quick movement of gaze from one fixation point to another) (Toker et al., 2013) and are analysed to demonstrate a viewer's attention patterns. These features are built by calculating statistics upon the fundamental eye-tracking metrics, such as the number of fixations and saccades. To facilitate the presentation of the results, this section is discussed in terms of users' cognitive type and the eye movement data they produce. The eye-tracking metrics that were applied for the purposes of this experiment include the following:

- Heat maps / scan paths analysis in association with the Field Dependence-Independence cognitive style.
- Fixations / saccades analysis in association with the Field Dependence-Independence cognitive style.

4.5.3. Comparisons of Heat Maps and Scan Paths EM Analyses

Figure 4.1 demonstrates the heat maps of the Field Dependent subjects by virtue of their interaction with the four embedded shapes of the study. The eye-tracking heat maps reflect the users' eye movement patterns while performing the visually Embedded Shapes tasks. These eye movement patterns demonstrate that the Field Dependents could not identify the correct shape as they were looking at different areas from the shape of interest. Additionally, we can see that the FD participants devoted more time to the incorrectly lettered shapes rather than the correct ones indicated by a circle. In contrast, **Figure 4.2** determines the heat maps produced by the Field Independents. Specifically, their eye gaze patterns exemplify their correct responses or their oriented behaviour while searching for the task. It was observed that FI could recognise the hidden lettered shape within the complex pattern as the green heat maps overlapped with the correct answers given by the users. The correct response to each corresponding complex stimulus is circled.

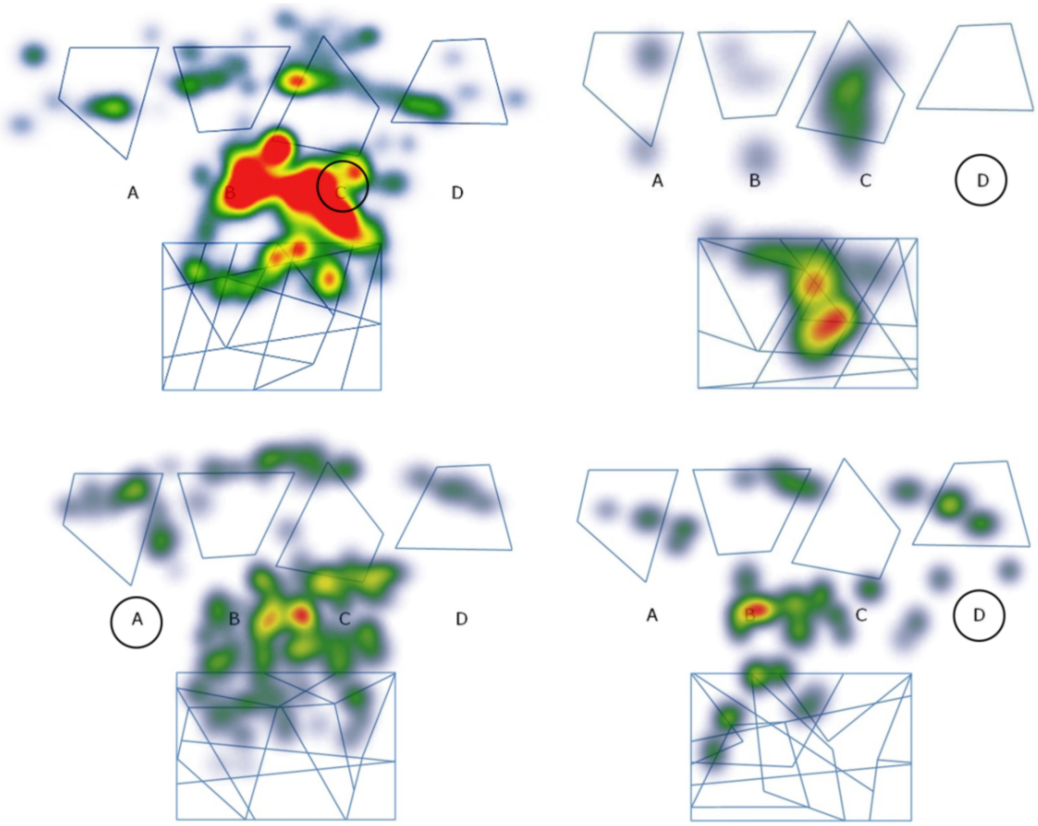


Figure 4.1 Heat maps of the four embedded shapes reflecting the FD subjects.

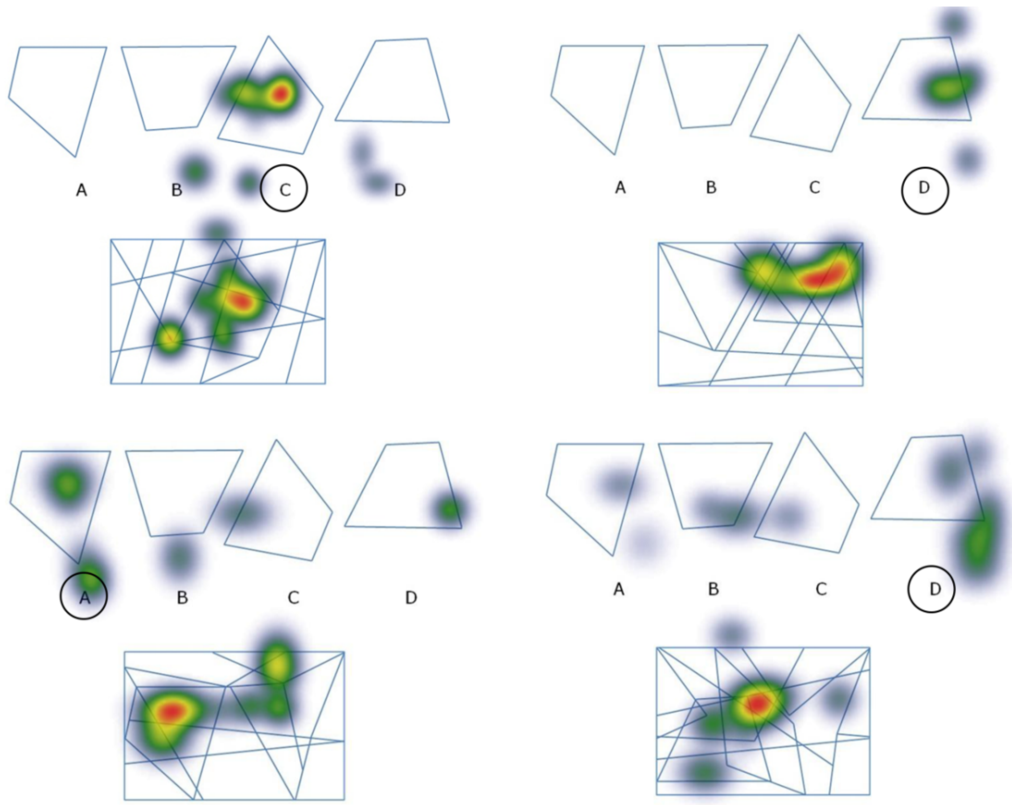


Figure 4.2 Heat maps of the four embedded shapes reflecting the FI subjects.

A study by Oliva, Mack, Shrestha and Peeper (2004) showed that the textures that contain oriented patterns are less complicated than the disorganised ones. The outcome above suggests that the more disorganised a pattern, the more complex is and opposed, the more organised; the less complex is. However, what happens when different cognitive groups of individuals interact with the same visual patterns? Do they all generate fewer complex or more complex eye movement patterns? A comparison of a set of scan paths between Field Dependent and Field Independent users demonstrated the differences in their eye movement patterns (see **Figure 4.3**). The scan paths of the FI revealed more oriented eye movement behaviour producing a fewer number of fixations and saccades than those of the FD participants. The latter group tended to generate more fixations and saccades and, as a result, exemplifies a more disoriented and disorganised gaze behaviour. This finding suggests that users' cognitive style in terms of the Field-Dependence/Independence dimension affects their eye movement patterns when the same visual patterns are produced. Therefore, although oriented patterns are considered to be less complex, this emerging result suggests that the eye movement behaviour a user generates relies upon his/her FD-I cognitive type.

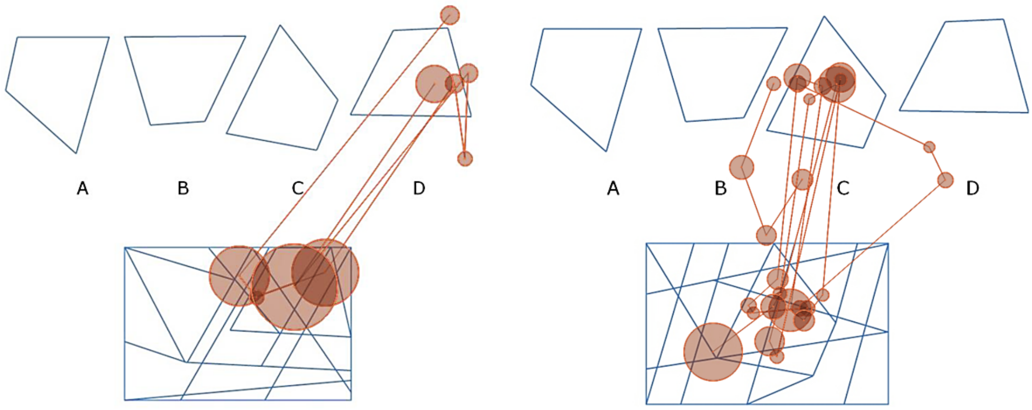


Figure 4.3 Scan path comparisons between FI (left) and FD (right) users.

Users were categorised into their FD-I cognitive style based on their performance on the paper-pencil Hidden Figures Test (see APPENDIX B, pg. 181) as in the experiment of Study 1. In consideration of the existing cut-off scores classification, **Table 4.1** summarises the range of the number of fixations and saccades each cognitive group produced after the interaction with the visual stimuli of the study. Looking at the values it is plain that Field Dependent users who revealed disoriented eye gaze patterns tend to produce on average a result greater than or equal to 100 fixations and saccades. On the other hand, Field Neutral fall between 60 to 100 in number and, finally, equal or beyond the range of 60 was found to be associated with Field Independence classification. It is worth mentioning that the outcome above needs to be further considered since this is an initial assumption of introducing new means of measuring and identifying a user's FD-I cognitive dimension based on eye gaze features.

Table 4.1 Participants eye movement behaviour and number of fixations and saccades per cognitive group.

Cognitive abilities	Eye gaze patterns	Eye movement components	
		Fixations	Saccades
Field Dependent	Disoriented	≥ 100	≥ 100
Field Neutral	Mixed	60 < NF <100	60 < NS<100
Field Independent	Oriented	≤ 60	≤ 60

Note. NF = number of fixations; NS = number of saccades

4.5.4. Fixations and Saccades Analyses

All participants' eye movements differ significantly between the three cognitive groups. A number of fixations and saccades were compared in relation to the FD-I cognitive dimension. **Table 4.2** demonstrates a comparison of the average total number of fixations and saccades between FD, FN and FI users during their interaction with the visual environment of the study. A significant variation in the average total number of both eye- movement derived metrics between the subjects of the three different cognitive groups was identified. Specifically, the average total number of fixations of the FD participants was nearly double that of the overall mean average of the FN learners, and close to four times higher than the values generated by the FI group. Additionally, the FN users doubled the average number of fixations and saccades produced by the FI group. The result of more overall fixations reflects search inefficiency by the user, while more saccades exemplify more searching (Goldberg & Kotval, 1999).

Consequently, FD learners yielded more fixations and saccades in their attempt to complete the visual image tasks than did the FI and FN learners. In addition, there were times that the FD learners they could not detect the correct response and, as a result, provided a wrong answer. Besides, it is a notable effect that the FN learners occasionally behave as FD or FI relative to the learning condition. This eye activity is verified and illustrated in **Table 4.3** with the average total number of the FI learners falling between the values performed by the FD and the FI cognitive groups.

Table 4.2 Average total number of fixations and saccades per cognitive group.

Cognitive group		Visual Stimuli: Embedded shapes				
		A	B	C	D	Total Average
FD	Fixations	251.63	159.33	103.13	114.96	157.26
	Saccades	238	164.25	100.83	111.88	153.74
FN	Fixations	116.25	97.81	45.36	73.38	83.20
	Saccades	130.25	85.88	46.88	75.19	84.55
FI	Fixations	59.93	38.29	36.79	38.21	43.30
	Saccades	58.64	37.21	35.14	37.57	42.14

Field Dependent-Independent and Fixation Effects. Most central to the purpose of this study was the observation of a statistically significant interaction between cognitive type and fixations. The descriptive statistics associated with eye movements across the three cognitive groups are reported in tabular form in **Table 4.3**. It can be observed that the Field Dependent group of users was associated with the numerically highest mean value of fixations (M = 157.26) during the visual images tasks, in comparison with the Field Neutral and the Field Independent participants. In order to test the hypothesis that individuals' FD-I cognitive style had an effect on their eye movement behaviour in relation to the number of fixations they produce, a one-way analysis of variance (ANOVA) was performed (see **Table 4.4**).

The independent variable was the cognitive style factor, divided into three groups: (a) Field Dependence, (b) Field Neutral and (c) Field Independent. The dependent variable was the difference in the number of fixations as a result of the user eye-movement activity. The findings yielded a statistically significant effect at the level $p < .001$ within the three cognitive groups, $F(2, 51) = 52.52$, $p < .001$, $\eta^2 = .67$. Thus, the null hypothesis of no differences between the means was rejected. The strength of the relationship was medium to high ($\eta^2 = .67$) with the cognitive type factor accounting for 67% of the variance of the dependent variable (number of fixations). As a medium to evaluate the nature of the differences between the three means, further comparisons were followed up, with the use of the Fisher's LSD post-hoc test (Hayter, 1986). The Fisher LSD is 8% more powerful than Tukey's HSD (Seaman, Levin and Serlin, 1991) and therefore was selected as the most appropriate post-hoc criterion. The LSD test revealed statistically significant differences between all the three different cognitive pairs (see **Table 4.5**). The differences between the Field Dependent and Field Independent (M = 113.96), Field Dependent and Field Neutral (M = 74.06) and the Field Independent and Field Neutral groups (M = 39.90) were statistically significant. Additionally, the statistically significant differences between the means were associated with medium effect sizes (d = -2.47; d = -2.48 and d = -2.45, respectively) based on Cohen's (1992) guidelines.

Table 4.3 Descriptive statistics for cognitive group x number of fixations; x number of saccades.

Cognitive group	*N*	*Means*		*SD*	
		Fixations	*Saccades*	*Fixations*	*Saccades*
FD	26	157.26	153.74	49.87	50.90
FN	16	83.20	84.55	9.76	18.00
FI	14	43.30	42.14	14.52	13.50
Total	54	105.77	104.31	59.52	59.20

Field Dependence-Independence and Saccades Effects. A visual depiction of the descriptive statistics of users' eye movements in relation to the three cognitive groups is presented in **Table 4.3**. It can be observed that FD participants generated a greater number of saccades (M = 153.74) in contrast to the FN and the FI users. A one-way ANOVA was computed to compare the effect of the FD-I cognitive construct style on users' eye movements with regards to the number of saccades they produce (see **Table 4.4**).

The independent variable remained the same (cognitive type factor), and the dependent variable was the change in the number of saccades in consequence to the user's eye patterns. The results showed that the effect of cognitive style on users' eye movement behaviour was significantly different across the three cognitive groups $F(2, 51) = 45.46$, $p < .001$, $\eta^2 = .64$ at the $p < .001$ level (see **Table 4.4**). With a view to understanding how much the independent variable (cognitive type) has affected the dependent variable (average number of saccades) the effect size was calculated with the use of the eta squared (η^2). The effect size related to the statistically significant effects is interpreted as moderate to high ($\eta^2 = .64$) and shows the strength of association between the variables. Therefore, the null hypothesis of no differences between the means was rejected, and the 64% change in the number of saccades was accounted for by the FD-I cognitive dimension.

In furtherance to better interpreting the data and being able to measure the degree of association between the variables, post-hoc analyses using the Fisher's LSD criterion for significance were conducted to evaluate the pairwise difference between the means, and to demonstrate what these differences entail. The test revealed statistically significant differences between all three different cognitive pairs (see **Table 4.5**). Significant differences in the means of the Field Dependent and Field Independent (M = 111.60), Field Dependent and Field Neutral (M = 69.19) and the Field Independent and Field Neutral groups (M = 42.40) were observed. Furthermore, the statistically significant differences between the means of the three cognitive groups were associated with medium effect sizes (d = -2.45; d = -2.46 and d = -2.43, respectively) based on Cohen's (1992) guidelines.

These results exemplified that the FD-I cognitive style factor influenced users' eye movement activity. Notably, the findings declare that the average number of saccades was significantly higher in the Field Dependent group than the two other groups (Field Neutral and Field Independent). This outcome confirms the results of a previous study in which the effect of FD-I cognitive dimension of website complexity was examined.

The findings demonstrated that the FD participants needed more time to complete a task within a visually complex website with regards to the FN and FI users' (Nisiforou, Michailidou, & Laghos, 2014).

Table 4.4 One-way ANOVA between the three cognitive groups x number of fixations; x number of saccades.

		SS	*df*	*MS*	*F*
Between Groups	Fixations	126407.30	2	63203.65	52.52**
	Saccades	118994.66		59497.33	45.46**
Within Groups	Fixations	61377.86	51	1203.49	
	Saccades	66745.30		1308.73	
Total	Fixations	187785.16	53		
	Saccades	185739.96			

** $p < .001$.

Table 4.5 Fisher LSD post-hoc comparisons between the three cognitive groups x fixations; x number of saccades.

Cognitive groups		Fixations	Saccades
		Mean	*Mean*
FD	FN	74.06*	69.19*
	FI	113.96*	111.59*
FN	FD	-74.06*	-69.19*
	FI	39.90**	42.40**
FI	FD	-113.96*	-111.59*
	FN	-39.90**	-42.40**

*$p < .01$. **$p<0.001$.

4.6. Discussion

The effect of the Field Dependence-Independence cognitive style on users' eye movement patterns was examined using eye-tracking analysis and statistical tests (one-way ANOVA). The objective of the study was to investigate (a) whether users' cognitive style affects their eye movement patterns and, if so, how, and (b) to explore the relationship between the three cognitive groups (FD, FN, FI) and the eye movement features (fixations and saccades). It was hypothesised that users of different cognitive style groups might exhibit different eye movement patterns. Specifically, it was assumed that the Field Dependent participants would be less task-oriented and disorganised in their image viewing processing, producing higher values of fixations and saccades, compared to the FN and FI groups. The next sections address the two research questions set in the experiment of the requirements of Study 2.

RQ 4.1: How does users' Field Dependence - Independence cognitive type affects their eye movement behaviour during visual search tasks?

The eye-tracking study revealed some implicit knowledge of users' cognitive characteristics and gaze patterns and exemplified that user navigation preferences do reflect their cognitive styles (Nakić & Granić, 2009). Earlier studies found that user cognitive abilities such as perceptual speed and visual/verbal memory have a significant impact on user gaze behaviour and user performance in terms of task difficulty within a given visualisation (Toker, Steichen, Gingerich, Conatiand & Carenini, 2014; Toker et al., 2012).

Specifically, in this study, eye movement patterns are influenced by users' FD-I cognitive type and were analysed through the eye-tracking gaze plots (scan path) and attention maps (heat maps) analysis. The results revealed that although participants were engaged in the same computer-based viewing stimuli, they tended to demonstrate different visual behaviour patterns. The resultant findings were discussed in view of common and different navigation patterns in relation to the three cognitive style categories.

The gaze date exemplified that the eye movement patterns of the three cognitive groups (Field Dependent, Field Neutral, Field Independent) is affected in a different way. As a case in point, the FD users' gaze plots analysis revealed that their scan paths during the visual images search tasks process were more disoriented and disorganised in contrast to those of the FI subjects, displayed more oriented and organised scan paths. These findings are in accordance with the results of a recent study that examined the online behaviour of FD, FI and FN in visually complex web pages with the use of the eye-tracker device. The authors stated that the FD users' scan paths appeared to be more disoriented and scattered within visually complex pages in contrast to the FI subjects, who revealed more oriented and organised gaze plots (Nisiforou & Laghos, 2014). Besides, Michailidou (2009) found that visually complex pages generate users' disoriented navigation, while visually simple pages produce the opposite perspective. Similar results were also reported in a work conducted by Harper, Michailidou and Stevens (2009). Additionally, the FD group heat maps indicated users' difficulty in detecting the correct response. This outcome reflects what was said by Goodenough (1987) that the people who are more Field Dependent experience difficulties perceiving a part separately from the complex whole in which it is embedded. On the contrary, the heat maps presented by the FI individuals illustrated that they could recognise the correct shape within the complex pattern as the green heat maps overlapped with the correct responses given by the users. This result is supported by Zhang's work (2004) that FI individuals face less difficulty in separating essential information from its context than do FD subjects.

RQ 4.2: What are the differences between users' FD-I cognitive style and eye movement (EM) behaviour in visual search tasks?

The majority of the existing studies examine the Field Dependence-Independence cognitive style in terms of time taken to respond to a problem-solving and task performance. The findings of the current study are discussed with respect to how Field Dependent, Field Neutral and Field Independent groups interact while performing visual images tasks and how this interaction differs in terms of the eye movement features (fixations and saccades) they produce. The number of fixations and saccades were compared in relation to the FD-I cognitive dimension. The results showed that the eye movements produced by the three cognitive groups differed significantly. In summary, the highest number of fixations and saccades were detected from the FD group, in contrast to the FN and FI groups, which produced fewer values of fixations and saccades.

Furthermore, the eye-tracking and simulated data also suggest that although users were processing the same visual stimuli, they tended to demonstrate different cognitive traits.

The effects of the two variables concerning the participants' FD-I cognitive type and eye movement features were significantly correlated. This fact reflects the findings of previous work where users' level of Field Dependence validated the data retrieved and a large variation in task completion time among the FD-I cognitive groups (Nisiforou & Laghos, 2013) was found. These findings seem to comply with Tinajero and Paramo's results (1997), which found that Field Independent students perform better than Field Dependent students. Isaak-Ploegman and Chinien (2009) mentioned in their study that Field Independent learners outperform Field Dependent students in terms of their scores on the Hidden Figures Test.

Additionally the results of previous work (Burnett, 2010) hypothesised that FI learners will outperform FD learners with respect to time taken to responsd correctly to the problem-solving task. An earlier study (Nisiforou & Laghos, 2013) found that the groups of FD and FI exemplified differences in their eye movement features in terms of task time completion, with the former group outperforming the latter. The results of the current study revealed that users' cognitive style has a significant impact on user gaze behaviour and that this influence is detectable through eye-tracking metrics. This outcome was discussed in a previous study where cognitive style was related to differences in the online searching tasks (Józsa & Hámornik, 2012).

4.7. Summary

Overall, the novel research findings indicated that eye movement behaviour differs significantly between different cognitive groups. Particularly, the Field Dependent (FD) group produced a more disoriented EM activity and generated the greatest number of fixations and saccades of the three cognitive groups. Specifically, the combination of FD-I cognitive style and EM components/fixations-saccades used in this study identified that: (i) the eye-tracking metrics revealed useful information regarding users' Field Dependence-Independence cognitive activity, (ii) the developed visual stimuli could be used as an additional objective battery to classify users' FD-I cognitive style. Also, these findings verify those presented in Chapter Three, where eye-tracking technology was revealed to be a promising tool for identifying individual differences in FD-I as well as in measuring level of Field Dependency. In the next chapter, Experiment

3 is presented and concentrates on the association between FD-I cognitive style, eye gaze patterns and creative thinking. 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 examining individuals' cognitive components in correlation to visual perception. Therefore, the purpose of the upcoming study 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 shift spontaneously back and forth between analytic and associative modes of thought according to the situation (Gabora, 2010). 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 (Ekstrom et al., 1976). Besides, focusing on specific patterns activates memory that supports divergence or convergence (Gabora, 2000). 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. Moreover, the notion that Field Independent people have been found to be more creative than those who are Field Dependent remains vague. Earlier studies have proposed that the use of ambiguous stimuli may in some way be associated with degrees of creativity (Urban, 2003; Wiseman, Watt, Gilhooly, & Georgiou, 2011; Dove & Jones, 2014). These lines of indication suggest that the more individuals can tolerate ambiguous objects, the more creative they become. Therefore, this evidence provided me with the opportunity to examine the plausible link between individuals' FD-I cognitive style, eye movements and creativity in the next chapter.

5. CHAPTER FIVE

STUDY 3 – FIELD DEPENDENCE-INDEPENDENCE AND CREATIVITY

5.1. Overview

Previous research has analyzed the impact of different cognitive styles on idea generation and creativity (Miron, Erez & Naveh, 2004). The Field-Independence/Dependence consists one of the perceptual phenomena that has been related to creativity (Goodenough, 1976). Creative people could be considered Field-Independent, in that they can extract useful information from a confusing matrix of input without being distracted or overwhelmed by extraneous and irrelevant external cues, as Field-Dependents would be. Hence, FI individuals could do well on tasks such as the ones involved in the hidden figures test, which examines the ease or difficulty of finding a simple figure embedded within a distracting complex pattern (Witkin et al., 1963). Martinsen and Kaufmann (1999) examined the link between the FD-I cognitive style and creativity and claimed that Field Dependent individuals are less creative than the Field Independents. The aim of Study 3 is to investigate this association and to strengthen past literature that supported this counter since the causality of these associations remains unclear. More specifically, Study 3 focuses on the investigation of individual differences in the Field Dependence-Independence cognitive style as resulted in their performance on the HFT compared to the level of creative thinking on their performance on the TTCT.

5.2. Research Questions

It is hypothesized that Field Dependency will have an effect on students' creative thinking. This hypothesis may be useful to explain differences in both creativity levels and its five components attributed to it. Particularly, it was surmised that Field Dependent individuals would be characterized as lower creative participants', whereas; Field Independents would be categorized as highly creative thinkers. Study 3 was designed to contribute towards the exploration of the following research questions:

RQ 5.1 What is the relationship between Field Dependence – Independence cognitive type, creative thinking and creative thinking?

RQ 5.2 How does Field Dependence – Independence cognitive type affects creative thinking?

RQ 5.1 What is the association between Field Dependence - Independence cognitive type and each of the five creativity components?

RQ 5.4 How does Field Dependence - Independence cognitive type affect creativity components?

5.3. Method

5.3.1. Participants

Forty psychology undergraduates with mean age 20,77 years (SD = 3.309) from the University of Plymouth in the U.K. participated in this experiment for course credit. The particular group of students was chosen as they are considered to have an extensive knowledge on the human cognitive developmental processed which are important for the design process of PLE and TEL environments.

5.3.2. Materials and Procedure

Participants' Field Dependence-Independence cognitive style and creative thinking were examined. Two research instruments were used to collect data. By using the FD-I cognitive approach, individuals level of Field Dependency was assessed with the Hidden Figures Test (HFT) as in the previous Studies 1 and 2 (Ekstrom et al., 1976) (see Psychometric Test Phase of Study 1, Chapter 3 p. 76).

To measure students' creativity, the Figural Form of the Torrance Tests of Creative Thinking (TTCT; Torrance, 1974) was employed. The TTCT was developed by Torrance (1966) and it is one of the most commonly tools used to measure the five dimensions of creative ability (Fluency, Originality, Abstractness of titles, Elaboration and Resistance to premature closure). It is composed of verbal and figural subtests and it is the most well-known and widely used tool for measuring creativity (Baer, 1993; Kim, 2006; Wechsler, 2002). The Scholastic Testing Service, Inc., holds the copyright of the TTCT, Torrance Tests of Creative Thinking (TTCT). According to the TTCT-Figural Manual of 1998, the reliability estimates of the creative index ranged between .89 and .94 (Kim, 2006).

For the requirements of this study, the TTCT-Figural Response Booklet A (Torrance & Ball, 1984; see also Torrance, 1966) was administered and scored according to the guidelines in the instruction manual and scoring guide (Torrance, 1966; Torrance & Ball, 1978, 1984). The Figural TTCT measures five aspects of creative ability: fluency, originality, abstractness of titles, elaboration, and resistance to premature closure. It is divided into 3 non-verbal activities: Picture Construction, Picture Completion, and Lines and Circles (repeated figures). The TTCT is divided into three sections: Picture Construction; Incomplete Figures Activity; and Repeated Figures Activity. It requires a total working time of 30 minutes with a 10-min to complete each activity, so speed is important. Once the time for each activity is over, participants have to move onto the next activity. In all three activities, the figures are scored for fluency (number of pictures drawn), flexibility (number of different categories of pictures drawn), originality, and elaboration. Participants provide a name title for each object or picture. The instructions encourage participants to make the title as clever and unique as possible, and to use it to help communicate their stories. The titles are evaluated for abstractness. A brief description of each activity is provided below.

In Activity I (Picture Construction), the participants' construct a picture or an object using a given pear or jelly bean shape provided on the page as a stimulus. The stimulus must be an integral part of the picture construction. The instructions encourage participants to think of new ideas that no one else will think of, thereby eliciting original responses. The product is scored for its elaboration (amount of detail added) and originality (statistical rarity or uncommonness).

Activity II (Picture Completion) requires the subject to use 10 incomplete figures and add lines to make an interesting object or picture for each incomplete picture. Each figure is scored for flexibility (resistance to premature closure), originality, and elaboration.

The last activity, Activity III (Lines), is composed of 30 lines spread across three pages that the subject is to use as a part of his or her picture (Torrance, 1966, 1974, 1990, 1998; Torrance & Ball, 1984). The participants have to sketch as many different objects or pictures as possible and put as many ideas as they can in each one, with the lines being the main part of their drawing. As with the other two activities, participants try to think of things that no one else will think of, and attempt to communicate an interesting story as they can.

5.4. Results

5.4.1. Field Dependence-Independence cognitive ability

The findings of the study are discussed in terms of the association between FD, FN and FI users and the level of creativity (Nisiforou, 2015). As previously mentioned, the Hidden Figure Test (HFT) was used to define users' FD-I current cognitive type (e.g. Field Dependent, Field Neutral/Mixed and Field Independent). 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 illustrated in **Table 5.1**. The testing activity involved in the HFT is a reliable and widely used approach for determining FD-I cognitive dimension. The alpha coefficient test for the reliability of the Hidden Figures Test reflected the degree of 0.851.

Table 5.1 Classification and Distribution of Subjects according to the FD-I Dimension (N = 40).

	FD- I Classification
Field Dependence (FD) HFT: 0-10	16*
Field Neutral (FN) HFT: 11-17	9
Field Independence (FI) HFT: 18-32	15

* Number of subjects, ** HFT cut off scores

5.4.2. Level of creative thinking

The results from the Torrance Test of Creative Thinking (TTCT) revealed participants' level of creative thinking. The measures result in 5 norm-referenced scores (Fluency, Originality, Elaboration, Abstractness of Titles and Resistance to Premature Closure) and 13 criterion-referenced (creative strengths) scores. The cut-off scores procedure for determining the three levels of creativity (Low, Moderate and High) was followed based on previous studies that have used the standard deviation and the mean of the Creativity Index (Nemeržitski, 2009; Rababah & Jdaitawi, 2013). The total creativity score known as Creativity index was the sum of the five components and the 13 creative strengths. Based on this classification, participants were classified as 8 Low creative thinkers, 28 moderate creatives, and 4 high creatives.

5.4.3. FD-I cognitive style and level of Creativity

A Pearson correlation coefficient was computed to assess the association between Field Dependence-Independence cognitive style and creativity. In addition, researchers now often argue that the overall Creativity Index is the best predictor of creative ability (e.g., Plucker, 1999; Baer, 2011).

There was a positive correlation between the two variables, $r = 0.428$, $n = 40$, $p = .006$. A one-way between subjects ANOVA was conducted to compare the effect of the FD-I on users' level of creative thinking. There was a significant impact on the level of Field Dependency on creative thinking at the $p<.05$ level for the three cognitive groups $F(2, 37) = 5.657$, $p = .007$. As a means to evaluate the nature of the differences between the three means, further comparisons were followed-up, with the use of the Fisher's LSD post-hoc test (Hayter, 1986).

The Fisher LSD is 8% more powerful than Tukey's HSD (Seaman, Levin & Serlin, 1991) and therefore selected as the most appropriate post-hoc criterion. The LSD test revealed statistically significant differences between all the three different cognitive pairs (see **Table 5.2**).

Creativity components		SS	df	MS	F	Sig.
Fluency	Between Groups	2273.98	2	1136.99	3.22	0.051
	Within Groups	13053.99	37	352.81		

	Total	15327.98	39			
Originality	Between Groups	3567.83	2	1783.92	5.72	0.007*
	Within Groups	11547.77	37	312.10		
	Total	15115.60	39			
Elaboration	Between Groups	981.40	2	490.70	6.52	0.004*
	Within Groups	2786.60	37	75.31		
	Total	3768.00	39			
AbstrTitles	Between Groups	2518.64	2	1259.32	2.32	0.112
	Within Groups	20076.34	37	542.60		
	Total	22594.96	39			
Closure	Between Groups	4219.28	2	2109.64	5.05	0.011*
	Within Groups	15446.62	37	417.48		
	Total	19665.90	39			
Creative Strengths	Between Groups	1690.62	2	845.31	1.96	0.155
	Within Groups	15973.16	37	431.71		
	Total	17663.76	39			
Creativity Index	Between Groups	8329.94	2	4164.97	5.66	.007*
	Within Groups	27239.16	37	736.19		
	Total	35569.10	39			

Table 5.2 One-way ANOVA between the three FD-I cognitive groups; creativity (components, strengths, index).

Note. * $p < .05$. ** $p < .01$.

Post-hoc comparisons using the Fisher's LSD criterion for significance indicated that the mean score for the Field Dependence cognitive group (M = 118.00, SD = 30.45) was significantly different from the Field Independence group (M = 147.27, SD = 22.80), $p = .005$. Moreover, the Field Neutral subjects (M = 116.56, SD = 28.75) were significantly different from the Field Independents), $p = .011$. Taken as a whole, these results suggest that users' level of Field Dependency has an effect on their level of creative thinking.

On the whole, the 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. However, it should be noted that there were no statistically significant differences between the Field Dependence and Field Neutral cognitive groups (p = .90).

5.4.4. Field Dependence-Independence cognitive style and Creativity components

5.4.4.1. Fluency

There was not a positive correlation between FD-I and Fluency two variables, p = .164. There was a not significant effect on the level of Field Dependency on creativity's fluency component $p<.05$ level for the three cognitive groups F (2, 37) = 3.22, p = .051. Post-hoc comparisons using the LSD test exemplified that the mean score for the Field Independence cognitive group (M = 147.27, SD = 22.80) was significantly different from the Field Neutral group (M = 116.56, SD = 28.75), p = .017. However, the pairs of FD-FN and FD-FI groups were not significantly different. This result can be supported by a recent study that determines the fluency component as less important creativity measurement than originality (Runco & Jaeger, 2012).

5.4.4.2. Originality

There was a positive correlation between the two variables (FD-I cognitive style and originality component), r = 0.368, n = 40, p = .019. A significant effect of the level of Field Dependency on originality component $p<.05$ level for the three cognitive groups F (2, 37) = 5.72, p =.007 was found. Post-hoc comparisons using the LSD test showed that the mean score for the Field Dependence cognitive group (M = 118.00, SD = 30.45) was significantly different from the Field Independence group (M = 147.27, SD = 22.80), p = .013. Moreover, the Field Neutral users' (M = 116.56, SD = 28.75) were significantly different from the Field Independents, p = .004. The pair of the FD and FN groups was not significantly different.

5.4.4.3. Elaboration

There was a positive correlation between FD-I and Elaboration variables, r = 0.373, n = 40, p = .018. A significant impact of the level of Field Dependency on elaboration component p<.05 level F (2, 37) = 6.52, p = .004 was found. Post-hoc comparisons using the LSD test indicated that the mean score for the FD cognitive group (M = 118.00, SD = 30.45) was significantly different from the FI group (147.27, SD = 22.80), p = .011. Moreover, the FI group was significantly different from the FN one (M = 116.56, SD = 28.75), p = .002. Besides, there was not a significant effect of the FD-I cognitive style on the elaboration component between the FD and FN groups of students.

5.4.4.4. Resistance to Premature Closure

The findings yielded a positive correlation between Field Dependence-Independence cognitive style and resistance to premature closure, r = 0.452, n = 40, p = .003. Besides, there was a significant effect of the level of Field Dependency on premature closure component of creativity p<.05 level for the three cognitive groups F (2, 37) = 5.05, p = .011. Post-hoc comparisons using the LSD test demonstrated that the mean score for the Field Dependence cognitive group of people (M = 118.00, SD = 30.45) was significantly different from the Field Independence individuals (147.27, SD = 22.80), p = .004. In addition, no significant differences exist between the FD and FN groups, p = .059.

However, it should be noted that there were no statistically significant differences between the FD-I cognitive style and the creativity subscale measures; Abstractness of Titles, F (2, 37) = 2.32, p = .112 and Creative strengths F (2, 37) = 1.96, p = .155.

5.5. Discussion

It was hypothesized that individuals' FD-I cognitive style affects their degree of creative thinking. Specifically, it was surmised that the Field Independent will produce a higher level of creativity, contrary to the Field Neutral and Field Dependent users who might exemplify a moderate and a lower creativity level, respectively. Overall the results suggest that the hypotheses of the study were supported by the data analysis.

The effect of the Field Dependence-Independence cognitive style on users' creative thinking was examined and statistically tested. The objectives of the study were to examine the association between Field Dependence-Independence cognitive style and creativity, (b) explore if FD-I has an effect on creativity index, and its five components (Fluency, Originality, Elaboration, Abstractness of Titles and Resistance to Premature Closure) and (c) provide insights on the causality of these associations which heretofore remained unclear. The subsequent sections are discussed in terms of the four research questions of the study.

RQ 5.1 What is the relationship between Field Dependence – Independence cognitive type, creative thinking and creative thinking?

RQ 5.2 How does Field Dependence – Independence cognitive type affect creative thinking?

A relationship and effect between the two variables were found in the data analysis, demonstrating that the link between FD-I and creative thinking is statistically significant. Moreover, the results yielded that creativity was influenced by their FD-I cognitive type. This is in accordance with the findings of a previous study that demonstrated a significant relationship between Field Dependence-Independence cognitive style and creativity (Miller, 2007). Although earlier work has used the Group Embedded Figures Test (GEFT) to assess participants FD-I cognitive type, this study has employed an alternative test (Hidden Figures Test) that measures the same cognitive dimension (Field Dependence-Independence). The emerged findings were discussed in view of common and different navigation patterns in relation to the three cognitive style categories. The results demonstrated that Field Dependent individuals are less creative than the Field Independent. This finding is in agreement with a previous study which revealed that participants' level of Field Dependency found to be related to creativity (Martinsen & Kaufmann, 1999) and claimed that Field Dependent individuals are less creative than the Field Independents. The subsequent section addresses the finding of the study with reference to the two following research questions.

RQ5.3. What is the association between Field Dependence - Independence cognitive type and each of the five creativity components?

RQ5.4. How does Field Dependence - Independence cognitive type affect creativity components?

The FD-I dimension was correlated significantly with the 4 out of the 5 creativity sub-scores along with the Abstractness of Titles component and the creative strengths. This finding can be explained and corroborated with a study that examined the relationship between FD-I cognitive classification by using the Group Embedded Figures Test (Niaz & Saud de Núñez, 1991) and creativity sub-scores on academic performance. Despite the fact that the researcher did not administer the HFT to classify students into their Field dependency, the difference between the GEFT and HFT test is negligible. Similarly to the findings of Niaz's and Saud de Núñez's study, the mobile students (synonym to Field Independent) scored significantly higher as compared to fixed students (alternative expression to Field Neutral) on all the sub-scores of the Torrance Tests of Creative Thinking (TTCT). The link in this analysis was in agreement with the predicted assumption, giving inference on the positive impact of FD-I on creativity. The results suggest that the higher the performance on the HFT, the higher the creativity score. More specifically, this outcome showed that the Field Independent individuals performed significantly higher on the TTCT than those who were classified as Field Dependent.

The finding can provide useful explanations for the derived differences in both creativity levels and its five components attributed to it. Taking everything into account, Field Independent individuals can be characterized as the ones who exemplify a more creative thinking than the Field Dependent ones who are turned out to be less creative people. Finally, the Field Neutral/Mixed individuals showed a more moderate creative thinking. This outcome was anticipated as the FN group of people sometimes behaves as Field Dependent or Field Independent according to the learning situation.

5.6. Summary

This study provides evidence for the hypotheses that both Field Dependent - Independent cognitive style and creativity are correlated. Results obtained support from the previous literature. The findings revealed differences between individuals' FD-I cognitive style and level of creative thinking. This result was statistically examined indicating significant differences between the three cognitive groups. Overall the results indicated that individuals’ level of Field Dependency has an effect on their level of creative thinking. The forthcoming study aims to investigate the mechanisms that underlie the association between FD-I cognitive style, eye gaze patterns, and creative thinking with the use of ambiguous figures and psychometric measures.

6. CHAPTER SIX

STUDY 4 - FIELD DEPENDENCE – INDEPENDENCE COGNITIVE ABILITY, CREATIVITY AND EYE MOVEMENTS

6.1. Overview

In this Chapter, Study 4 concentrates on the association between FD-I cognitive style, eye gaze patterns and creativity during interaction on a set of visual tasks. Evidences gathered from the previous studies reported in this thesis provided promisingly fertile ground, and make it plausible that there is a link between the three concepts.

More specifically, Study 1 elucidated the potential of eye-tracker as a new method of assessing users' individual differences in the Field Dependence-Independence cognitive style. The experiment in Study 2 captured the real-time eye gaze information of adults and investigated further the FD-I cognitive type in association with the eye movement (EM) patterns while interacting with a set of visual tasks. The results found that users' cognitive style has an effect on eye gaze behaviour and these differences were manifested in eye-gaze patterns. Subsequently Study 3, on the other hand, revealed differences between individuals' FD-I cognitive style and level of creative thinking. Overall the results indicated that individuals' level of Field Dependency has an effect on their level of creative thinking.

Therefore, the purpose of the upcoming Study 4 is to look for any possible connections between the FD-I processing style, creativity and eye movements. The use of the two psychometric tests (HFT and TTCT), a set of ambiguous figures and the eye- tracking biometric technique were employed to investigate the mechanisms that underlie the association between the variables tested.

6.2. Research Questions

To provide information regarding the link between FD-I cognitive style, eye gaze patterns and creativity the below research questions were raised:

> RQ 6.1 What is the relationship between individuals' FD-I processing style and visual search performance on perceptual tasks?
>
> RQ 6.1 What is the relationship between individuals' level of creativity and visual search performance on perceptual tasks?
>
> RQ 6.3 How can FD-I cognitive style and creativity predict a learner's performance on visual search task?

6.3. Method

6.3.5. Participants

Forty-four psychology undergraduates with mean age 20, 8 years (SD = 3, 2) from a Public University in the U.K. participated in this experiment for course credit. All participants were right-handed native English speakers with normal or corrected-to-normal vision.

6.3.6. Experimental design

The experimental design of the environment was programmed through the iView SDK software development (kit-interface). Data were collected in three-phases following a random order.

a) Phase 1 was the completion of the Psychometric tests (see Appendix F) for permission of use),
b) Phase 2 the Practice/Trial, and
c) Phase 3 the Ambiguous/ Figures Task.

The entire study lasted approximately 1 hour and 30 minutes. After signing the consent form, instructions were presented specific to each test, and participants had short breaks between the three phases. As a means to reduce the chances of affecting the results due to order effects, a counterbalanced design was followed. Thus, each individual participated in the three phases of the experiment in a random order.

6.3.7. Materials

A number of twenty ambiguous images (ten Content ambiguous figures and ten Figure/ground ambiguous images) and ten unambiguous images (normed images; control images) were retrieved from Snodgrass and Vanderwart's (1980) norms and were served as the visual stimuli of the experiment. The stimuli were scaled to the same dimension (1280x1024 pixels), equalized for intensity (see **Figure 6.1**) and appeared in a random order. Thirty images were used for the main experiment and four for the practise/trial phase.

6.3.8. Procedure

Participants were placed in front of an eye-tracker and asked to perform perceptual tasks on thirty images. While viewing the images, subjects' eye activity was recorded with the use of the eye-tracking system. Gaze was calculated and sampled at 60 Hz. Before starting the main experimental phase, a trial version using four stimuli took place and the eye-tracker was calibrated and validated using a standard nine-point calibration displayed on the monitor. Participants were required to successively fixate each of the nine points. Calibration procedure was repeated until it was processed successfully. In addition, students were naïve to the purpose of the study and have never seen the ambiguous/reversible figures before. The individuals were initially categorized into their current FD-I cognitive style (Field Dependent, Field Neutral and Field Independent) and creativity level on their performance on the Hidden Figures Test (HFT) (Ekstrom et al., 1976) and Torrance Test of Creative Thinking (TTCT) (Torrance, 1966). Finally, the three phases of the study are described thoroughly in the next sections.

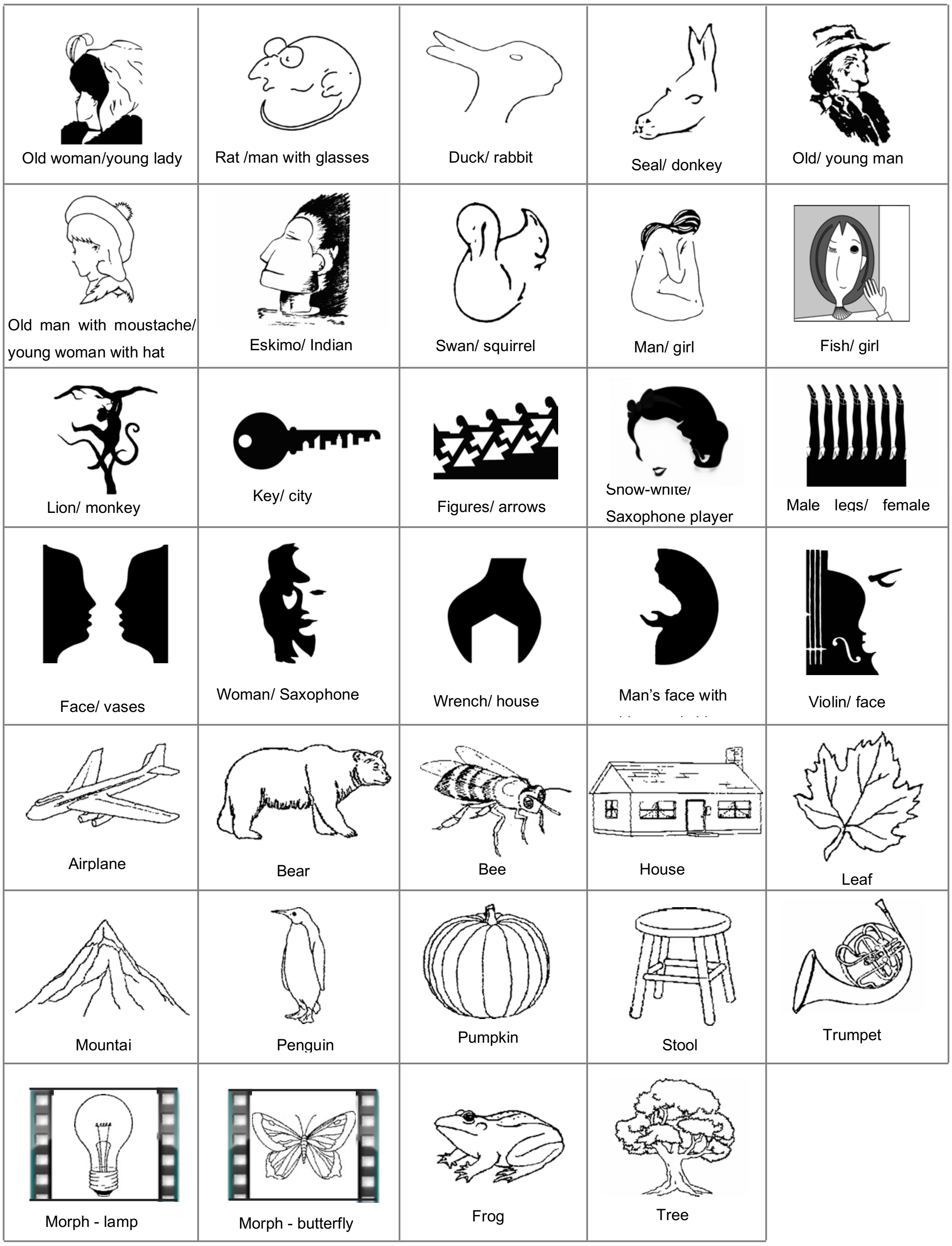


Figure 6.1 Index of the thirty-four stimuli of the trial and experimental phase.

This phase refers to the completion of the two psychometric tests; the Hidden Figures Test (HFT) and the Torrance Test of Creative Thinking (TTCT). The total duration time for the completion of the two tests was fifty-four minutes; 24 minutes and 30 minutes respectively.

6.3.8.1. **Hidden Figures Test** (HFT)

Participants' level of Field Dependency was measured with the use of the Hidden Figures Test (Chen & Macredie, 2004; Angeli, 2013, Nisiforou & Laghos, 2013, Nisiforou & Laghos, 2015). The test was the same one used for the requirements of the previous studies (Study 1, Study 2 and Study 3) including different sample (see Psychometric Test Phase of Study 1, Chapter Three, p. 76). In this research study the reliability of the internal consistency of the Hidden Figures Test was 0.851 as obtained through Cronbach's alpha coefficient (Cronbach, 1977).

6.3.8.2. **Torrance Test of Creative Thinking** (TTCT)

Participants' level of creative thinking was assessed with the use of the TTCT; the well-known and widely used tool for measuring creativity (Baer, 1993; Kim, 2006; Wechsler, 2002). On the report of the TTCT-Figural Manual of 1998, the reliability estimates of the creative index ranged between .89 and .94 (Kim, 2006). For the requirements of this study, the TTCT-Figural Response Booklet A (Torrance & Ball, 1984; see also Torrance, 1966) was administered and scored according to the guidelines in the instruction manual and scoring guide (Torrance, 1966; Torrance & Ball, 1978, 1984). The TTCT was used for the requirements of the previous study (Study 3) containing a different sample (see 5.3.2. Chapter Five, Materials and Procedure, p.79).

6.3.8.3. Ambiguous Figures Task - Training phase

The practice/trial phase (see **Figure 6.2**) consists of two images: one morphed that changed from a vase to a lamp or from a ribbon to a butterfly and one normed image that did not change and pictured a frog or a tree. Images remained on screen for 60 seconds each followed by a 500ms inter-stimulus interval (ISI) - time window, showing a blank screen with a fixation point between the presentation of each image. This phase aimed to introduce the subjects into the experimental procedure (learn which bottom to press and when) as well as to familiarize themselves with the concept of change without introducing them to the concept of ambiguity. Participants were instructed to press the "SPACE" or "ENTER" button as soon as they could tell what the image was. If they could see the image changes into something else, they had to press the button again.

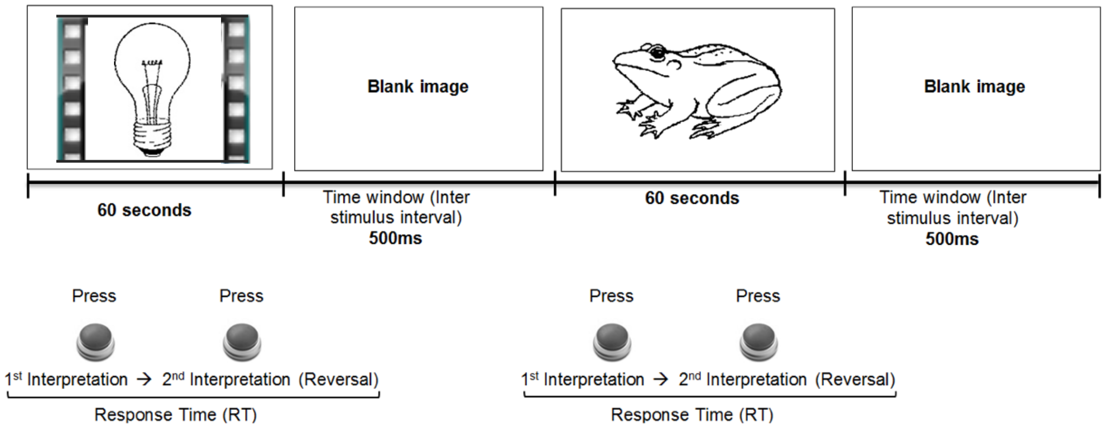


Figure 6.2 Set up of the experiment practice/trial procedure.

6.3.8.4. Ambiguous Figures Task - Main Experiment

Phase 3 consists of the main experiment (see **Figure 6.3**). Participants' were requested to perform ambiguous figures tasks and identify the two meanings (interpretations) that were embedded in each ambiguous figure. They were asked to indicate their response by pressing the "SPACE" or "ENTER" button when they see the first interpretation and press again if they see the content of the image changing into something else (second interpretation). The presentation time of each figure remained the same as that of the Practice/ Trial Phase 1 as a means to capture each individual's real stage time of performance on the stimuli interaction. Each one of the thirty (30) images was presented for 60 seconds in random order across participants. A blank page with a fixation point appeared in the center of the screen with a time-window of 500 ms between the presentation of each stimulus. More specifically, if the participant sees both interpretations, then the button is pressed two times and thus the experiment moves immediately onto the next stimulus. On the other hand, if the participant sees one interpretation, the, button is therefore pressed only one time. Hence, the second button is not pressed and the experiment moves onto the next stimulus after 60 seconds. An example of the space ecology of the experiment is illustrated in **Figure 6.4**.

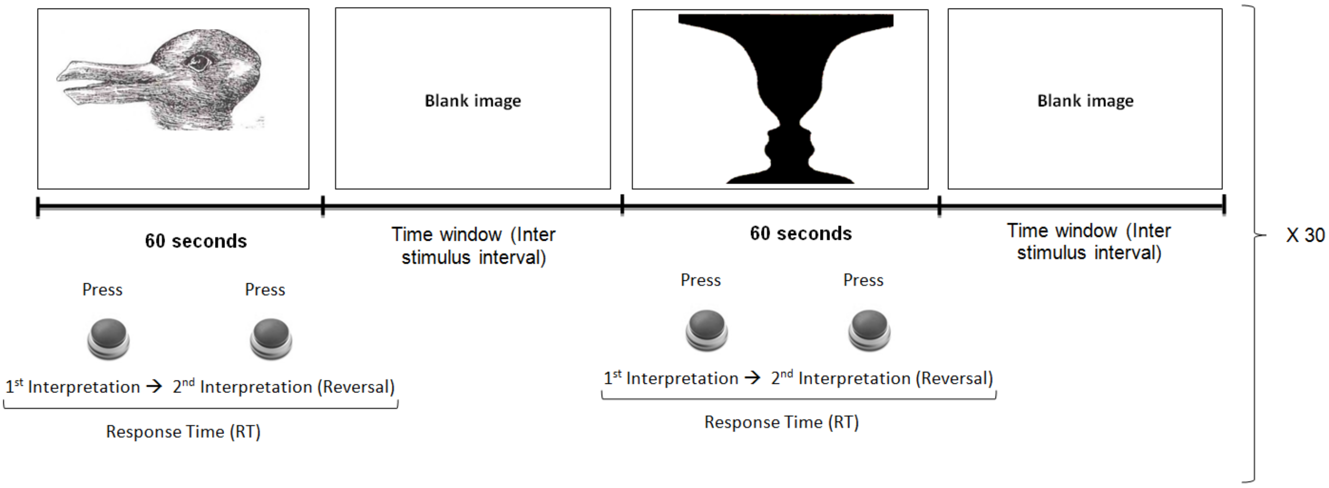


Figure 6.3 Illustration of the experiment loop structure (experimental paradigm).

Figure 6.4 Space ecology and example of an ambiguous figure presented on the monitor during the experimental phase.

By the end of the experiment participants had to respond to a close-ended question to report their naivety on the visual stimuli of the experiment. This question posted was Have you seen these images before?

6.4. Data Analyses

Participants' eye movements were recorded from the stimulus onset to the first button press and also between the first and second button press if one occurred. The eye-tracker-derived data and the HFT and TTCT tests were then statistically analysed with the use of the Statistical Package for the Social Sciences (SPSS) version 22.0.0.

6.5. Results

After the data were collected they were analysed with the use of the SPSS. In this section the findings addressing the research questions of the study are discussed in terms of the association between FD, FN and FI participants, their ability to reverse (perceptual switching) on ambiguous images (visual stimuli) and the eye movement components (number of fixations and saccades) they generate during a perceptual task process. Specifically the research questions where: "What is the relationship between individuals' FD-I processing style and ability to reverse (performance on the given task)? What is the relationship between individuals' level of creativity and ability to reverse?"

It was surmised that people, who have a higher FD-I processing style (Field Independents) and level of creativity (High level), will be more likely to perform better on visual perceptual tasks in terms of response time (reverse on ambiguous figures tasks) and, therefore, experience multiple interpretations of ambiguous stimuli.

To test the assumptions, a one-way analyses of variance (ANOVAs) (Post-hoc analysis using Fisher's LSD criterion) were performed to examine the effect of each independent variable (IVs': FD-I and CI) on participants' ability to reverse (DV: perceptual switching) ambiguous figures namely on response time (RT1, RT2) and eye movement components (number of fixations and saccades). FD-I processing style and creativity conditions were entered as a within participants factors. When a significant main group effect was found, analysis was followed by an LSD post-hoc test. The descriptive statistics are presented in a tabular form in **Table 6.1** and **Table 6.2** and show the means and standard deviations for each measure. **Table 6.3** and **Table 6.4** show the correlations among the measures.

Table 6.1 Descriptive statistics of FD-I processing style with respect to the ability to reverse and eye movement components.

FD-I Processing Style	*N*	Means (SD)			
		Ability to reverse		Eye movements	
		RT1	*RT2*	*Fixations*	*Saccades*
FD	19	3712.80 (4950.93)	31747.32 (14891.23)	192.42 (52.32)	199.80 (55.83)
FN	9	2563.56 (1422.56)	25808.22 (8431.19)	167.89 (91.48)	154.78 (47.26)
FI	16	3721.63 (7218.71)	19936.70 (14030.81)	156.70 (35.63)	155.00 (36.00)
Total	44	3480.93 (5388.55)	26237.73 (14246.00)	174.41 (58.43)	174.30 (51.74)

Table 6.2 Descriptive statistics of creativity level with respect to the ability to reverse and eye movement components.

Creative Thinking level	*N*	Means (SD)			
		Ability to reverse		Eye movements	
		RT1	*RT2*	*Fixations*	*Saccades*
Low	8	2060.88 (1629.83)	36384.63 (10439.32)	225.90 (80.00)	215.63 (47.03)
Moderate	31	4148.58 (6277.94)	25389.00 (14344.00)	163.70 (48.63)	166.30 (50.80)
High	5	1613.60 (231.50)	15265.00 (9266.08)	158.80 (35.82)	157.80 (36.50)
Total	44	3480.93 (5388.60)	26237.73 (14246.00)	174.41 (58.43)	174.30 (51.74)

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

6.5.1. Pearson Bivariate Correlations between dependent and independent variables

Forty-four participants were examined on their level of FPS (IV) (M= 1.93, SD= 0.90) and ability to reverse (DV) in terms of response time 2 (M= 26237.73, SD= 14246.00). A Pearson's r data analysis revealed a moderate negative correlation, *r* = -.40 (Table 5.3). Participants who had a lower level of FD-I processing style reported greater average number for response time 2 (RT2) in their ability to reverse. In addition, subjects' level of FPS and ability to reverse with respect to eye movement components (average number of saccades) was tested. The Pearson correlation demonstrated a moderate negative correlation, *r* = -.33 (see **Table 6.3**). Those who displayed lower levels of FD-I processing style reported greater average number of saccades in their ability to reverse on ambiguous figures.

Participants were also tested about their level of creativity and ability to reverse in terms of response time (T1 and T2). A Pearson's r data analysis revealed a moderate negative correlation, *r* = -.42 (see **Table 6.4**). Therefore, the data supported that those participants who exemplified a lower level of creative thinking reported greater average number of RT2 while reversing on ambiguous figures. In the following sections, first, the HFT data are presented. The TTCT data follow according to each creativity component.

Particularly, people with lower visuospatial type need more time to focus on specific patterns and therefore process information on visual search tasks. The correlation between the pair FD-I type and creativity yielded a positive correlation, *r* = .44. This result supports that people with higher FD-I processing type are more creative than those who are classified as Field Dependents and Field Neutrals individuals. Moreover, the saccadic and fixation eye movements are strongly positive correlated. Interestingly, the correlation between the number of fixations and creativity demonstrated a strong negative correlation. This result provides useful information for the participants who produced greater number of saccades, indicating their difficulty in extracting information from a scene, such as the ambiguous figures used in this study. In addition, the correlation between the number of fixations and participants' RT2 in the performing task was moderate positive. Those who displayed higher number of saccadic eye movements needed more time to perform the tasks and hence show greater RT2 than those who produced lower number of saccades. In addition, the Pearson correlation between the number of fixations and creativity was substantially negative following the same line of explanation as the corresponding pair between the number of saccades and creativity. The correlations between all the measures and the RT1 variable were not correlated.

A substantial negative correlation was found between RT2 and creativity. Therefore, we can say that participants who exemplified a lower level of creative thinking needed more time to identify the second image which was embedded in each ambiguous figure and therefore reverse on ambiguous figures and experience perceptual ambiguity.

Table 6.3 Bivariate Correlation between HFT performance (scores), TTCT performance (all components), ability to reverse, and eye movements. *$p < .05$, ** $p < .001$.

Subscale (Scores)	1	2	3	4	5	6	7	8	9	10	11
1. HFT	-										
2. Creativity Index	.43**	-									
3. Fluency	.10	.30**	-								
4. Originality	.18	.53**	.61**	-							
5. Elaboration	.19	.45**	.67**	.65**	-						
6. Titles	.41**	.57**	.10	.22	.07	-					
7. Closure	.43**	.68**	.21	.47**	.39**	.37*	-				
8. Strengths	.37*	.91**	.02	.31*	.22	.46**	.52**	-			
9. ReactionTime 1	-.04	-.12	.02	.02	.10	.03	-.06	-.19	-		
10. ReactionTime 2	-.40**	-.42**	.07	-.08	-.08	-.30	-.39**	-.43**	.48**	-	
11. Fixations	-.22	-.15	-.32**	-.23	-.15	-.20	-.10	-.06	.22	.53**	-
12. Saccades	-.33*	-.27	-.27	-.24	-.21	-.28	-.14	-.20	.23	.57**	.91**

Note. Cognitive style group scores: FD ≤ 11, 11 < FN ≤ 17, 17 < FI ≤ 32;

Cognitive style group levels: Field Dependent, Field Neutral, Field Independent

Titles = Abstractness of Titles; Closure = Resistance to Premature Closure; Strengths = Creative Strengths.

Table 6.4 Pearson Correlation coefficient (r) between HFT levels, Creativity and components levels, ability to reverse and eye movements.

Subscale (Levels)	1	2	3	4	5	6	7	8	9	10	11
1. HFT	-										
2. Creativity Index	.46**	-									
3. Fluency	.20	.24	-								
4. Originality	.38*	.18	.55**	-							
5. Elaboration	.25	.25	.61**	.48**	-						
6. Titles	.29	.36*	.24	.13	.13	-					
7. Closure	.25	.56**	.29	.16	.30*	.41**	-				
8. Strengths	.28	.59**	.00	.08	.21	.20	.35*	-			
9. ReactionTime 1	-.00	.02	-.05	.21	-.03	-.03	-.05	-.16	-		
10. ReactionTime2	-.37**	-.41**	-.04	.06	-.09	-.24	-.34*	-.37*	.48*	-	
11. Fixations	-.28	-.36*	-.34*	-.06	-.18	-.15	-.11	-.01	.22	.53**	-
12. Saccades	-.40**	-.34*	-.29	-.10	-.26	-.20	-.14	-.16	.23	.57**	.91**

*$p < .05$, ** $p < .001$. *Note.* Titles = Abstractness of Titles; Closure = Resistance to Premature Closure; Strengths = Creative Strengths.
Levels = Low, Moderate, High

6.5.2. FD-I processing style based on the Hidden Figures Test performance

Scoring procedure - The HFT test score was obtained by taking the total correct responses out of 32 items and subtracting the number of incorrect responses, as suggested in its manual (Ekstrom, et al., 1976). If the resulting number was negative, it was set to 0 for the analyses. Based on this classification the participants were categorised into their cognitive type as follows: 19 Field Dependents, 9 Field Neutrals and 16 Field Independents.

6.5.3. Creative thinking based on the TTCT Performance

Scoring procedure - The Torrance Test of Creative Thinking is designed to measure 5 norm-referenced scores of principal cognitive processes of creativity and thirteen mental characteristics (known as creative strengths) (Torrance, 1974; Torrance & Ball, 1984; Torrance, 1990). The 5 norm-referenced measures include:

(a) Fluency - the number of relevant ideas,

(b) Originality - uncommon or novelty responses The scoring procedure counts the most common responses as 0 and all other legitimate responses as 1,

(c) Abstractness of Titles - abstraction of thought,

(d) Elaboration - number of details / added ideas used,

(e) Resistance to Premature Closure - variety of information when processing information.

The thirteen creative strengths are emotional expressiveness, storytelling articulateness, movement or action, expressiveness of titles, synthesis of incomplete figures, synthesis of lines or circles, unusual visualization, internal visualization, extending or breaking boundaries, humour, richness of imagery, colourfulness of imagery, and fantasy.

The TTCT was scored according to the guidelines in the Streamlined Scoring Guide (Torrance & Ball, 1978) (see APPENDIX B, pg. 181) and results in an overall creativity index. To obtain an overall creativity index, the aforesaid five normalized measures are averaged and then the bonus is added. The overall creativity index has a mean of 100 and a standard deviation of 15 (Torrance & Ball, 1984). Specifically, to count the CI, the standard scores of each of five variables are used according to the TTCT Norms-Technical Manual (Torrance, 1998). Raw scores are converted into standard scores with means of 100 and standard deviations of 20. The standard scores of each subscale can be ranged as follows: Fluency, 40–154; Originality, 40–160; Elaboration, 40–160; Abstractness of Titles, 40–160; Resistance to Premature Closure, 40–160. The standard scores for each of the five norm-referenced measures are averaged to produce an overall indicator of creative potential. For the frequency of creative strength, a + or ++ is awarded as a bonus score for extensive use of the other sub-measures on the basis of the scoring guide. The number of +s' is added (range for Creative Strengths: 0–26) to the averaged standard scores to yield a Creative Index (Torrance, 1998). Two undergraduate research assistants received training by the researcher to score the 1/3 of the tests for reliability and validity purposes. The researcher has chosen to evaluate the tests in this way because of the high inter-rater reliability shown in previous research (Torrance, 1974). According to Plucker (1990) findings, the creative index is the best predictor for adult creative thinking. Moreover, based on the TTCT- figural manual of 1990, the inter-rater reliability was above .90 (Torrance, 1990).

The results from the Torrance Test of Creative Thinking (TTCT) revealed participants' creativity level. The cut off scores procedure of the three levels of creativity (Low, Moderate and High) was subject to previous studies values that took into account the standard deviation and mean of the Creativity Index (Rababah & Jdaitawi, 2013). The total creativity score (Creativity index) was the sum of the five components and the 13 creative strengths. Participants were classified as 8 Low creative thinkers, 31 moderate creatives, and 5 high creative achievers.

6.5.4. One-way ANOVA - Level of creativity and ability to reverse

To further evaluate differences, repeated measures analysis of variance A One-way ANOVA was calculated on participants' creative thinking and performance on the visual tasks with respect to the ability to reverse in terms of responses time (T1, T2) and eye movements components (Fixations and Saccades). The results exemplified statistical significant differences between participants' creative thinking and ability to reverse. The analysis on participants' creative level and ability to reverse with refer to response T2 was significant with high effect size, $F(2, 41) = 4.08$, $p = .024$, $\eta^2 = .17$.

The analysis was not significant in terms of RT1. The LSD post-hoc comparisons tests exemplified that the mean score for the Low creative thinking group (M = 36384.63, SD = 10439.32) was significantly different from the Moderate (M =25389.00, SD = 14344.00) and High (M = 15265.00, SD = 9266.08) creative groups. In addition, a main effect of participants' Field Dependence-Independence processing style on the numbers of fixations and the number of saccades (eye movements components) was found, $F(2, 41) = 4.41$, $p = .018$*, $\eta^2 = .18$ and $F(2, 41) = 3.56$, $p = .038$*, $\eta^2 = .15$, respectively. The effect size related with the statistically significant effects is interpreted as high (or large) effect size. The post-hoc analysis showed that the mean score for the Low creativity level (M = 225.90, SD = 80.00; M = 215.63, SD = 47.03) group on both eye movement components (number of fixations and saccades) was significantly different than the Moderate (M = 163.70, SD = 48.63; M = 166.30, SD = 50.80) and High (M = 158.80, SD = 35.82; M = 157.80, SD = 36.50). The effects between the moderate and high level creative thinkers' pairs on the eye movement components were not significant.

6.5.5. One-way ANOVA on FD-I processing style and ability to reverse

Four one-way ANOVAs were calculated on participants' FPS (IV) and ability to reverse (DV) with regards to response T1, response T2, and participants' FPS (IV) and eye movements components (DV) with respect to the number of fixations and number of saccades. There was a significant effect of participants' FPS on ability to reverse with refer to response T2, $F(2, 41) = 3.31$, $p = .046$, $\eta^2 = .14$. Post-hoc comparisons using the Fisher's LSD tests (effects still hold with other post-hoc comparison tests) indicated that the mean score for the FD group (M = 31747.32. SD = 14891.23) was significantly different than the FI (M = 19936.70, SD = 14030.81). However, the FN group (M = 25808.22, SD = 8431.19) did not significantly differ from the FD and FI conditions. This outcome exemplifies that Field Dependent participants took longer to reverse than the Field Independent ones.

Table 6.5 Fisher LSD post-hoc comparisons between the three cognitive groups, ability to reverse and eye movements.

FD-I Processing Style	Pairs	Ability to reverse *Means*		Eye movements *Means*	
		RT1	*RT2*	*Fixations*	*Saccades*
FD	FN	1149.23	5939.10	24.53	45.01*
	FI	-8.84	11810.63*	35.73	44.79*
FN	FD	-1149.23	-5939.10	-24.53	-45.01*
	FI	-1158.07	5871.54	11.20	-0.22
FI	FD	8.84	-11810.63*	-35.73	-44.79*
	FN	1158.07	-5871.54	-11.20	0.22

*$p < .05$.

The results yielded statistical significant differences between participants' FD-I processing style and performance on search task (ability to reverse). Four one-way ANOVAs were calculated on participants' FD-I (IV) and performance on the visual tasks (ability to reverse) (DV) with regards to response T1, response T2, and participants' FPS (IV) and eye movements components (DV) with respect to the number of fixations and number of saccades. There was a significant effect of participants' FPS on ability to reverse with refer to response T2, $F(2, 41) = 3.31$, $p = .046$, $\eta^2 = .14$. Post-hoc comparisons using the Fisher's LSD tests indicated that the mean score for the FD group (M = 31747.32. SD = 14891.23) was significantly different than the FI (M = 19936.70, SD = 14030.81). However, the FN group (M = 25808.22, SD = 8431.19) did not significantly differ from the FD and FI conditions. In addition the effect of participants' FPS on the numbers of saccades (eye movements component) was also significant, $F(2, 41) = 4.78$, $p = .014$*, $\eta^2 = .19$. The LSD post-hoc comparisons revealed that the mean score for the FD (M = 199.80, SD = 55.83) group was significantly different than the FI (M = 155.00, SD = 36.00) and FN (M = 154.78, SD = 47.26).

However, the effect of participants' Field Dependence-Independence processing style on their eye movement components with respect to the number of fixations was not significant. Taken together, these results suggest that the FD-I processing style does have an effect on ability to reverse and eye gaze behaviour. Specifically, our results suggest that when humans are classified with higher levels of FPS, they are more likely to reverse on ambiguous figures and therefore experience multiple interpretations. Based on Cohen guideline's this is deemed as a very large effect size as 14% of the variance was caused by the IV.

Table 6.6 Fisher LSD post-hoc comparisons between the three creativity levels, ability to reverse and eye movements.

Creativity level	Pairs	Ability to reverse		Eye movements	
		RT1	*RT2*	*Fixations*	*Saccades*
Low	Moderate	-2087.71	10995.66*	62.23*	49.34*
	High	447.28	21119.63*	67.08*	57.83*
Moderate	Low	2087.71	-10995.66*	-62.23*	-49.34*
	High	2535.00	10124.00	4.85	8.50
High	Low	-447.28	-21119.63*	-67.08*	-57.83*
	Moderate	-2535.00	-10124.00	-4.85	-8.50

*$p < .05$.

6.5.6. Simple Linear Regression Analyses

The ambiguous figures task has been designed to exemplify important information regarding participants FD-I cognitive processes for creativity in the area of visual performance. The analysis of the results suggested three predictors as the strongest, for predicting FD-I cognitive style and creativity; these were fixation and saccadic eye movements and response time. The results suggest that these three predictors can be used for early identification of learners FD-I cognitive style and creativity in order to avoid lack of their creative capabilities and understanding of individual cognitive needs and skills that will enhance their leaning.

A simple linear regression was calculated to predict participants' Field Dependence-Independence processing style based on their performance (response time) on the perceptual task. The analysis suggests that a significant proportion of the total variation in FD-I cognitive style was predicted by task performance with respect to response time. In other words, participants' ability to complete the search task (ability to reverse ambiguous figures) in terms of response time 2 (identification of the second ambiguous meaning and therefore completion of the task) is a good predictor of their Field Dependence-Independence cognitive style (RT2), $R^2 = 0.117$, $F (1, 42) = 5.46$, $p = 0.024$. Response time 1 was not a significant predictor, $p = 0.524$. Moreover eye gaze behaviour (regarding number of saccades) on the perceptual task was a significant predictor for the FD-I cognitive style $R^2 = 0.141$, $F (1, 42) = 6.73$, $p = 0.013$. However, the eye movement component; number of fixations was not a significant factor for predicting FD-I style, $p = 0.095$. Furthermore the regression analysis revealed that performance on the ambiguous figures task with regards to response time 2 did significantly predict participants' Creative Thinking, $R^2 = 1.195$, $F (1, 42) = 9.96$, $p = 0.003$. Besides, both eye movements components (number of fixations; number of saccades), were also found to be significant predictors of participants' Creativity ($R^2 = 0.134$, $F (1, 42) = 6.32$, $p = 0.016$; $R^2 = 0.124$, $F (1, 42) = 5.83$, $p = 0.020$, for fixations and saccades, respectively. The regression analyses revealed that time taken to perform the ambiguous figures tasks was a significant predictor for FD-I cognitive style and Creativity. These findings support the research questions (see Section 6.2, p. 117) that better performance on visual search tasks it is more likely to occur from people with higher FD-I processing style and level of Creative Thinking. This suggests that those people who need less time to reverse on a perceptual task (performance on the visual search tasks and identification of both interpretations embedded in ambiguous figures) are more likely to have a higher FD-I style and higher level of Creativity.

Table 6.7 Simple regression analyses summary (N = 42) showing only the 3 out of the 4 independent variables (total average response time 1, total average response time 2, number of saccades, number of fixations) predicting the dependent variables (FD-I cognitive style, creativity).

Predictor variables	Model Variables		*B*	*SE B*	*β*	R^2
FD-I cognitive style	Performance	Constant	2.53	0.28		
		ResponseTime2*	-0.00	0.00	-0.34	
		Overall model				0.10
	Eye Gaze	Constant	3.10	0.46		
		Saccades	-0.01	0.00	-0.38	
		Overall model				0.12
Creativity	Performance	Constant	2.40	0.17		
		ReponseTime2	-0.00	0.00	-0.44	
		Overall model				0.18
	Eye Gaze	Constant	2.53	0.25		
		Fixations	-0.00	0.00	-0.37	
		Overall model				0.11
		Constant	2.59	0.28		
		Saccades	-0.00	0.00	-0.35	
		Overall model				0.10

*$p < .05$. **$p < .01$.

Notes. B regression coefficient, β standardized regression coefficient (the positive constants of all regression models), R^2 determination coefficient.

6.5.7. Eye movements: Scan paths

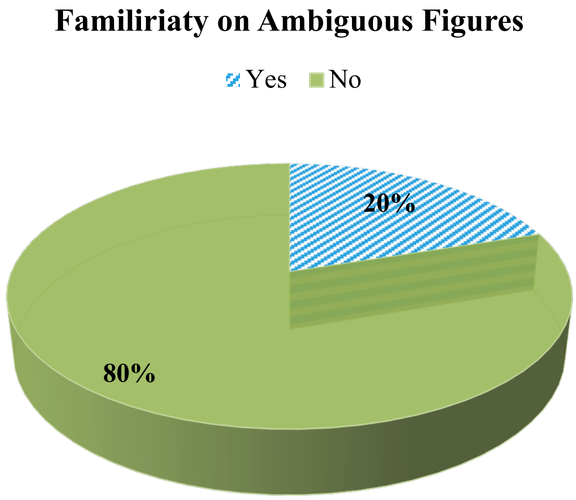
Figure 6.5 shows the scan paths of the Field Dependent, Field Neutral, and Field Independent subjects as a result of their interaction in some of the ambiguous figures used in the experiment. The eye-tracking scan paths reflected participants' eye gaze patterns while performing the perceptual visual tasks. It was hypothesized that individuals FD-I cognitive style and creative thinking will affect their degree of ability to reverse. 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 demonstrated that individuals who have a FD cognitive style produce a greater (longer and more) number of fixations and saccades, showing disoriented eye movement behaviour. In contrast, the Field Independents' and Field Neutrals' avert their eye gaze activity more often or for longer, showing a more oriented navigation, which results in less number of fixations and saccades.

Figure 6.5 Subjects' scan paths demonstrating their FD, FN and FI cognitive style (from left to right): My Wife and Mother-in-Law © W. E. Hill (up)

6.5.8. Naivety on ambiguous figures

The column chart below shows participants' familiarity on the twenty ambiguous figures of the study as a response to the close-ended question which was posed to examine their naivety on the visual stimuli (see p, 119). Specifically, the majority of the participants (80%) were not familiar with the ambiguous figures used in the experiment, thus they were naïve to the purpose of the study. Only 4 out of 20 images were recognized (seen before) by the students.



6.6. Discussion

The objectives of the study were twofold. The former attempts to identify if users' cognitive style affects their creative thinking and eye movement patterns and the latter to explore whether FD-I cognitive style and creativity can act as predictors of users' eye movement behaviour and performance on visual search tasks. It was hypothesised that users of different cognitive style groups might exhibit different eye movement patterns. Specifically, it was assumed that the Field Dependent participants would be less task-oriented and disorganised in their image viewing processing, producing higher values of fixations and saccades, compared to the FN and FI groups. The next sections are discussed by addressing the three research questions.

RQ 6.1 What is the relationship between individuals' FD-I processing style and visual search performance on perceptual tasks?

RQ 6.2 What is the relationship between individuals' level of creativity and visual search performance on perceptual tasks?

RQ6.3 How can FD-I cognitive style and creativity predict a learner's performance on visual search task?

Students’ eye-movement patterns were compared in terms of their FD-I processing style and creative level. Significant individual differences in eye-movement patterns were identified. The findings demonstrated two types of users while performing the visual search tasks. In particular, those individuals who generated a higher level FD-I processing style resultant to be more creative and perform better on the visual search task (perceive the two interpretations embedded in each figure) in contrast to the users’ who had lower level of Field Dependence-Independence type and creativity level. The outcomes declare that eye movements are essential components for inference of users’ creativity and FD - I cognitive style. This study provides evidence for the assumption that Field Dependent - Independent cognitive style, creativity and eye movements are correlated. Moreover, the analysis demonstrated that both FD-I and creativity can act as predictors for individuals’ performance on visual tasks as manifested in their eye gaze behaviour. Results obtained support from the previous literature. Overall, the novel research findings indicated that eye movement behaviour differs significantly between different cognitive groups of people. Particularly, the Field Dependent (FD) group produced a more disoriented EM activity and generated the greatest number of fixations and saccades of the three cognitive groups.

Eye movement patterns are influenced by users’ FD-I cognitive type and were analysed through the eye-tracking gaze plots (scan path) and attention maps (heat maps) analysis. The results revealed that although participants were engaged in the same computer-based viewing stimuli, they tended to demonstrate different visual behaviour patterns. The resultant findings were discussed in view of common and different navigation patterns in relation to the three cognitive style categories. The gaze data exemplified that the eye movement patterns of the three cognitive groups (Field Dependent, Field Neutral, Field Independent) is affected in a different way. The relationship in this analysis was in line with the predicted assumption, giving inference on the positive impact of FD-I on creativity. The results suggest that the higher the performance on the HFT, the higher the creativity score. More specifically, this outcome showed that the Field Independent individuals performed significantly higher on the TTCT than those who were classified as Field Dependent. The predicted relationship and effect between the three variables were found in the data analysis. It is demonstrated that the relationship between FD-I, creative thinking, and eye movements is statistically significant. The results yielded that creativity was influenced by participants FD-I cognitive type. This is in line with the findings of a previous study that demonstrated a significant relationship between Field Dependence-Independence cognitive style and creativity (Miller, 2007). The emerged findings were discussed in view of common and different navigation patterns in relation to the three cognitive style categories. An earlier study revealed that participants' level of Field Dependency found to be related with creativity (Martinsen & Kaufmann, 1999) and claimed that Field Dependent individuals are less creative than the Field Independents.)

This novel finding between FD-I, creativity and eye movements can provide useful explanations for the derived differences in both creativity levels and its five components attributed to it. Taking everything into account, Field Independent individuals can be characterized as those who exemplify the most creative thinking among the three cognitive groups. Finally, the Field Neutral/Mixed individuals showed a more moderate creative thinking. This outcome was expected as the FN group of people sometimes behaves as Field Dependent or Field Independent according to the learning situation. 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 (Gabora, 2010). This approach is related to what we know about the different ways individuals' process and perceive visual stimuli.

The eye-tracking study revealed some implicit knowledge of users' cognitive characteristics and gaze patterns and exemplified that user navigation preferences do reflect their cognitive styles (Nakić & Granić, 2009). Earlier studies found that user cognitive abilities such as perceptual speed and visual/verbal memory have a significant impact on user gaze behaviour and user performance in terms of task difficulty within a given visualisation (Toker, Steichen, Gingerich, Conatiand Carenini, 2014; Toker et al., 2012). As a case in point, the FD users' gaze plots analysis revealed that their scan paths during the visual images search tasks process were more disoriented and disorganised in contrast to those of the FI subjects, displayed more oriented and organised scan paths. These findings are in accordance with the results of a recent study that examined the online behaviour of FD, FI and FN in visually complex web pages with the use of the eye-tracker device. The authors stated that the FD users' scan paths appeared to be more disoriented and scattered within visually complex pages in contrast to the FI subjects, who revealed more oriented and organised gaze plots (Nisiforou & Laghos, 2013). Besides, Michailidou (2009) found that visually complex pages generate users' disoriented navigation, while visually simple pages produce the opposite perspective. Similar results were also reported in a work conducted by Harper, Michailidou and Stevens (2009). Additionally, the FD group heat maps indicated users' difficulty in detecting the correct response. This outcome reflects what was said by Goodenough (1987) that the people who are more Field Dependent experience difficulties perceiving a part separately from the complex whole in which it is embedded. On the contrary, the heat maps presented by the FI individuals illustrated that they could recognise the correct shape within the complex pattern as the green heat maps overlapped with the correct responses given by the users. This result is supported by Zhang's work (2004) that FI individuals face less difficulty in separating essential information from its context than do FD subjects.

Furthermore, the eye-tracking and simulated data also suggest that although users were processing the same visual stimuli, they tended to demonstrate different cognitive traits. The effects of the two variables concerning the participants' FD-I cognitive type and eye movement features were significantly correlated. This fact reflects the findings of previous work where users' level of Field Dependence validated the data retrieved and a large variation in task completion time among the FD-I cognitive groups (Nisiforou & Laghos, 2013) was found. These findings seem to comply with Tinajero and Paramo's results (1997), which found that Field Independent students perform better than Field Dependent students. Isaak-Ploegman and Chinien (2009) mentioned in their study that Field Independent learners outperform Field Dependent students in terms of their scores on the Hidden Figures Test.

Additionally the results of previous work (Burnett, 2010) hypothesied that FI learners will outperform FD learners with respect to time taken to respond correctly to the problem-solving task. An earlier study (Nisiforou & Laghos, 2013) found that the groups of FD and FI exemplified differences in their eye movement features in terms of task time completion, with the former group outperforming the latter. The results of the current study revealed that users' cognitive style has a significant impact on user gaze behaviour and that this influence is detectable through eye-tracking metrics. This outcome was discussed in a previous study where cognitive style was related to differences in the online searching tasks (Józsa & Hámornik, 2012).

6.7. Summary

Eye-tracking is a biometric measuring device that allows user experience (UX) researchers to collect objective behavioural data. It records the behaviour of a person's eyes when exposed to visual stimuli. These stimuli can be almost anything, from fixed images, videos, web pages, to simple print documents. Eye-tracking studies provide an additional dimension to the measurement of respondents' experience as well as compelling data visualisations that will increase the understanding of results. Pairing eye-tracking with psychophysiology it enables researchers to move beyond the subjective interpretation of visual elements. Students' eye-movement patterns were compared in terms of their FD-I processing style and creative level. To sum up, FD - I style is an essential characteristic for inference of users' creativity and eye movements in complex visual search tasks. The forthcoming study aims to investigate the neural underpinnings that underlie the association between FD-I cognitive style, eye gaze patterns, and creative thinking by combining biometric and neurometric measurements. The mishmash of neuro-metrics and biometrics has an unparalleled access to users' emotional and cognitive responses. These measures allow researchers to determine responses to specific events and items with extreme precision, and this helps us become much better at measuring, understanding and predicting users' behaviour. Taking this study further the eye-tracker technology and the EEG were synchronized and combined to elucidate implicit understandings on users' Field Dependence-Independence cognitive style.

7. CHAPTER SEVEN

STUDY 5 – FIELD DEPENDENCE-INDEPENDENCE, CREATIVITY, EYE GAZE AND BRAIN ACTIVITY

7.1 Overview

The notion that individuals differ in the way they approach or solve visual tasks has provided a key underpinning for research. Visual appeal is an essential element in the design of online learning environments. Currently, there is an escalation of studies examining individuals' cognitive components in correlation to visual perception. Creativity involves the capacity to shift spontaneously back and forth between analytic and associative modes of thought according to the situation (Gabora, 2010). These types of thought demonstrate individual differences in how visual information is perceived. One of the most widely used tests to assess associative and analytic processing is the Hidden Figures Test (French, Harman & Dermen, 1976) which constitutes the main research instrument of the studies encompassed in this dissertation. Focusing on specific patterns activates memory that supports divergence or convergence (Gabora, 2000). Earlier studies have proposed that the use of ambiguous stimuli may in some way be associated with degrees of creativity (Urban, 2003; Wiseman, Watt, Gilhooly, & Georgiou, 2011; Dove, 2014) but future studies need to clarify this link by employing a broader set of stimuli. These lines of indication suggest that the more individuals can tolerate ambiguous objects, the more creative they become. Field Dependence-Independence (FD-I) visuospatial processing styles are broadly studied in cognitive and educational fields, but the psychophysiological and neural underpinnings of FD-I cognitive styles and creativity have rarely been investigated (Ambrose, Cohen & Tannenbaum, 2003). From a HCI psychophysiology angle, individual differences in Field Dependent-Independent visuospatial type and creativity using the combination of the eye-tracker and EEG neuroimaging have never been examined. In order to make a good progress in visual search performance, objective measures such as biometric and neurometric data are needed so we can design suitable adaptive and personalized interfaces that can accelerate users' online experiences. According to this route of research, the purpose of the current study is to build on the four previous studies of the thesis as these were reported in Chapters 3 to 6 and investigate the psychophysiological measures related to individual differences in FD-I visuospatial processing type and creativity. This Chapter brings forward user interaction on visual perceptual tasks using specific modalities of psychophysiological measures as a means to elucidate implicit understandings of how these measures affect users' visual interaction.

The study combined psychophysiological measures to determine how the visual system underlies perceptual reversals during ambiguous figures tasks through. Participants were asked to perform perceptual tasks while capturing their eye gaze behaviour and brain activity via a wireless head-mounted electroencephalogram (EEG) recording device. Their task was to press keyboard buttons every time they see the image changing (maximum two key buttons). A total of one hundred and two images were used (fifty ambiguous images, condition 1, fifty normalised images, condition 2). The study investigated which of the psychophysiological measures such as eye gaze components, and brain activation underlie the association between FD-I cognitive style, creative thinking, and perceptual bistability on ambiguous figures.

7.2 Research Questions

In the current study, eye fixations were used to generate ERPs during a visual search task through the eye-tracking and EEG synchronization. As a means to gain insights into the eye gaze and neural processes underlying individual differences in psychophysiological measures, users' visual search patterns were examined during ambiguous figures task. Therefore, the following research questions (RQs') were addressed:

RQ 7.1 What is the correlation between users' FD-I visuospatial type, creativity and eye movements during visual search performance on perceptual task (bistability)?

RQ 7.2 What are the individual differences in users' FD-I visuospatial type and creativity that underlie perceptual bistability during visual search performance?

7.3 Method

7.3.1 Participants

Thirty-one students with mean age 21 years and 2 months (SD = 5.22) from Plymouth University in the U.K. participated in this experiment for course credit. All participants were right-handed, English natives with normal or corrected-to-normal vision. All students were informed about the procedure and purpose of the study, which lasted approximately 3 hours, comprising of the EEG set-up, the training session, the experiment, and the completion of the HFT and TTCT. In order to ensure protection from harm, participants, were asked to fill in an EEG/ERP Safety Questionnaire and sign a consent form.

7.3.2 Materials and Experimental set - up

A total of one-hundred images (see Appendix I) were randomly selected from an existing collection, fifty of which met the requirements of the bistable condition (condition 1) and another fifty for the norm condition (condition 2) which served as the control condition. The ambiguous images (images with two possible interpretations) chosen for the bistable condition and the fifty normalised images used for the normed condition (just a single meaning) were retrieved from Snodgrass and Vanderwart (1980). Two images, one for each condition, were used for 10 initial training rounds before the start of the experiment. Instructions were given, and a trial test of the experiment took place.

7.3.3 Eye-tracking and Electroencephalogram recording techniques

Eye-tracking technology can be used to drive real-time EEG recordings, providing an indication of the analysis process. Brain-computer interface (BCI) is a communication system that identifies user's command from the brainwaves and responds according to them. BCI application in Human-computer interaction (HCI) was employed by combining and synchronizing two modalities; an active EEG approach with an eye-tracking device. Electroencephalography (EEG) is a physiological technique used for the recording of brain electric activity and it is the most widely known and studied brain imaging modality (Makeig, Kothe, Mullen and Bigdely-Shamlo, 2012). As a consequence of imaging process, certain characteristics of the brainwaves are raised and can be used for user's command recognition or certain EEG components. The event-related potentials (ERPs) or evoked potentials various components are significant voltage fluctuations resulting from evoked neural activity (Teplan, 2002). ERPSs have been used to study noninvasively visual processing in response to stimulus presentation (Luck, Woodman & Vogel, 2000). One component particularly important in visual processing is the P3, a time-locked deflection which appears 300 – 400 ms after stimulus presentation (Sutton, Braren, Zubin, & John, 1965).

The synchronization of the eye-tracker device and the EEG required a series of programming processes to be followed. These prerequisites were developed under programming assistance by the Plymouth University tech office team as part of the Erasmus+ Mobility Programme in 2014. The design of the stimuli presentation was programmed and deployed using the software OpenSesame version 2.9 (Mathôt, Schreij & Theeuwes, 2012). EEG was recorded using OpenVIBE-0.18 (see Renard et al., 2010). The data was stored using the European Data Format (EDF+) described in Kemp and Olivan (2003) as well as the General Data Format for Biomedical Signals (GDF) Version 1.25 (Schlögl, Filz, Ramoser & Pfurtscheller, 2005).

The digitised data was transmitted from the EEG capturing device via Bluetooth to OpenVIBE's Acquisition Server. Events from the stimuli presentation application OpenSesame were combined with the incoming EEG data stream at Acquisition Server level using the Stimulation Connection class which allowed a low latency inter-process communication. Eye-tracking data was recorded directly from OpenSesame using SMI's iView X API. This allowed a low latency synchronisation between stimulus presentation and gaze data. A set of the equipment is shown in **Figure 7.1** Scalp recordings of neuronal activity in the brain, identified as the EEG, allow measurement of potential changes over time in basic electric circuit conducting between signal (active) electrode and reference electrode (Kondraske, 1986; Teplan, 2002).

Figure 7.1 Consumables for EEG recording: conductive jel, injection, aid for disinfection. 1 package of cotton swabs, 1 bottle of Isopropyl alcohol, 2 syringes pre-filled with Abralyt HiCl abrasive electrolyte gel, a cleaning brush, 2 Spades, set of medical plastic

A mBrainTrain Smarting device was used along with 24 passive electrodes to capture 24 channels of EEG data at a sampling frequency of 500 Hz with a 24 bit resolution. The 24 electrodes were placed on the participants' scalp using elastic cap closely fitted to their head size. The electrodes placement on the scalp was applied following the international 10-20 system and was prepared using abrasive and conductive gels. The impedance for each single electrode was lowered below 10 kΩ before the recording was started. Data from the recording electrodes positions FP1, F7, FC1, C3, T7, CP1, CP5, TP9, P3, and O1 on the left hemisphere along with their right counterparts FP2, F8, FC2, C4, T8, CP2, CP6, TP10, P4, and O2, and center electrodes Fz, Cz, and Cpz were recorded. Extra third electrode, called ground electrode, is needed for getting differential voltage by subtracting the same voltages showing at active and reference points. Minimal configuration for monochannel EEG measurement consists of one active electrode, one (or two specially linked together) reference and one ground electrode. The multi-channel configurations can comprise up to 128 or 256 active electrodes.

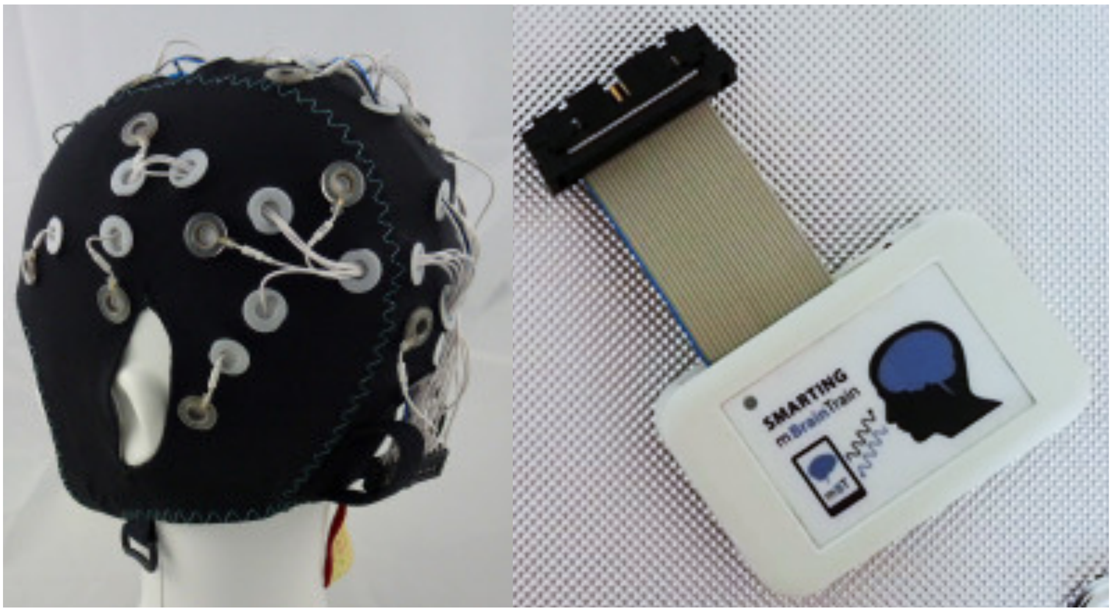


Figure 7.2 Equipment for EEG recording; electrode cap (left) and mBrainTrain Smarting amplifier unit (right).

Eye-tracking data was gathered using an SMI RED-m device at a sampling frequency of 120Hz. The viewing distance between the screen, the eye-tracker and the participant was individually measured and was within the operating distance of 50 to 75 cm. Before starting the experiment, the eye-tracker was calibrated and validated using the high precision 9-point calibration method. The calibration procedure was repeated until it was processed successfully.

Data were collected using four different methods:

(a) FD-I Visuospatial processing type on the performance on the Hidden Figures Test (HFT),

(b) Creativity as a result of individuals' performance on the Torrance Test of Creative Thinking (TTCT),

(c) Training Procedure on the Ambiguous Perceptual Task, and

(d) Testing procedure on the Ambiguous Perceptual Task

7.3.4 Procedure and Tasks

7.3.4.1 FD-I Visuospatial Performance Task

Participants' Field Dependence-Independence type was measured as a result of their performance on the Hidden Figures Test (see APPENDIX B, p.181) (Ekstrom et al., 1976; Chen & Macredie, 2004; Angeli, 2013, Nisiforou & Laghos, 2013, Nisiforou & Laghos, 2015). The total duration time for the completion of the psychometric test was 24 minutes (12 minutes each part). People who take longer to solve the tasks are classified as "Field Dependent" and those who need less time are considered "Field Independent". The HFT scoring procedure was obtained by taking the total correct responses out of 32 items and subtracting the number of incorrect responses, as suggested in its manual (Ekstrom et al., 1976; Chen & Macredie, 2004; Angeli, 2013, Nisiforou & Laghos, 2013, Nisiforou & Laghos, 2015). Reliability of the internal consistency of the Hidden Figures Test of this study was 0.869 as found through Cronbach's alpha coefficient.

7.3.4.2 Creativity Performance Task

To measure students' creativity, the Torrance Test of Creative Thinking (TTCT) - Figural Response Booklet A was administered and it is one of the most commonly tools used to measure the five dimensions of creativity (Fluency, Originality, Abstractness of titles, Elaboration and Resistance to premature closure) (Torrance & Ball, 1984; see also Torrance, 1966). The TTCT is divided into 3 non-verbal activities: Picture Construction, Picture Completion, and Lines and Circles (repeated figures) and requires a total working time of 30 minutes. In all three activities, the figures are scored for fluency (number of pictures drawn), flexibility (number of different categories of pictures drawn), originality, and elaboration. Participants provide a written title for each object or picture as clever and unique as possible and use it to help communicate their stories.

7.3.4.3 Training Procedure - Ambiguous Perceptual Task

The training contained two pre-selected images: one ambiguous and one normalised image. Each trial started with a fixation cross on screen for a randomized time between 800ms and 1300 ms. The onset of the image was recorded as an event in the EEG and eye-tracking data. Images remained on screen either for 5000 ms each or until two different meanings were perceived and confirmed by a button press. On the follow-up screens, participants were asked to give three self-ratings on seven item Likert scales which are not included analysed. Before the start of the next training round an image displaying a pair of eyes reminded the participants to blink before the appearance of the next stimulus.

These ten trials aimed to introduce participants into the experimental procedure, especially which button to press and when, as well as to familiarize themselves with the concept of change without introducing them to the concept of ambiguity. Participants were instructed to press the "SPACE" or “ENTER” button as soon as they could tell what the image was. If they could see the image changes into something else, they were instructed to press the same button again (see **Figure 7.3** for the experimental set-up and exemplar of a stimulus).

7.3.4.4 Testing procedure - Ambiguous Perceptual Task

Participants were requested to perform a perceptual task on one-hundred images. The stimuli were scaled to the same dimension (1280x1024 pixels) and were presented statically as black-white figures. An image could either be a bistable image (condition 1, bistable condition) or a normalised image (condition 2, norm condition). Their task was to recognize two meanings (interpretations) embedded in each ambiguous figure. They were asked to press the button once they could notice an initial interpretation and press again if the image was changing into something else (second interpretation) (see **Figure 7.3**). If the participant could see both interpretations, then the button was pressed twice (one time for each subsequent reversal) and the presentation of the stimuli ended after the second button press. If the participant could recognize only one (or none) interpretation, the experiment progressed onto the next stimulus after 5000 ms. The order of the stimuli was randomized across participants.

The procedure was similar to the training: at the beginning of each trial a blank page with a fixation cross appeared in the center of the screen for a randomized time between 800ms and 1300ms. Subsequently, before the start of the next round they would see a pair of eyes on the screen for 2000ms to remind them to blink their eyes between trials.

7.3.4.5 Data recording and analysis

Ambiguous Perceptual Task

Participants' eye movements and reaction time were recorded from the stimulus onset to the first button press and also between the first and second button press if this occurred. The eye-tracker derived-data were analysed with the aid of the SMI-BeGaze software. For the analysis, participants' visual behaviour was measured and analysed with regards to the number of fixations, number of saccades, scan path and heat maps eye-gaze analysis and reaction time for each stimulus. All the psychophysiological data were then statistically analysed with the use of the Statistical Package for the Social Sciences (SPSS) version 22.0.0.

Figure 7.3 Experimental set-up and exemplar of a stimulus (mountain | bear) displayed on the monitor while the participant was performing the ambiguous figure perceptual task.

The EEG data recorded using the previously described mBrainTrain device, 24 passive electrodes, and OpenVIBE software was analysed using MATLAB and the EEGLAB toolbox (Delorme & Makeig, 2004). Data per channel loaded from GDF files and were assigned to locations on the scalp according to the 10-20 electrode positioning system. Linear trends in the data, which occur due to increased impedance over the course of the experiment, were removed using a finite impulse response filter. Afterwards, the data was re-referenced to the mean of electrodes Cz, TP9, and TP10. In a next step, the trials in which participants had confirmed the perception of the initial meaning were identified. For those trials the EEG data from 1 second before the image appeared on the screen until 5 seconds after was extracted. Amplitudes of ERP components are extracted from a set of single recordings by digital averaging of epochs (recording periods) of EEG time-locked to repeated occurrences of cognitive events (Gevins & Remond, 1987; Teplan, 2002). The spontaneous background EEG fluctuations, which are random relatively to time point when the stimuli occurred, are averaged out, leaving the event-related brain potentials. These electrical signals reflect only the activity which is consistently associated with the stimulus processing in a time-locked way. The ERP thus reflects, with high temporal resolution, the patterns of neuronal activity evoked by a stimulus (Teplan, 2002).

Using the appearance of the images as the event, event related potentials (ERPs) were assigned to condition 1 or condition 2 respectively in accordance to the type of image. In addition all trials in which participants reported seeing a second meaning for bistable stimuli were identified and assigned to condition 3. In this case the moment participants report understanding the first image, this was set as an event. The extracted ERP uses the same time span, starting 1 second before the reporting until 5 seconds after. It is noteworthy that there was no baseline normalisation performed on the data since the baseline for condition 3 would overlap with the understanding of the first meaning of a bistable image. Only data for the first 100 trials was analysed. For those 100 trials there was no data recorded for three participants (6, 11, 21). Data from another participant (9) was excluded as only one bistable image was identified correctly as well as having a low overall response rate for the initial meaning.

7.4 Results

7.4.1 Performance on the Visuospatial Task (HFT)

Users' were classified into their FD-I visuospatial type as a result of their performance on the HFT. The scores were obtained by subtracting the number of incorrect responses from the total correct responses out of 32 question-tasks, as proposed in the test manual (French, Harman, & Dermen, 1976). Based on this classification, the participants were classified into their visuospatial attention type as follows: 13 Field Dependents, 8 Field Neutrals and 8 Field Independents.

7.4.2 Performance on the Creativity Task (TTCT)

The scores from the Torrance Test of Creative Thinking (TTCT) yield participants' level of creative thinking. The TTCT was scored according to the guidelines enclosed in the Streamlined Scoring Guide (Torrance & Ball, 1978) and results in an overall creativity index. To obtain an overall creativity index, the five normalized measures are averaged and then the bonus is added. The overall creativity index has a mean of 100 and a standard deviation of 15 (Torrance & Ball, 1984). Specifically, to count the CI, the standard scores of each of five variables are used according to the TTCT Norms-Technical Manual. Raw scores are converted into standard scores with means of 100 and standard deviations of 20. The standard scores of each subscale can be ranged as follows: Fluency, 40–154; Originality, 40–160; Elaboration, 40–160; Abstractness of Titles, 40–160; Resistance to Premature Closure, 40–160.

The standard scores for each of the five norm-referenced measures are averaged to produce an overall indicator of creative potential. For the frequency of creative strength, a + or ++ is awarded as a bonus score for extensive use of the other sub-measures on the basis of the scoring guide (Torrance, 1998). The number of +s' is added (range for Creative Strengths: 0–26) to the averaged standard scores to yield a Creative Index (Torrance, 1998). According to Plucker's findings, the creative index is the best predictor for adult creative thinking (1990). Moreover, based on the TTCT- figural manual of 1990, the inter-rater reliability was above .90 (Torrance, 1990).

7.4.3 Ambiguous Figures Task

7.4.3.1 Descriptive statistics of the studied parameters

Means of the reaction times on the perceptual reversals (RT1, RT2), eye gaze (number of fixations and saccades) and users' creativity with respect to their FD-I cognitive type are shown in **Table 7.1** participants with a Field Dependence visuospatial type took longer to reverse the 50 ambiguous figures and, therefore, experience perceptual bistability at a later time than those who were classified as Filed Neutral and Field Independent.

Users' differences in the ability to reverse ambiguous figures can be interpreted through their eye gaze behaviour as these were manifested in the number of fixations and saccades each group exemplified. According to creativity means, these illustrate that people with higher FD-I visuospatial type are more creative that the FD, who are classified as having a lower FD-I cognitive type.

Table 7.1 Means of the studied parameters; Reaction Time 1 (RT1), Reaction Time 2 (RT2), number of Fixations, Saccades, and Creativity, in terms of the three visuospatial cognitive groups, Field Dependent, Field Neutral and Field Independent. Standard deviations are shown.

FD-I	**N**	**Reaction Time**		**Eye Gaze**		**Creat.**
		RT1	RT 2	Fix.	Sac.	
FD	15	1416.53 (695.24)	1853.33 (724.96)	21.60 (4.34)	20.73 (5.02)	118.73 (22.86)
FN	8	1209.00 (667.83)	2134.50 (431.87)	19.88 (8.10)	18.88 (7.50)	128.63 (19.69)
FI	8	1066.75 (464.66)	1501.75 (486.62)	19.25 (10.03)	20.13 (8.13)	124.38 23.622
	31	1272.71 (634.63)	1835.16 (630.67)	20.55 (6.98)	20.10 (6.40)	122.74 (21.96)

Note. RT1 = Reaction Time 1; RT2 = Reaction Time 2; Fix. = Fixations; Sac. = Saccades; Creat. = Creativity.

7.4.3.2 Pearson Coefficient Correlations of Measures

Thirty-one participants were examined on their FD-I visuospatial type (IV) (M = 1.77, SD = 0.85), eye movement behaviour (M = 20.55; 20.10, SD = 6.95; 6.40 for fixations and saccades respectively), reaction time (M = 1272.71, 1835.16, SD = 634.63; 630.67, for RT1 and RT2 respectively) on their performance on the ambiguous figures task (ability to reverse) and creativity (DV) (M= 122.74, SD= 21.96) (see **Table 7.2**). A Pearson's r data analysis between FD-I type and reaction time 2 revealed a moderate negative correlation, $r = -0.39$. Participants who had a lower level of FD-I processing style reported greater average number for reaction time 2 (RT2) on their performance on the ambiguous figures task (ability to reverse).

Particularly, people with lower visuospatial type need more time to focus on specific patterns and therefore process information on visual search tasks. The correlation between the pair FD-I type and creativity yielded a positive correlation, $r = .44$. This result supports that people with higher FD-I processing type are more creative than those who are classified as Field Dependents and Field Neutrals individuals. Moreover, the saccadic and fixation eye movements are strongly positive correlated. Interestingly, the correlation between the number of fixations and creativity demonstrated a strong negative correlation. This result provides useful information for the participants who produced greater number of saccades, indicating their difficulty in extracting information from a scene, such as the ambiguous figures used in this study. In addition, the correlation between the number of fixations and participants' RT2 in the performing task was moderate positive. Those who displayed higher number of saccadic eye movements needed more time to perform the tasks and hence show greater RT2 than those who produced lower number of saccades. In addition, the Pearson correlation between the number of fixations and creativity was substantially negative following the same line of explanation as the corresponding pair between the number of saccades and creativity. The correlations between all the measures and the RT1 were not correlated.

A substantial negative correlation was found between RT2 and creativity. Therefore, we can say that participants who exemplified a lower level of creative thinking needed more time to identify the second image which was embedded in each ambiguous figure and therefore reverse on ambiguous figures and experience perceptual ambiguity.

Table 7.2 Correlations between the parameters studied.

Measures		1	2	3	4	5
1.	FD-I type					
2.	Saccades	-.18				
3.	Fixations	-.26	.98**			
4.	RT1	-.19	.30	.28		
5.	RT2	-.39*	.38*	.42*	-.04	
6.	Creativity	.44*	-.51**	-.50**	-.10	-.43**

Correlations are Pearson's r significant: *$p < 0.05$, ** $p < 0.01$.

7.4.3.3 Eye-tracking – fixations and saccades

Users' eye gaze data as a result of their interaction on the ambiguous figures task was analysed with the aid of the BeGaze analysis software provided by SMI. **Figure 7.4** and **Figure 7.5** show the scan paths and the heat maps of the Field Dependent, Field Neutral, and Field Independent subjects during visual search tasks. The derived eye movement data illustrate individual differences in the FD-I visuospatial type. These differences are manifested through their eye gaze patterns as a result of their interaction on the ambiguous perceptual tasks. The use of ambiguous figures and eye gaze behaviour provide insights regarding individuals' changes in perceptual awareness. Specifically, individuals who have a FD visuospatial type produce a greater (longer) number of fixations and saccades, showing disoriented eye movement behaviour. In contrast, the Field Independents' and Field Neutrals' avert their eye gaze activity more often or for longer, showing a more oriented navigation, triggering less number of fixations and saccades. Therefore these findings suggest that changes in perceptual/ conscious awareness due to people interaction with the ambiguous figures can be explained through their visuospatial style. In particular, people associated with higher FD-I visuospatial processes have robust visual information processing abilities which enable them to observe changes in visually complex images such as the ambiguous figures.

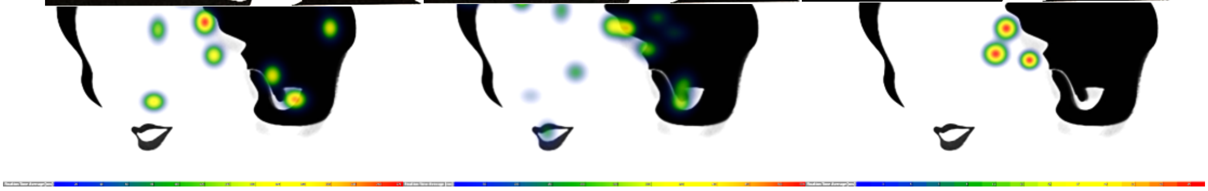


Figure 7.4 Subjects' had to identify the Old and Young Lady embedded in the ambiguous figure during a perceptual task. The scan paths demonstrate their visuospatial type (FD, FN left to right, top | FI centre, and bottom).

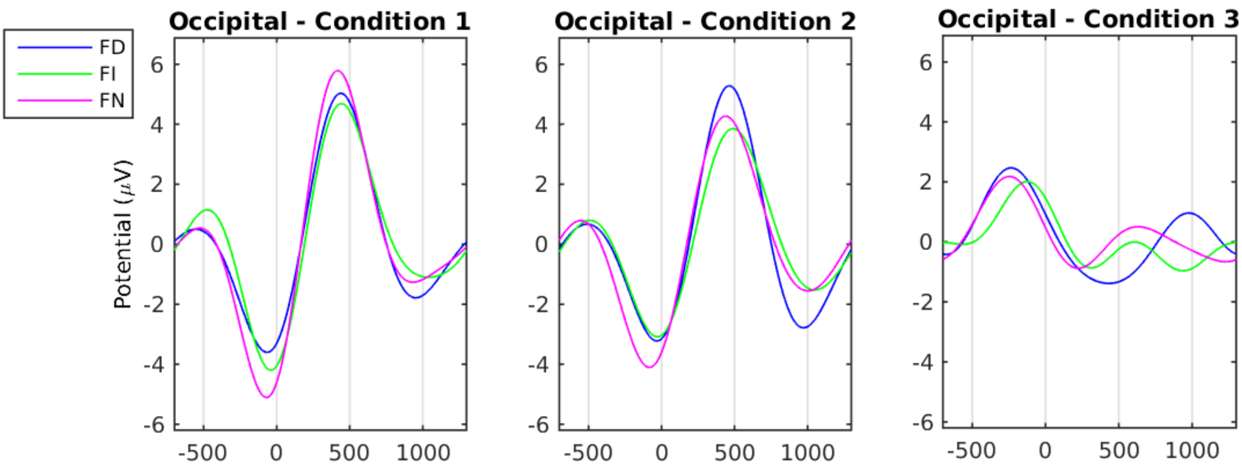
Figure 7.5 Subjects' had to identify the two interpretations (snow-white | man with pipe) embedded in the ambiguous figure during a perceptual task. The heat maps reflect their visuospatial type (FD, FN, FI | from left to right).

7.4.3.4 EEG/ERP - Frontal and Occipital Lobe

Data was processed in Matlab using the EEGLAB toolbox (Delorme & Makeig, 2004). Data per channel loaded from GDF files and were assigned to locations on the scalp according to the 10-20 electrode positioning system. Linear trends in the data, which occur due to increased impedence over the course of the experiment, were removed using a finite impulse response filter. Afterwards, the data was re-referenced to the mean of electrodes Cz, TP9, and TP10. In a next step, the trials in which participants had confirmed the perception of the initial meaning were identified. For those trials the EEG data from 1 second before the image appeared on the screen until 5 seconds after was extracted. Using the appearance of the images as the event, event related potentials (ERPs) were assigned to condition 1 or condition 2 respectively in accordance to the type of image. In addition all trials in which participants reported seeing a second meaning for bistable stimuli were identified and assigned to condition 3. In this case the moment participants report understanding the first image, this was set as an event. The extracted ERP uses the same time span, starting 1 second before the reporting until 5 seconds after. Only data for the first 100 trials was analysed. For those 100 trials there was no data recorded for three participants (6, 11, 21). Data from another participant (9) was excluded as only one bistable image was identified correctly as well as having a low overall response rate for the initial meaning. The data shown in the following figures therefore represents recordings from a total of 26 participants. All plots were developed for a time window of 700ms before the event and for a total length of 2000ms until 1300ms after the event was triggered. It is noteworthy to mention that there was no baseline normalisation performed on the data since the baseline was not easily computable for the condition 3.

In **Graph 7.1** the average recordings for the occipital electrodes are shown. In general, the signal for FD type participants is the same for condition 1 as well as for the control condition 2. On the other hand participants in the FI group seem to have a slightly stronger peak around 480ms while the peak of the participants identified as FN type is much stronger in condition 1 using bistable stimuli than in the control condition 2 seeing normed images. This finding is opposed to previous studies which found neural activity to be weaker in bistable figures compared to the normed stimuli (Knapen et al., 2011, Crowley & Pitt., 2013).

It is surmise that this resultant outcome was occurred because the data was analysed with regards to individuals' differences in FD-I visuospatial groups. This result elucidates a deeper understanding of the neural underpinnings of ambiguous reversals. Since all participants saw the images in a randomized order this difference between conditions cannot be attributed to intersubjective differences.

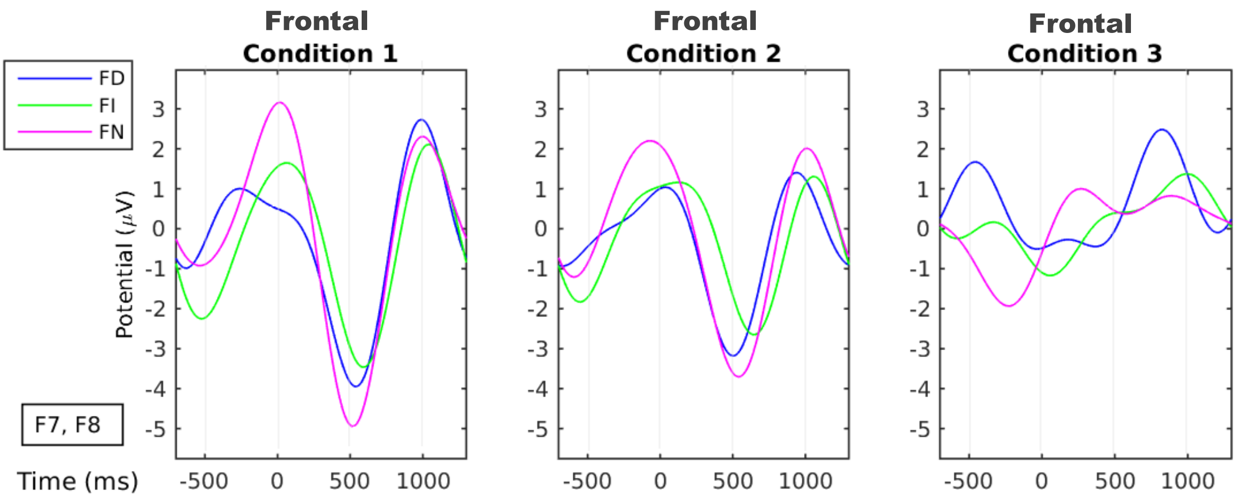


Graph 7.1 Occipital electrodes (O1, O2) for the 3 Conditions between the FD-I visuospatial groups for understanding of the first meaning of bistable images (condition 1), perception of normalised images (condition 2; control condition), and the second meaning of bistable stimuli (condition 3).

Condition 3, which is the understanding of the second meaning of bistable stimuli, is based on a self-reported event. Individual differences in reaction times to the understanding of the first image result in a great difference of the calculated ERPs. Furthermore, the reaction time of pressing the button after understanding the first meaning already overlaps with the cognitive task of switching to the second meaning. Therefore the peak at around -250ms might be related to the peak at 500ms in condition 1 and condition 2.

In **Graph 7.2** the recordings from the frontal lobe can be observed. As for the occipital electrodes a similar pattern in latency for different visuospatial types can be observed: participants identified as FI show a slightly longer latency than the other groups. Regarding signal strength, the participants identified as FD visuospatial type react with similar strength around N500 in condition 1 compared to the control condition 2.

In contrast, FI type participants seem to show slightly stronger reaction in condition 1 than compared to condition 2 and, again, participants of visuospatial type FI have a considerably stronger signal in condition 1. In this case the description of the signal in condition 3 is more complex and speculative, but again this can be explained through different reaction times and individual differences in reporting the perception of the initial meaning of the bistable images.



Graph 7.2 ERP signals from frontal electrodes (F7, F8) between the FD-I visuospatial groups for identifying the first meaning of ambiguous images (condition 1), normed images (condition 2; control), and switch to the second meaning of the bistable stimuli (condition 3).

7.5 Discussion

Individual differences in psychophysiological measures during ambiguous figures tasks (perceptual bistablity) were examined using combined eye-tracking and EEG techniques. The research questions (Section 7.2, p. 144). The eye-tracking data revealed some implicit information regarding the psychophysiological measures related to users' perceptual bistability (ability to switch form one interpretation to another) during visually complex stimuli (e.g. ambiguous figures).

Participants' ability to observe changes in perceptual stimuli was associated with their FD-I visuospatial processing style, eye movement components, creativity and reaction time. Earlier studies found that user cognitive abilities such as perceptual speed and visual/verbal memory have a significant impact on user gaze behaviour and user performance in terms of task difficulty within a given visualisation (Toker, Steichen, Conati & Carenini, 2014).

A significant variation in the means of the variables tested was identified in terms of individuals' visuospatial group. Specifically, the means of the all the variables of the FD participants were higher than the values generated by the FI and FN groups. This finding is in accordance with the results of a previous study that found Field Dependent users to generate greater number of fixations and saccades than the two other groups (Nisiforou & Laghos, 2015). The result of more overall fixations reflects search inefficiency by the user, while more saccades exemplify more searching (Goldberg & Kotval, 1999). Furthermore, the eye-tracking and simulated data also suggest that although users were processing the same visual stimuli, they tended to demonstrate different cognitive traits. These findings seem to comply with Tinajero and Paramo's results, which found that Field Independent students perform better than Field Dependent students mentioned in their study that Field Independent learners outperform Field Dependent students in terms of their scores on the Hidden Figures Test (Tinajero & Páramo, 1997; Isaak-Ploegman & Chinien, 2009). A recent study found that users' cognitive style has a significant impact on user gaze behaviour during visual search tasks (Tinajero, & Páramo, 1997). This finding was discussed in a previous study where cognitive style was related to differences in the online searching tasks. The eye-tracking data are supported with evidence driven the EEG analysis. The finding of stronger signals for ambiguous stimuli is oppose to previous studies which found neural activity to be weaker in bistable figures compared to the normed stimuli (Crowley & Pitt, 2013, Knapen et al., 2011).

We surmise the effect we have seen is only observable with regards to individuals' differences in FD-I visuospatial groups. This result elucidates a deeper understanding of the neural underpinnings of ambiguous reversals. The individual differences observed in reaction time during perceptual task are associated with changes in the neural activity of different FD-I visuospatial type users. A recent study suggests that frontal and parietal brain regions seem to be involved in perceptual switching (Britz, Landis & Michel, 2009; Knapen et al., 2011). Results of an earlier research yielded that changing percept's of ambiguous figures are associated with neural activity in the early visual cortical areas and posterior parts of the brain (Kleinschmidt, Büchel, Zeki & Frackowiak, 1998).These findings are partially in accordance with our result as we found individuals differences of FD-I visuospatial users during perceptual bistability in the frontal and occipital lobes. Specifically, the FI subjects can be defined as higher switchers than the FD users. Their stronger signal in ambiguous reversal in both occipital and frontal regions considers them as being more spatially and perceptually skilled individuals compared to the FD. The faster reversal observed in their reaction time as manifested in the occipital and frontal lobes reflect a higher state of alertness and attention. In addition, Field Independent individuals' stronger signal in the bistable condition and in condition 3 (recognition of the second interpretation of the ambiguous figures) can be interpreted as recognition of perceptual reversal which alternated perceptual dis-embedding of ambiguous figures, compare to the Field Dependent individuals. This finding can be relied on FIs' functioning of cognitive processes which is responsible for their robust visual information processing. As demonstrated in **Figure 7.6**, the FD-I visuospatial type seems to be a key in the process of perceptual bistability and can be considered a characteristic of the FD-I cognitive processing style.

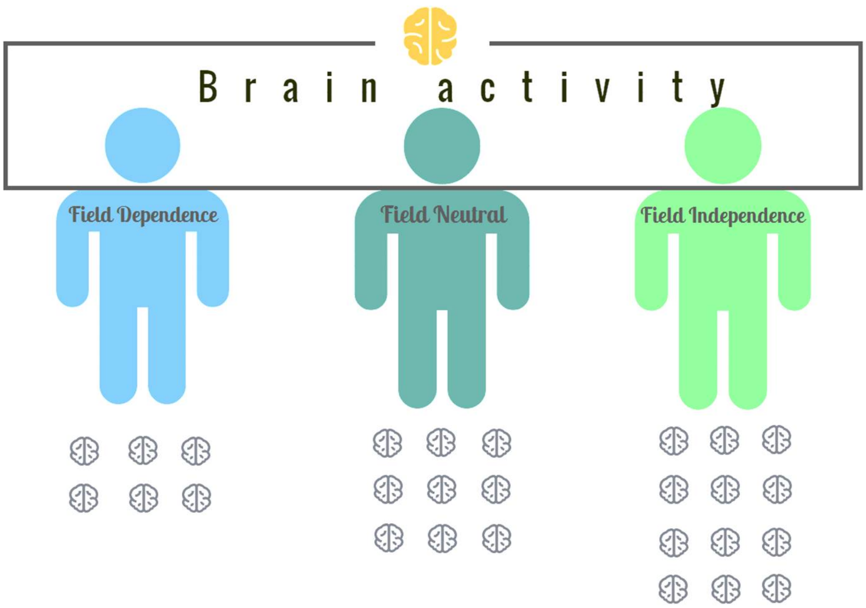


Figure 7.6 Visuospatial perception and FD-I cognitive processing style**.**

The results support previous studies on neural correlates that frontal regions play a crucial role in processing contextual information across different visuospatial tasks. Robust activity of frontal regions was noted. These findings suggest that visuospatial attention can be used as a moderator responsible for individual differences in perceptual bistabilty. Visuospatial functions needed during perceptual bistability of ambiguous figures tasks involve active maintenance of visuospatial information (i.e. seeing embedded shapes). This visuospatial information is considered a characteristic of the FD-I visuospatial processing type.

7.6 Summary

Individual differences in perceptual bistability were found among students, in terms of the Field Dependent-Independent visuospatial type, eye movement patterns, creativity and reaction time during ambiguous figures task.

The results of the study suggest that people with higher FD-I visuospatial style are more like to show greater perceptual awareness and therefore experience perceptual bistability because of their robust information processing abilities. These subjects have a more global perception that enables them to focus attention on more featural elements of stimuli. This ability was manifested in their eye movements showing more organized eye gaze patterns than those who have less analytical perception. In addition, the higher FD-I visuospatial attention type facilitates the speed of information processing, thus Field Independent individuals outperformed the Field Dependent individuals with respect to the reaction time on the ambiguous figures task performance. Thereby, looking at the whole suggested more creativity than looking at the specific and this was because of the greatly accentuated by the capacity to shift between associative and analytic thinking as a medium to be creative.

The outcomes of the study can act as a rudder that will potentially provide research paradigms on how to improve Web experience of different cognitive groups of individuals' taking into account their psychophysiological and neural characteristics. Understanding how individuals' psychophysiological measures affect their online interaction, will betterment their online experience. These kinds of evidence are essential for improving brain-based research practice that will add further to the evidence and theory base of psychophysiology for the good of HCI. Such findings have applications in Education, Special Education, Games development, Advertisement etc. (see Chapter Eight for applications in different disciplines).

8. CHAPTER EIGHT

SUMMARY AND CONCLUSIONS

8.1. Overview

The immense rise of online learning has initiated or produced many accessibility challenges. Open content, adaptive systems, Massive Open Online Courses (MOOCs), games and big data sources are transforming the way we look at education, providing valuable access to learning for a countless number of individuals, and creating new challenges that eradicate barriers in education such as literacy and the search for information. Therefore the empirical and experimental results obtained in this work, with the detection of psychophysiological individual differences in the FD-I cognitive style, revealed some of prime aspects of possible directions for future research in HCI education and NeuroTEL of online learning. Individual differences in cognitive abilities with regards to capturing, comprehending and utilising visual information should be integrated when developing systematic personalised learning environments. Hence identifying such patterns should be considered the initial step in the establishment of personalised tuition that supports improved and accelerated learning outcomes at an individual level based on tailored instructional activities.

The research undertaken endeavoured to investigate cognitive and creative processes which consist of vague and complex phenomena and a set of experimental studies has been integrated in five consequent chapters. Specifically it aimed to examine the influence of Field Dependence-Independence cognitive style on users' performance during navigation patterns in visual environments, and to investigate psychophysiological differences in relation to novel combined methods used with subjective and objective methods, namely psychometric tests, biometric (Eye-tracking) and neurometric (EEG) measures.

This Chapter brings together all five studies into a coherent discussion and summarises the major findings of the thesis by addressing the research objectives. Drawn from the findings and conclusions of the work, implications for practice and research along with the caveats of the research are also illustrated herein. As a final point, potential areas of further research are suggested.

8.2. Summary of the research findings

The main aim underpinning the PhD thesis was to examine learners visuospatial capabilities in the FD-I cognitive style through user interaction patterns in visual environments in order to provide feedback towards the improvement of future HCI, TEL and PLE communities.

In answering the research objectives as described in Chapter One (see section 1.4, p. 33), related work has been reviewed to assess the extent to which individuals' cognitive differences play a part in the development of adaptive and personalised learning environments in the future. A body of literature in the domain of education, neuroscience and psychology, even if quite extensive, has not yet been tapped by the HCI community. Hence one of the goals of the research undertaken was to establish such a connection. A set of five consecutive studies as described in Chapters 3-7 were set up using cutting-edge technologies (either dependently or independently) in order to identify individuals' differences in FD-I cognitive style in terms of psychophysiological factors.

Employing empirical and experimental methods to investigate such individual differences, and taking the concept of interdisciplinary as a basic principle, this research stands at the crossroads of rich bi-directional and reciprocal interactions between HCI (User Experience), Neuroscience, Education and disciplines. By investigating brain and gaze activity (both individually and combined) during visual search tasks, participants were categorised into three clusters: Field Dependent, Field Independent and Field Neutral, according to their level of Field Dependency.

Overall, the findings revealed a strong relationship between the participants' FD-I cognitive abilities and psychophysiological measures in relation to eye movements and brain activity, affecting users visual performance. Therefore, this work encapsulates concepts from different disciplines in a novel research setting in the HCI community, contributing knowledge on how user differences manifest themselves during certain visual tasks.

A general finding which was revealed in the research studies outcomes was that FD-I visuospatial cognitive ability has a key role in the future of education, and will emerge as a separate entity to PLE based on its prominence. Tailoring content to suit individual learners is essential to increasing motivation when learning and for improved learning outcomes. To assess the potential detection of cognitive and creative processes directly through user-interaction patterns in online learning environments, behaviour-based biometric technologies and brain-based research need to be considered.

Henceforth, the current PhD thesis has revealed a number of research contributions to the fields of HCI, Educational Neuroscience, TEL and Psychology for implications in adaptive and personalised learning systems, models and algorithm development.

The examination of the methods, core research findings and the research objectives are subsequently evaluated and answered I the outcome of the work which ensued from each consecutive study' as summarised in **Table 8.1**.

Table 8.1 A brief tabular representation of the methods used, the findings and research objectives reported in the PhD.

			Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7
Data type			Study 1	Study 2	Study 3	Study 4	Study 5
Sample (N)			16	54	30	44	31
Concepts			FD-I[1]	FD-I & EM[2]	FD-I & C[3]	FD-I, EM & C	FD-I, EM, C & BA[4]
Method(s)[5]/ Technique(s)	Psychometric	HFT	✓	✓	✓	✓	✓
		TTCT			✓	✓	✓
	Biometric	ET	✓	✓		✓	✓
	Neurometric	EEG					✓
			▪ The Hidden Figures Test (HFT) and the Eye-tracking (ET) derived data showed statistically significant correlation.	▪ FD-I cognitive style affects eye movements (EM).	▪ FD-I affects creativity (C). ▪ Creativity is introduced as an	▪ Strong relationship between FD-I, EM & C.	▪ The combined methods assess individuals' psycho-physiological differences

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[1] Field Dependence-Independence
[2] Eye Movements
[3] Creativity
[4] Brain Activity
[5] Multi-Channel Process Data

Findings	▪ The FD participants produced higher time means than the FI with respect to the time completion of the tasks. ▪ ET can be used as a method of detecting FD-I.	▪ EM are suggested as an attribute of the FD-I. ▪ EM differ significantly between FD-I groups. ▪ FD group generated a disoriented EM activity.	added attribute of the FD-I. ▪ The FD individuals exemplified lower levels of creative thinking. ▪ The FI were classified as higher creative thinkers. ▪ The FN group showed a moderate C level compared to the FI.	▪ EM explicit important information regarding creativity. ▪ EM are proposed as an attribute of creativity. ▪ FD group generates the highest number of fixations and saccades. ▪ Ambiguous Figures have the potential to be used as a tool for evaluating FD-I & C.	(saccadic and fixation eye movements, creativity and reaction time) in the FD-I, such as in the visual search task (perceptual bistability). ▪ Neurophysiological differences in reaction time in the ambiguous figures, normed and second interpretation conditions were found among the FD-I visuospatial groups in the Occipital and Frontal brain regions.
Research Objectives	Contributed to all	Contributed to all	Contributed to all	Contributed to all	Contributed to all

8.3. Contributions

This PhD thesis offered a number of contributions. Most significantly, it carried out an innovative analytical, theoretical and methodological approach for assessing human psychophysiological differences in the FD-I cognitive processing style. The originality of the thesis offers important educational, theoretical and research output. With emerging opportunities enabling online learning, the topic which currently holds a promising position at the edge of the research community is "Education for All on the Web". Education for all on the web is currently trending as a research theme in many local and international conferences.

The suggested alternative methods of evaluation regarding the identification of cognitive abilities examined in this research are Eye-tracking and Electroencephalography (EEG) systems.

First, the PhD work encounters innovative methods and concepts on four-pronged path' which involves four disciplines (see **Figure 8.1**) and suggests that the results will be helpful in understanding the relationship between the domains of HCI (User Experience), Neuroscience, Education and Psychology. Relevant aspects of these disciplines were integrated together seamlessly to address the objectives of this thesis which have been presented thoroughly. Conducting interdisciplinary research that involves these areas makes this project innovative.

As Antonenko, van Gog and Fred Paas (2014) suggested, real, interdisciplinary research can conduct experimental research and produce innovative designs that can allow researchers to update and develop new instructional theories and principles. Therefore, the work has followed a multidimensional theoretical and practical understanding of the FD-I cognitive concept by interpreting the results on a consortium of four disciplines. The interdisciplinary approach can fill the gaps in the international literature and contribute further to the evidence and theory base of the nature of the learner's cognitive and creative processes during user interaction within visual tasks. Ultimately, these findings will further enhance each field both independently and jointly, with the ultimate goal of integrating these features in the adaptive and PLE to optimise learners' experience and performance.

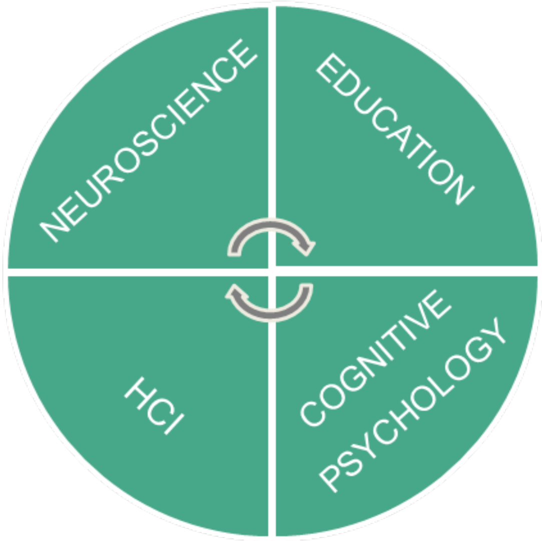

Figure 8.1 PhD four-way street with bi-directional and reciprocal connections between four disciplines.

Second, the thesis used a triangular technique which is defined as "the use of two or more methods of data collection in the study of some aspect of human behaviour" (Cohen, Manion & Morrison, 2009, pg. 141). The multi-metric method approach used valid and reliable existing psychometric methods (HFT and TTCT), and biometric and neurometric techniques such as the Eye-tracking and the EEG methods. This innovative setting, as demonstrated in **Figure 1.1** (see Chapter One, p. 35), has offered a holistic perception of cognition and acts as a frontrunner in bringing out the "first approximation" of the FD-I cognitive styles-abilities, while taking into account the sheer complexity and individuality of the human mind and vision as mapped via the eyes and the human brain. It has, specifically, tracked and grasped the user's behaviour in real time as a medium to provide a deep understanding of the relationship between brain cognitive process in terms of FD-I visuospatial attention and creativity. Users' glancing habits can give important information on where they first look when they reach an online environment, which areas they pay more attention to, and for how long they concentrate on specific parts of the environment. Hence, knowing how cognitive abilities are explained through eye gaze sensors such as eye-tracking can lead to solutions that improve users' online experiences.

Third, the heterogeneity of the sample size of any experimental research in HCI allows the researcher to strengthen the argument that the results of the study are applicable and can be generalisable to the wider population (Jacko, 2012). In addition, the higher sample size allows the researcher to observe greater statistical power and ascertain moderate to large sample effects to reflect actual individual differences. This will result in an increased-largest significance level of findings and hence mirror the behaviour of the participants tested. In light of this statement, a total number of one hundred and thirty (n=130) human participants were sourced across the experiments reported in this thesis as determined by an a priori power analysis using the Gpower computer program (Buchner & Erdfelder, 1998) indicated that a total sample of 128 people would be needed to detect medium effects (d=.5) with 90% power using one-way Anova test with alpha at .05. Even though no cross-cultural differences in relation to the FD-I cognitive ability have been employed, the population of the study was recruited out of a wider demographic loop and in particular was composed of participants of different cultures, ages, genders and disciplines.

Eventually, through this multi-dimensional and interdisciplinary method approach, the contribution is disclosed in order that practitioners and researchers can either integrate input in the development of adaptive and PLE systems or adjust existing ones. Most of the outcomes of this research study has been published, therefore, not only enrich the international literature on FD-I cognitive style but also fill in the gaps with respect to PLE development at a time of a rapid technological change at a worldwide level.

8.4. Outstanding issues

Whilst all research is subject to limitations, there are caveats which need to be considered and are subject to Sampling and Research design. These limitations do not affect the outcomes of the studies, thus the findings and conclusion of this thesis are worthwhile.

Firstly, caveats exist in the sampling with respect to user characteristics, as this could include not only adults but also children.

With respect to the research design, this includes the methods and technologies used. Notwithstanding, portable eye-tracking devices such as the eye-tracking glasses or online eye gaze software could be employed to limit participants' distraction. In addition, other units of eye-tracking analysis could be included in future studies, such as eye dilation, in order to more deeply illuminate how individuals' cognitive characteristics affect their EM patterns. It is also important to acknowledge that the current results are more likely to reflect the aspects of the Hidden Figures Test, as it was the only one prevalent measuring method of classifying participants into their FD-I cognitive style employed as per the requirements of this study. Thus, it is important to validate the degree to which the suggested mapping between Field Dependent-Independent can be generalised to other well-known FD-I tests such as the Embedded Figures Test or the Rod and Frame Test (Riding & Cheema, 1991; Arthour, Doverspike & Bell, 2004).

Moreover, all participants had normal or corrected-to-normal vision based on their written statement. Since the online stimuli were coloured images it was important to check participants' colour blindness. This can be further examined with the use of the Ishihara Test of Colour Blindness; being the most known and used worldwide (Ishihara, 1970).

The EEG neuroimaging device is not easy to use without the necessary training. In addition, this technology could not be relocated from the lab, thus placing constraints on its accessibility. Henceforth, it was only made available on demand from an external laboratory in Cyprus. Therefore, the schedule had to be adjusted on the basis of the EEG availability and only within a short period of time. These practicality and accessibility issues were timely and costly, making it difficult for the researcher to conduct this part of the research. Finally, the training period on the EEG alongside Study 4 and Study 5 experiments was conducted in Plymouth, UK, at the Cognition Institute under the scheme of Erasmus+ Mobility placement.

8.5. Implications for practice and research

To the extent of our knowledge, the results provided in the thesis contain the first empirical and experimental evidence of the Field Dependence-Independence cognitive ability dimension within visual environments in relation to psychophysiological differences. The findings can provide implications for practice and research in different interdisciplinary fields and offer valuable insights and practical applications. First and foremost the FD-I cognitive ability-style has implications for many practitioners and researchers. It appears that, based on the extensive literature review and the research findings of the thesis, the knowledge of individual psychophysiological differences in the FD-I is cemented in the realm of research and has not quite been exploited in the practical world. Based on the literature review, practitioners do not appear to differentiate their teaching processes with regard to the FD-I cognitive ability, and yet it is deemed critical. The relatively new cross-disciplinary area of research (see **Figure 8.1**) implies a need for educators and scientists to engage with each other.

The outcomes provide implications for practitioners including instructional designers, multimedia designers, interface developers, stakeholders, teachers, instructors and researchers. Research should be expanded to discover how adults become more Field Independent, and information applied to help Field Dependent children perform better in appropriate settings. Practitioners must integrate FD-I attributes as part of the curriculum by taking into account the main advances in Educational Neuroscience (also known as Mind Brain and Education - MBE) and Human-Computer Interaction. Thus, by combining what we know about eye gaze and the brain together with the affordances of modern learning technology, practitioners could systematically design effective teaching and learning guidelines.

At a practical level, the results of the current work allow designers and instructors to understand how people learn on the basis of their level of FD-I and creative thinking, and thus recognise the fundamental differences among diverse groups of learners. Instructors could accommodate teaching and learning practices in classroom-based and e-learning environments and be able to provide an array of instructional solutions for the design and development of learning environments. Subsequently, instructional designers and developers can benefit from the instructors' needs and solutions for the design of environments that will be accessible to all users by matching the visual interface design of their online environments with the users' cognitive characteristics and interaction type. Additionally, education authorities should adjust resources and curricula in all subjects based on learners' psychophysiological differences to nurture both their cognitive and creative processes. In addition, creativity in learning should be embedded in all subject areas. The following synopsis captures the most important research results that have implications for practitioners.

For example, when interacting with Field Dependent learners, instructors need to provide clear, explicit directions and a maximum amount of guidance, including oriented strategies before instruction. Standardised and well-organised materials within the given subject should also be provided, and exercises should be begun with a clear structure, abundant cues, and the provision of consistent feedback and scaffolding as the student progresses. These strategies will assist students in their concentration on the information, allowing them to apply their problem-solving skills while at the same time training their attention with regards to looking for a specific thing, lessening their need to provide structure to ambiguous information. Henceforth, the lower perceptual ability can be improved and in some cases revoke the information more analytically rather than globally (e.g. analyse the whole picture less able to see the elements). Moreover, the teaching needs to be equipped with situations that will enrich a learner's creative manner, as this group are less creative thinkers. As a result of the novel findings discovered with respect to the disorganised, disoriented eye movement behaviour, Field Independents outperform Field Dependent and Field Neutral during visual search tasks. This can be achieved by embedding more analytical questions throughout the teaching and learning processes. Additionally, students' who fall in the FD cognitive ability-style benefit from group work performance. On the contrary, Field Independents analyse information more structurally, thus can distinguish relevant items from non-relevant items by identifying the salient or important aspects of any body of information, especially when that information is ambiguous or disorganised. Additionally, it is important to provide an independent, self-instructing learning environment which will allow student-directed learning, taking into account that FIs are more autonomous learners. Moreover, those who fall into the FI cognitive dimension demonstrate more organised and oriented eye movements as opposed to their

FD counterparts, and are not easily distracted by external cues. Thus, instructors can offer minimal guidance and direction but without imposing structure, and provide large amounts of reference and resource materials to sort through during problem-solving tasks.

Demand for programming skills is higher than ever, and employers are looking for motivated individuals of all backgrounds to fill the gap. Since the influence of cognitive abilities on HCI implications becomes critically important, the findings of the study enhance the understanding regarding user cognitive characteristics, indicating ways to improve users' online experience and performance. The findings have implications for the research community. These apply in Assistive technology, and examples are provided with respect to Eye control for adaptive and personalised environments, the Autism Spectrum and other learning difficulties.

It is suggested that users' differences in visual attention should be taken into consideration when developing and implementing instructional e-learning environments. The aim of adaptive systems is the adjustment of the learning process to suit an individual learner. This can be achieved by taking into account their cognitive ability. Within the research to date, the learner profile-based adaptation features rely heavily on the use of manual questionnaire-based instruments to model the learner's profile. Consequently PLE Technology needs to tackle each of the non-content related issues such as FD-I cognitive style, eye gaze components, creativity and its association with neurophysiological elements on a personal level.

Moreover, researchers can implement eye-tracking derived-data and brain-based findings related to FD-I and creativity with the end goal of creating standard operating procedures for the use of eye-tracking and EEG as a clinical outcome measure in single and multi-site projects targeting mental health. A multidisciplinary team guided by experts in eye-tracking, electrophysiological, behavioural and educational research - for instance in Autism Spectrum Disorders (ASD), Attention deficit hyperactivity disorder (ADHD) and other learning difficulties such as dyslexia - can work together to improve the quality and usability of collected data for the wellbeing of this population. Specifically, as an end goal, an eye-tracking data pipeline can be developed to collect and analyse data gathered from a wider population to examine the potential of eye-tracking and the proposed use of ambiguous figures as a biomarker for clinical trials or educational purposes in special populations. Additionally the results can assist in the understanding of the nature of the difficulties that children of these populations face, and will help to refine and develop methods for monitoring and evaluating the effects of treatment.

8.6. Future directions

Nevertheless, there is fertile ground for further investigation and improvement, including, but not limited to, the research design, sample and techniques used, and it is believed that the following work would be desirable:

- Conduct experiments using a broader base of learners' cognitive abilities in an authentic learning context of wider educational levels from pre-school to higher education.
- Include greater user characteristics such as age, gender, other personality features such as emotion, culture and different academic disciplines should be taken into consideration.
- Examine the association between cognitive abilities and web page complexity.
- As eye-tracking technology becomes smaller and less cumbersome, it is important to canvass the advantages of these technologies and extend the work to include the use of mobile and handheld devices with inbuilt eye-trackers for applications in mobile learning and online education.
- Data gathering from eye gaze and visualisation patterns could also be related to avatar movement and environmental observation for GBL environments, and is also an area of consideration for future applications of this research.
- Explore the user cognitive effort on interaction with educational environments in the case of MOOCs.

- Examine the effect of the FD-I cognitive visuospatial ability, creativity and eye gaze (independently and jointly) on game-based learning and emotions.
- Use other methods of EEG analysis such as mathematical simulations and functional connectivity analysis to identify the neural underpinnings of the different FD-I cognitive groups of users.
- Integrate FD-I cognitive ability, creativity and eye gaze physiological data as attributes within the code of a visual complexity algorithm (i.e. ViCRAM) to support advances in web accessibility and visual complexity.
- Develop algorithms that can predict learners FD-I cognitive visuospatial ability and creative thinking through eye gaze physiological data for the development of personalised learning environments, tailored to learners' cognitive demands.
- Conduct user-customer eye gaze activity while participants watch an advertisement to identify the link between Field Dependency, cognitive features and emotions. Scanning the areas to which people are attentive and engaged will reveal their general feelings concerning what is being advertised.

8.7. General Conclusion

On the basis of the novel method employed, this PhD thesis attempted to map out the complex phenomenon of individual differences in the Field Dependence-Independence cognitive processing with psychophysiological traits (creativity, eye movements and brain activity) by following a multi-metric method approach. This multi-metric method combined valid and reliable existing behavioural psychometric methods with biometric and neurometric techniques, such as eye-tracking (ET) and electroencephalography (EEG) under a new empirical and novel experimental research context that has never been applied before.

The results of the research provided insights into the effects of FD-I cognitive abilities-styles of students in their visual search task performances based on interaction patterns which were compared to psychophysiological factors. Therefore, as the aging population grows and technologies continue to develop it is imperative to understand how to design interfaces that support the needs and preferences of learners. For the first time, this study has revealed apparent proof that the FD-I construct has an effect on users' eye movements as a valid enmeshed contributory determinant.

This thesis suggests that creativity and FD-I cognitive style can be introduced as assemblages in HCI design practices. Researchers will have to nurture and to grapple with the methods for evaluating their products to support creativity and FD-I cognitive ability dimension. The proposed new method of assessing and evaluating FD-I and creativity based on physiological and neurophysiological signals, directly relying on user experience, is one of the main contributions of this project. Re-thinking user interfaces to support individuals' cognitive needs will guide user experience (UX) practitioners and researchers of interface development in various novel approaches. Designed – instructional materials need to accommodate the specific characteristics of learners (i.e. individual information-processing and/or disembedding capabilities) to enable them to accelerate their learning.

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APPENDIX A

List of Relevant Publications

JOURNALS

- **Nisiforou, E.** (under review). Assessing connections between Field Dependence-Independence Cognitive Type and Creative Thinking.
- Michailidou, E., & **Nisiforou, E.** (under review). Field Dependence – Independence cognitive style and Visual Complexity: Web Users' behavior.
- **Nisiforou, E.,** & Laghos, A. (2015). Field dependence-independence and eye movement patterns: investigating users' differences through an eye-tracking study. *Interacting with Computers*, doi: 10.1093/iwc/iwv015
- **Nisiforou, E.,** & Laghos, A. (2013). Do the eyes have it? Using Eye-tracking to Assess Students Cognitive Dimensions. *Journal of Educational Media International, 50*(4).

CONFERENCE PROCEEDINGS

- **Nisiforou, E.,** Loesche, F., & Dernham, S. (under review). Combined Psychophysiological Measures Underlie Individual Differences in Perceptual Bistability.
- **Nisiforou, E.** (2015). Examining the association between users' creative thinking and field dependence-independence cognitive style through eye movement components. In *Proceedings of the 11th ACM Conference on Creativity & Cognition*.
- **Nisiforou, E. A.,** Michailidou, E., & Laghos, A. (2014). Using Eye-tracking to Understand the Impact of Cognitive Abilities on Search Tasks. In *Proceedings of Human Computer Interaction International (HCII) Conference.* Universal Access in Human-Computer Interaction, Design for All and Accessibility Practice (pp. 46-57). Springer International Publishing.

- **Nisiforou, E.** (2013).Using Eye-tracking and Electroencephalography to assess and evaluate students' cognitive dimensions. In *Proceedings of EC-TEL Doctoral Consortium*, Paphos, Cyprus.
- **Nisiforou, E.,** & Laghos, A. (2012). A Pilot Study using Electroencephalography and Eye-Tracking to Assess and Evaluate Cognitive Styles. In *Proceedings of the 62nd Annual Conference International Council for Educational Media* 2012, Nicosia, Cyprus.

APPENDIX B

Psychometric Assessments

(1) Hidden Figures Test (HFT) and scoring form

(2) Torrance Test of Creative Thinking (TTCT) and streamlined scoring form

Name ____________________

HIDDEN FIGURES TEST — CF-1 (Rev.)

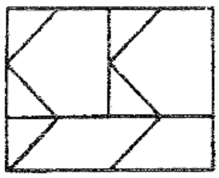
This is a test of your ability to tell which one of five simple figures can be found in a more complex pattern. At the top of each page in this test are five simple figures lettered A, B, C, D, and E. Beneath each row of figures is a page of patterns. Each pattern has a row of letters beneath it. Indicate your answer by putting an X through the letter of the figure which you find in the pattern.

NOTE: There is only one of these figures in each pattern, and this figure will always be right side up and exactly the same size as one of the five lettered figures.

Now try these 2 examples.

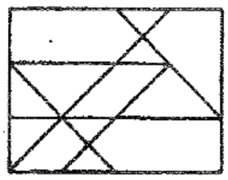
A B C D E

I



A B C D E

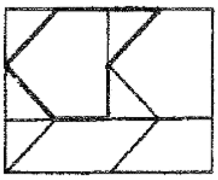
II



A B C D E

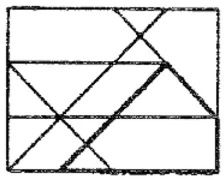
The figures below show how the figures are included in the problems. Figure A is in the first problem and figure D in the second.

I



~~A~~ B C D E

II



A B C ~~D~~ E

Your score on this test will be the number marked correctly minus a fraction of the number marked incorrectly. Therefore, it will not be to your advantage to guess unless you are able to eliminate one or more of the answer choices as wrong.

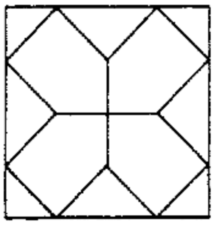
You will have 12 minutes for each of the two parts of this test. Each part has 2 pages. When you have finished Part 1, STOP. Please do not go on to Part 2 until you are asked to do so.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO.

Part 1 (12 minutes)

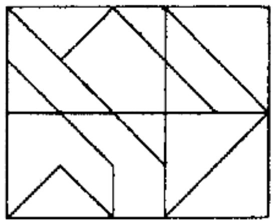
A B C D E

1.



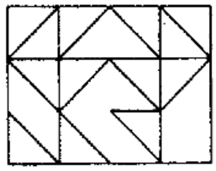
A B C D E

2.



A B C D E

3.



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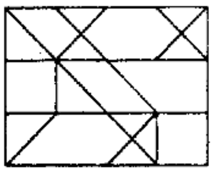
4.



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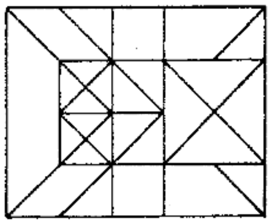
5.



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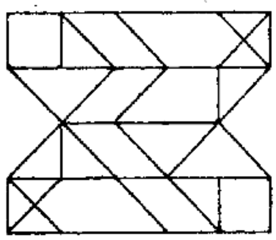
6.



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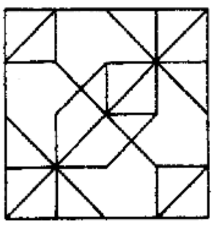
7.



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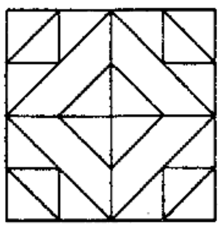

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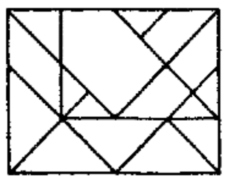
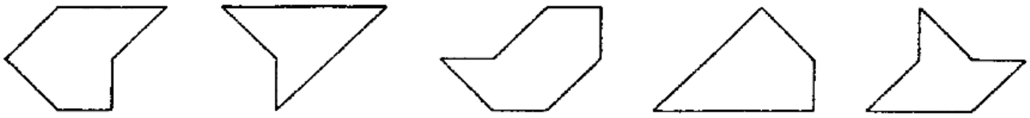
9.



A B C D E

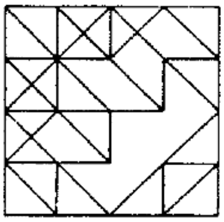
GO ON TO THE NEXT PAGE

Part 1 (continued)



A B C D E

10.



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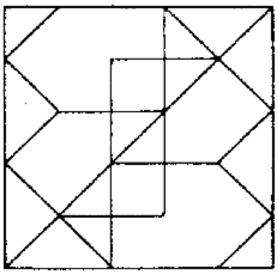
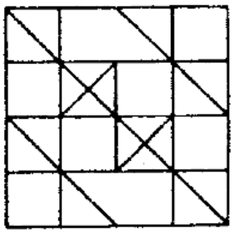
11.



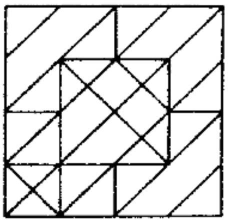
A B C D E

12.



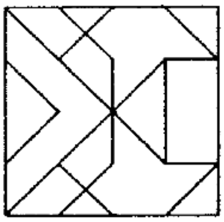
A B C D E

13.



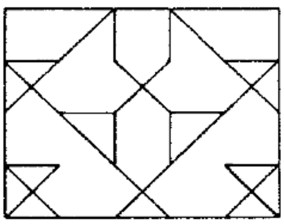
A B C D E

14.



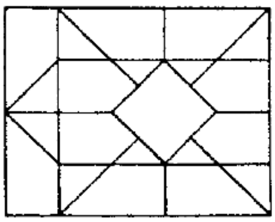
A B C D E

15.



A B C D E

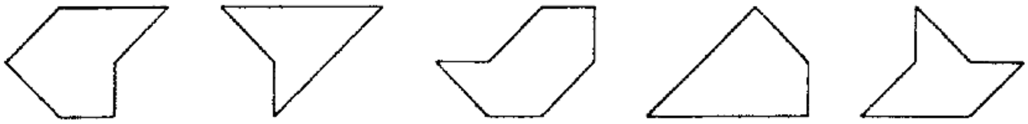
16.



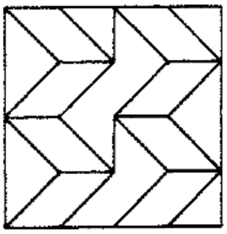
A B C D E

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO STOP.

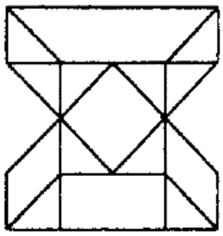
Part 2 (12 minutes)



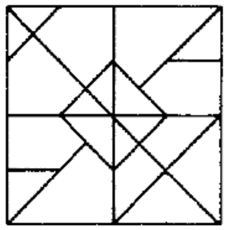
A B C D E

17. 

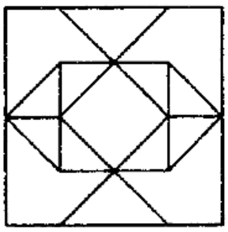
A B C D E

18. 

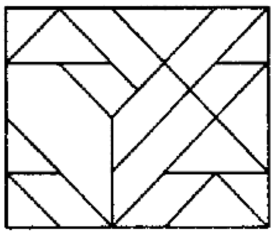
A B C D E

19. 

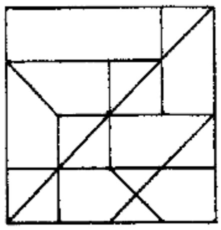
A B C D E

20. 

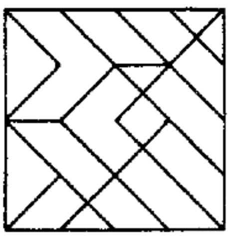
A B C D E

21. 

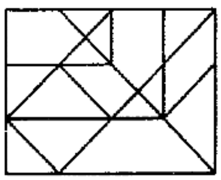
A B C D E

22. 

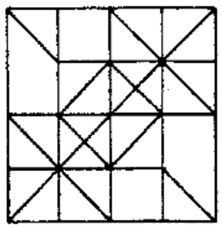
A B C D E

23. 

A B C D E

24. 

A B C D E

25. 

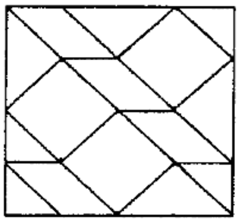
A B C D E

GO ON TO THE NEXT PAGE

Part 2 (continued)

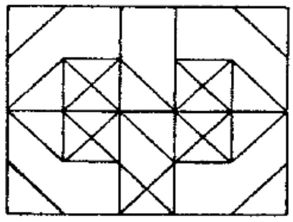
A B C D E

26.



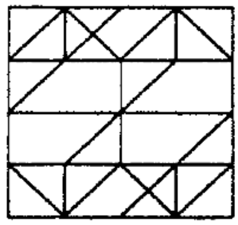
A B C D E

27.



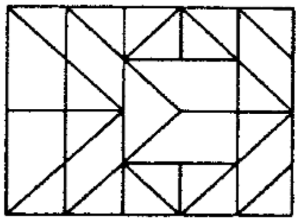
A B C D E

28.



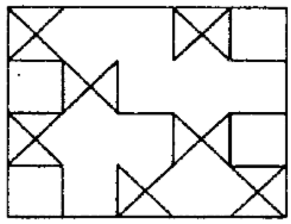
A B C D E

29.



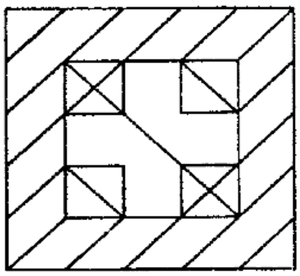
A B C D E

30.



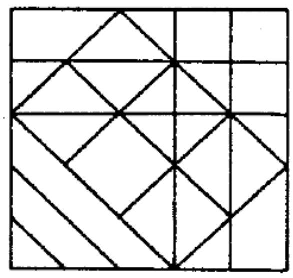
A B C D E

31.



A B C D E

32.



A B C D E

DO NOT GO BACK TO PART 1, AND
DO NOT GO ON TO ANY OTHER TEST UNTIL ASKED TO DO SO.

STOP.

Scoring Keys

Hidden Figures Test -- CF-1 (Rev.)

Part 1

1.	A	9.	E
2.	B	10.	D
3.	A	11.	A
4.	E	12.	C
5.	B	13.	D
6.	C	14.	E
7.	D	15.	C
8.	B	16.	E

Part 2

17.	E	25.	C
18.	A	26.	C
19.	B	27.	B
20.	C	28.	E
21.	D	29.	A
22.	B	30.	E
23.	D	31.	E
24.	A	32.	D

Hidden Patterns Test -- CF-2 (Rev.)

Part 1

Page 2

O, O, X, X, X, O, O, X, O, X,
X, X, O, X, O, X, X, O, X, X,
O, X, X, O, X, X, X, O, X, X,
X, O, O, X, O, O, O, O, X, O,
O, O, X, O, O, X, X, O, O, O,
X, O, X, O, X, X, O, X, O, X,
O, X, O, O, X, O, X, O, X, X,
O, X, X, X, X, X, O, X, O, X,
X, X, O, X, O, O, O, X, O, O,
O, O, X, O, X, X, X, X, X, O

Part 1 (continued)

Page 3

X, O, O, X, X, O, X, O, O, O,
X, X, O, O, O, X, X, X, O, X,
O, X, O, X, O, O, X, O, X, O,
X, O, O, O, X, O, O, O, O, O,
O, X, X, X, O, X, X, X, O, X,
X, O, X, X, O, O, X, X, O, X,
X, X, X, X, O, O, O, O, X, O,
X, O, O, O, O, X, O, O, X, X,
X, O, X, X, X, O, X, X, X, O,
O, O, X, O, O, X, X, O, O, O

Part 2

Page 4

X, O, O, O, X, O, X, O, X, X,
X, O, O, X, X, O, O, X, O, X,
O, X, X, O, O, X, O, X, X, O,
X, O, O, X, O, X, O, X, O, X,
O, O, O, X, X, O, X, O, O, X,
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O, O, O, O, X, O, X, O, X, O,
X, O, X, X, O, X, O, X, X, X,
X, O, X, O, O, X, X, O, O, O,
X, X, O, O, X, X, O, X, X, O,

Part 2 (continued)

Page 5

O, X, X, O, O, O, X, O, O, X,
X, O, O, X, O, O, O, X, O, X,
O, X, X, X, X, X, O, X, O, X,
X, O, O, X, X, X, O, X, X, O,
X, O, O, O, O, O, O, O, X, X,
O, O, X, O, X, O, O, X, O, X,
O, X, O, O, O, X, O, O, X, X,
X, X, O, O, X, O, X, O, O, X,
X, X, O, X, X, O, X, X, X, O,
O, O, X, X, X, X, X, O, X, O

Copying Test -- CF-3

Preparation of the key is left to the user.

THINKING CREATIVELY WITH PICTURES

By E. Paul Torrance

FIGURAL RESPONSE BOOKLET A

NAME ____________________

AGE ________ GENDER ________

SCHOOL ____________________

GRADE ____________________

CITY ____________________

DATE ____________________

STS MEASUREMENT EVALUATION Streamlined Edition

SCHOLASTIC TESTING SERVICE, INC.
480 Meyer Road
Bensenville, Illinois 60106–1617

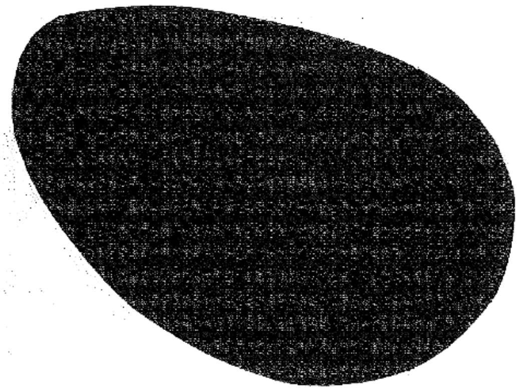
Activity 1. PICTURE CONSTRUCTION

On the opposite page is a curved shape. Think of a picture or an object which you can draw with this shape as a part.

Try to think of a picture that no one else will think of. Keep adding new ideas to your first idea to make it tell as interesting and as exciting a story as you can.

When you have completed your picture, think up a name or title for it and write it at the bottom of the page in the space provided. Make your title as clever and unusual as possible. Use it to help tell your story.

Published by Scholastic Testing Service, Inc., Bensenville, Illinois 60106–1617. Printed in the United States of America.

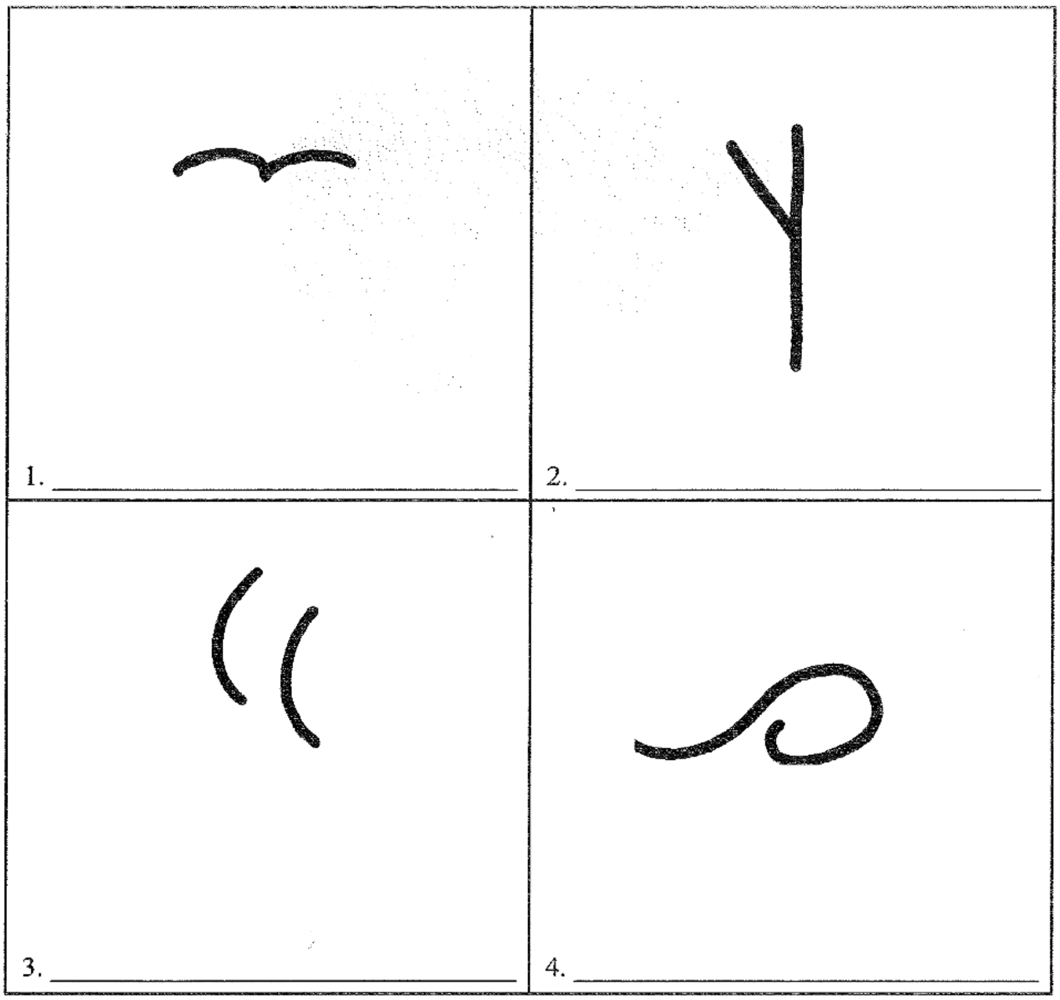


YOUR TITLE: ____

3

Activity 2. PICTURE COMPLETION

By adding lines to the incomplete figures on this and the next page, you can sketch some interesting objects or pictures. Again, try to think of some picture or object that no one else will think of. Try to make it tell as complete and as interesting a story as you can by adding to and building up your first idea. Make up an interesting title for each of your drawings and write it at the bottom of each block next to the number of the figure.



5. ______________________

6. ______________________

7. ______________________

8. ______________________

9. ______________________

10. ______________________

Activity 3. LINES

In ten minutes see how many objects or pictures you can make from the pairs of straight lines below and on the next two pages. The pairs of straight lines should be the main part of whatever you make. With pencil or crayon add lines to the pairs of lines to complete your picture. You can place marks between the lines, on the lines, and outside the lines—wherever you want to in order to make your picture. Try to think of things that no one else will think of. Make as many different pictures or objects as you can and put as many ideas as you can in each one. Make them tell as complete and as interesting a story as you can. Add names or titles in the spaces provided.

1. ____________ 2. ____________ 3. ____________

4. ____________ 5. ____________ 6. ____________

7. ______ 8. ______ 9. ______

10. ______ 11. ______ 12. ______

13. ______ 14. ______ 15. ______

16. ______ 17. ______ 18. ______

GO ON TO NEXT PAGE

19. ______ 20. ______ 21. ______

22. ______ 23. ______ 24. ______

25. ______ 26. ______ 27. ______

28. ______ 29. ______ 30. ______

STREAMLINED SCORING WORKSHEET
TORRANCE® TESTS OF CREATIVE THINKING, FIGURAL FORMS A and B

Name: ______________________ Test Date: ______________ Form: ______

Grade: ______ Age: ________ Gender: ________ School: ______________________

		Raw Score	National Percentile Age	Standard Score Age	National Percentile Grade	Standard Score Grade
1. Fluency: Act. 2 ____ + Act. 3 ____	=	____	____	____	____	____
2. Originality: Act. 1 ____ + Act. 2 ____ + Bonus ____ + Act. 3 ____ + Bonus ____	=	____	____	____	____	____
3. Elaboration (Circle appropriate number 1–6 for A *or* B)	=	____	____	____	____	____

A	Act. 1:	1 (0–5)	2 (6–12)	3 (13–19)	4 (20–26)	5 (27–33)	6 (34+)
A	Act. 2:	1 (0–8)	2 (9–17)	3 (18–28)	4 (29–39)	5 (40–50)	6 (51+)
A	Act. 3:	1 (0–7)	2 (8–16)	3 (17–27)	4 (28–37)	5 (38–47)	6 (48+)
B	Act. 1:	1 (0–5)	2 (6–13)	3 (14–21)	4 (22–29)	5 (30–37)	6 (38+)
B	Act. 2:	1 (0–9)	2 (10–19)	3 (20–29)	4 (30–39)	5 (40–49)	6 (50+)
B	Act. 3:	1 (0–14)	2 (15–24)	3 (25–34)	4 (35–44)	5 (45–54)	6 (55+)

		Raw Score	National Percentile Age	Standard Score Age	National Percentile Grade	Standard Score Grade
4. Abstractness of Titles: Act. 1 ____ + Act. 2 ____	=	____	____	____	____	____
5. Resistance to Premature Closure: Act. 2 ____	=	____	____	____	____	____
Sum of Standard Scores	=			____		____
Average Standard Score	=		____	[ ]	____	[ ]

Ability	**Interpretation**								
1. Fluency									
2. Originality									
3. Elaboration									
4. Abstractness of Titles									
5. Resistance to Premature Closure									
Standard Score		40	60	80	100	120	140	160	180
Percentile			2	16	50	84	98	99+	

Checklist of Creative Strengths (CCS):

______ 1. Emotional Expressiveness (in drawings, titles) 1 or 2 = +, 3 or more = + +

______ 2. Storytelling Articulateness (context, environment) 1 or 2 = +, 3 or more = + +

______ 3. Movement or Action (running, dancing, flying, falling, etc.) 1 or 2 = +, 3 or more = + +

______ 4. Expressiveness of Titles 1 or 2 = +, 3 or more = + +

______ 5. Synthesis of Incomplete Figures (combination of 2 or more) 1 = +, 2 or more combinations = + +

______ 6. Synthesis of Lines (combination of 2 or more sets, Activity 3, Form A) 1 or 2 combinations = +, 3 or more combinations = + + or
Synthesis of Circles (combination of 2 or more, Activity 3, Form B) 1 or 2 combinations = +, 3 more combinations = + +

______ 7. Unusual Visualization (above, below, at angle, etc.) 1 or 2 = +, 3 or more = + +

______ 8. Internal Visualization (inside, cross section, etc.) 1 or 2 = +, 3 or more = + +

______ 9. Extending or Breaking Boundaries (outside the box, lines, circles) 1 or 2 = +, 3 or more = + +

______ 10. Humor (in titles, captions, drawings, etc.) 1 or 2 = +, 3 or more = + +

______ 11. Richness of Imagery (variety, vividness, strength, etc.) 4 or 5 responses = +, 6 or more responses = + +

______ 12. Colorfulness of Imagery (excitingness, earthiness, etc.) 1 or 2 = +, 3 or more = + +

______ 13. Fantasy (figures in myths, fables, fairy tales, science fiction, etc.) 1 or 2 = +, 3 or more = ++

[ ] **TOTAL +'s (CCS Total)**

				Creativity Index	**National Percentile**
Creativity Index by Age: Average Standard Score by Age	[ ]	+ CCS Total [ ]	=	____	____
Creativity Index by Grade: Average Standard Score by Grade	[ ]	+ CCS Total [ ]	=	____	____

Comments: ____

	Fluency	Originality*	Elaboration	Titles	Closure	Emotion	Storytelling Articulateness	Movement or Action	Expressiveness of Titles	Synthesis of Incomplete Figures	Synthesis of Lines (Circles)	Unusual Visualization	Internal Visualization	Extending Boundaries	Humor	Richness	Colorfulness	Fantasy
	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	11	12	13
Activity 1																		
1																		
Totals for Activity 1	N/A				N/A					N/A	N/A			N/A				
Activity 2																		
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
Totals for Activity 2											N/A			N/A				
Activity 3																		
1																		
2																		
3																		
4																		
5																		
6																		
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30																		
Totals for Activity 3				N/A	N/A					N/A								

*Bonus points may be awarded in Activities 2 and 3 for Originality.

CAT# TT114077

APPENDIX C

Consent Form to Participate in Research Project

(1) Cyprus University of Technology ❘ Faculty of Applied Arts

(2) Plymouth University ❘ Faculty of Health and Human Sciences

Consent Form for Participants Taking Part in Research Projects

Title of Work: "Cognitive Abilities and Users' behaviour"

Name of Researchers: Efi Nisiforou

Affiliation: Cyprus University of Technology,

Department of Multimedia and Graphic Arts, Faculty of Fine and Applied Arts

Participant (volunteer)

Please read this and if you are happy to proceed, sign below.

The researcher has explained the nature of the research and what I would be asked to do as a participant. I understand that the experiment is for a research project and that the confidentiality of the information I provide will be safeguarded. The researcher has discussed the contents of the experiment with me and given me the opportunity to ask questions about it. She has informed me that my name will be anonymous and confidential. The data collections and the results will be used only for the publication of the research work and not for any other purposes.

I agree to take part as a participant in this research and I understand that I am free to withdraw at any time without giving any reason and without detriment to myself.

Signed:…………………………………..…………………………………………

Date:…………………………………………………………………………….….

Family Name BLOCK LETTERS:……………………………………………………………….……………

Other Name(s) BLOCK LETTERS:…………………………………………..……………………………...

Date:…………………………………………………………………………………

Researcher

I, the researcher, confirm that I have discussed with the participant the contents of the information sheet.

Signed:………………………………………………………………………………
Date:……………………………….

RESEARCH WITH PLYMOUTH UNIVERSITY

CONSENT FORM TO PARICIPATE IN RESEARCH PROJECT

UNIVERSITY OF PLYMOUTH

FACULTY OF HEALTH AND HUMAN SCIENCES

Name of Principal Investigator Efi Nisiforou

Title of Research “Introducing new ways in assessing and evaluating individuals’ cognitive abilities”

Brief statement of purpose of work
Eye tracker and EEG technologies will be utilised to reflect the complex nature of cognitive abilities. The project aims to provide rich information and a more concrete picture of individual differences in cognitive behaviour in terms of the Field Dependent Independent cognitive concept. The project pursues to value the relationship between the Hidden Figure Test (HFT) scores, the Torrance Test of Creative Thinking (TTCT) with the use of the two cutting edge technologies.

The objectives of this research have been explained to me.

- ✓ I understand that I am free to withdraw from the research at any stage, and ask for my data to be destroyed if I wish.
- ✓ I understand that my anonymity is guaranteed, unless I expressly state otherwise.
- ✓ I understand that the Principal Investigator of this work will have attempted, as far as possible, to avoid any risks, and that safety and health risks are assessed.

I have read the information form and understand its contents including my rights to confidentiality, anonymity and to withdraw without giving a reason.
If you are happy to take part in the research please complete and sign the consent form below.

Under these circumstances, I agree to participate in the research.

Participant ID:.....……………………..……………

Signature: ....…………….. Date: …… /…… /………….

Researcher
I, the researcher, confirm that I have discussed with the participant the contents of the information form.

Signature:………………………………………….. Date: …… /…… /…………

APPENDIX D

Information Sheet, Debriefing Form and Safety Questionnaire

UNIVERSITY OF PLYMOUTH

FACULTY OF HEALTH AND HUMAN SCIENCES

RESEARCH INFORMATION SHEET

Please read this and if you are happy to proceed, sign below.

You are being invited to take part in a research study as part of a student project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Name and contact details of Principal Investigator

Ms Efi Nisiforou
Address: A108, Portland Square, Drake Circus, Plymouth, Devon, PL4 8AA
Email: enisiforou@plymouth.ac.uk
Mobile number: 07840419298

Title of Research Project

"Introducing new ways in assessing and evaluating individuals' cognitive abilities"

Note: Individual project under the CogNovo Project

- **What is the study about?**

This research seeks to examine individuals' differences in cognitive ability, during ambiguous images viewing through the implementation of EEG and eye-tracking technologies. The main focus of the proposed study is to evaluate user's cognitive abilities identification based on the Field Dependent-Independent classification.

It aims to introduce new ways in measuring individuals' level of Field Dependence-Independence cognitive style. We assert that knowing how cognitive abilities can be detected through eye-tracking technology we can lead to solutions that improve users' online experiences.

• **What will be expected of me as a participant?**

Participating in this research will involve wearing a head-mounted EEG device during ambiguous images viewing through a computer-based task. Participation will take place at the University of Plymouth, and will take about two hours in total (including experiment set-up, actual experiment and tests completion).

You will be asked to perform a computer-based task while wearing a head-mounted EEG recording device during ambiguous figure perception task viewing. While performing the tasks your eye-movements and brain activity will be measured. This EEG procedure is the recording of electrical activity along the scalp. The headset includes an elastic fabric cap fitted closely to the scalp which involves the placement of small electrodes on different parts of the brain on the scalp. This soft electrode elastic cap will be fitted on your head and will cover your hair. The recording is obtained by placing electrodes on the scalp with a conductive, electrolyte paste/gel, usually after preparing the scalp area.

Eligibility Requirements

Normal or corrected-to-normal vision and hearing, Right handed with no history of neurological problems (e.g epilepsy) or language related disorders (e.g. dyslexia)

Specific tasks:

- You will be asked to complete two tests about your level of creativity and your level of Field-Dependence Independence cognitive type with the use of the Torrance test of Creative Thinking (TTCT) and Hidden Figures Test (HFT), respectively.
- You will also be asked to perform a computer-based task. In the task, you will see a series of ambiguous images. Your task is to identify the two interpretations that are embedded in each image.
- while you perform the tasks your eye-movements will be unobtrusively measured
- while you perform the tasks you will wear EEG recording devices and your brain activity will be measured

• **Will it be confidential?**
The project will respect the confidentiality of the respondents.

I will ensure that no names of the participants will be collected and participation ID will be attached to the data. All the data will be kept secure, password protected and their name will not be included.

• **Will it be anonymous?**

Anonymity will be safeguarded and all the data will be dealt with immense confidentiality.
• **Will it affect my relationship with the University?**
No

- **Can I withdraw?**

Yes

It is up to you to decide whether or not to take part.

If you decide to take part you will be given this information sheet and be asked to sign a consent form.

If you decide to take part you are still free to withdraw at any time until the very of the experiment without giving a reason and without detriment to yourself.

- **How will I notify my intention to withdraw?**

Verbally mention that you want to withdraw before, during or immediately after the experiment.

- **How can I get further information if I so wish?**

Contact the investigator.

If you are dissatisfied with the way the research is conducted, please contact the principal investigator in the first instance: telephone number *07840419298,* email *enisiforou@plymouth.ac.uk* If you feel the problem has not been resolved please contact the secretary to the Faculty of Health and Human Sciences Ethics Committee: Mrs Sarah Jones 01752 585339.

Please read the statements below and tick whenever is appropriate ✓

I have read and understood the information about the research.	
I have had the chance to find out more about the study if I wished to.	
I know what my part will be in the study and I know how long it will take.	
I know how the study will affect me. I have been told if there are any possible risks.	
I understand that personal information is strictly confidential.	
I freely consent to be a participant in the study. No one has put pressure on me.	
I know that I can stop taking part in the study at any time.	
Refusal to take part will make no difference to my university studies.	
I know that if there are any problems I can contact.	

Participant details:

Participant ID: ……………………………………………………….……………

Age: ………………… Gender (✓) : Male ☐ Female ☐

Signature: ....……………….. Date: …… /…… /……....

Debriefing Form

Project Title: *"Introducing new ways in assessing and evaluating individuals' cognitive abilities"*

The idea that users' features such as cognitive abilities and personality are affecting the effectiveness of information visualization techniques is continuously growing. It is important therefore to understand how individual cognitive features relate to interface design in order to model human behaviour by designing suitable learning environments based on the assumption that individuals learn differently. The purpose of this project is to examine individual differences in the Field Dependence-Independence cognitive style and investigate its association with visual creativity while performing visual stimuli task. The study further attempts to examine new possibilities for measuring the Field Dependence-Independence cognitive style with the use of ambiguous images.

Field Dependence/Independence dimensions are formed based on the individual's reliance on the context to extract specific meaning and describe three contrasting ways of processing information; the Field-Dependence (FD), Field-Independence (FI) and Field Neutral or Mixed (FN/FM) individuals' distinct approach. The Field Dependents find it difficult to identify a simple geometric figure that is embedded in a complex figure, while Field Independent learners can identify the separate parts of a whole.

Participants' level of Field Independence and visual creativity were measured via the Hidden Figures Test and Torrance Test of Creative Thinking. Their eye movements and brain activity were recorded via an SMI eye-tracker and EEG recording device while performing an ambiguous figure perception task.

We assert that individual' differences between the Field Dependence-Independence cognitive groups will be detected providing fruitful solutions that will improve users' online experiences and be able to tolerate personalized environments.

Your participation in this research is greatly appreciated.

If you have any questions or comments, feel free to ask me now. If you have any further questions or comments, please contact Efi Nisiforou, School of Psychology, Faculty of Health & Human Sciences.

07840419298,
enisiforou@plymouth.ac.uk

Safety Questionnaire

Participant ID: ___________________ Sex: M F Age : _________

Date : ___________________

Handedness
You are (please circle):

Left Handed Right Handed Ambidextrous

In the following table please cross your preferred hand for each of the activities or objects. Mark with a single **X** for a significant preference, or **XX** if you would be incapable of using the other hand. An **X** in both hands would indicate that you have no preference.

	L	R		L	R
writing			tennis racket		
drawing			golf club		
throwing			screwdriver		
scissors			hammer		
comb			spoon		
brushing teeth			knife		

Health

1. Do you have any significant health conditions? _________________________
   If yes please list these conditions: _____________________________________
2. Have you currently, or at any time in the past, had any hearing loss, or problems or deficits with your hearing? _______________________________
   If yes please describe.
   ____
3. Do you have a dermatological or other condition that might result in an adverse reaction to abrasive defoliant creams or surgical tape (such as haemophilia)?
   If yes, please describe this condition: _________________________________
4. Please list any medicines you have taken today:_________________________
5. Have you ever suffered from a cerebral problem or serious head injury?
   If yes please describe: ____
6. Do you have normal vision, or do you require glasses or contact lenses?
   ____

APPENDIX E

Ethics Application

PLYMOUTH UNIVERSITY
FACULTY OF HEALTH & HUMAN SCIENCES

Application No:

(for FREC use)

RESEARCH WITH PLYMOUTH UNIVERSITY

Faculty Research Ethics Committee
APPLICATION FOR ETHICAL APPROVAL OF RESEARCH

Title of research:
"Introducing new ways in assessing and evaluating individuals' cognitive abilities"

Individual project under the CogNovo Project

1. Nature of approval sought (Please tick relevant boxes)

(a) PROJECT*: ✓ (b) PROGRAMME*: ☐

If (a) then please indicate which category:

- Funded research project ☐
- MPhil/PhD project ✓
- Other (please specify): ☐

*Note: *In most cases, approval should be sought individually for each project. Programme approval is granted for research which comprises an ongoing set of studies or investigations utilising the same methods and methodology and where the precise number and timing of such studies cannot be specified in advance. Such approval is normally appropriate only for ongoing, and typically unfunded, scholarly research activity.*

2. Investigators/Supervisors

Principal Investigator (staff or postgraduate student)*:
Name: Ms Efi Nisiforou
Email: nisiforou.efi@gmail.com / enisiforou@plymouth.ac.cy

Other staff investigators:

	Dr. Marina Wimmer Department of Psychology Telephone: +441752585881 Email: marina.wimmer@plymouth.ac.uk Director of Studies/other supervisors (only where Principal Investigator is a postgraduate student): Prof. Sue Denham, School of Psychology, (Faculty of Health & Human Sciences) Address: A219, Portland Square, Drake Circus, Plymouth, Devon, PL4 8AA Telephone: +441752584913 Email: S.Denham@plymouth.ac.uk Dr. Giorgio Ganis, School of Psychology (Faculty of Health & Human Sciences) Address: A219, Portland Square, Drake Circus, Plymouth, Devon, PL4 8AA Telephone: +44 1752 584812 Email: giorgio.ganis@plymouth.ac.uk *Please indicate Department of each named individual, including collaborators external to the Faculty:* **Note: Principal investigators are responsible for ensuring that all staff employed on projects (including research assistants, technicians and clerical staff) act in accordance with the University's ethical principles, the design of the research described in this proposal and any conditions attached to its approval.*
3.	**Funded Research** Funding body (if any) Cyprus University of Technology, Erasmus Mobility Scholarship Is there a potential conflict of interest in the research arising from the source of the funding for the research (for example, a tobacco company funding a study of the effects of smoking on lung function)? Yes ☐ No ☒ If the answer to the above question is yes, please outline the nature of the potential conflict of interest and how you will address this:
4	**Duration of project/programme with dates*:** 1 October 2014 – 31January 2015

This period is indicated for the Data Collection stage of the initial PhD project taking place from the sending institution. Part of the Erasmus Learning agreement the exchange period is for 4 months.

Approval is granted for the duration of projects or for a maximum of three years in the case of programmes. Further approval is necessary for any extension of programmes.

5. Research Outline:

Please provide an outline of the proposed research. Note that this should be sufficient to enable the committee to have a clear understanding of the project. It should normally be a maximum of 2,000 words. While this should be written in a way appropriate for your research you should address the following areas:

Background: situating the study within its research area, including references, and, where appropriate, within relevant policy and practice developments or professional agendas

Aims/Key Questions: should be stated clearly, including how the researcher anticipates their fulfilment will move forward knowledge and, where appropriate, policy or practice

Recruitment: of participants – including where and how participants will be recruited; any inclusion or exclusion criteria; justification of the sample size

Methodology: the application should contain a clear outline of methodology, including both data collection and data analysis processes. This should include a description, including references of the particular methodology being used; how it will be employed in relation to this study; which techniques of analysis will be used once data are collected and how this will be applied to the particular data set.

(*Please expand to requirements*)

Research Outline

1. Theoretical background

The field of cognitive dimensions is complex and challenging. The visual appearance of interactive systems, such as Web pages and e-learning environments, tends to convey more information than we imagine. Eye-tracking and usability evaluation studies try to investigate and understand user behaviour (Rayner, 1998). With the use of eye-tracking technology and electroencephalography (EEG) as measures of noticing users' cognitive ability during visual processing, we can further enrich our knowledge in e-learning and adaptive environments design, by understanding how learners of different cognitive types interact within the same tasks. Cognitive style data is being incorporated into adaptive e-learning systems for the development of personalized user models. The link between eye-tracking and cognitive modelling is an extremely intuitive and fruitful area of research. It is important therefore to understand precisely what the eyes and the brain reveal in order to model human behaviour by designing suitable learning environments based on the assumption that individuals learn differently.

This research intends to provide insights of the relation between cognitive abilities and brain cognitive process. The Field Dependence-Independence (FDI) is among the most broadly studied of the variety of cognitive style dimensions appearing in the literature and especially in the educational technology domain (Dragon, 2009). FDI dimensions are formed based on the individual's reliance on the context to extract specific meaning and describe three contrasting ways of processing information; the Field-Dependent (FD), Field-Independent (FI) and Field Neutral or Mixed (FN/FM) individuals' distinct approach.

A general conclusion is that user interaction depends on the visual factors (nearby visual features) and scene semantics (general knowledge about the scene layout). Understanding how this information and cognitive overload affects user perception and Web interaction can lead to solutions that improve users' Web experience. The eye-tracking measures aid the enhancement of usability as they can give information on issues such as cognitive activity (Boksem, Meijman & Lorist, 2005). Moreover, an earlier study demonstrated that eye-tracking technology can be used as a tool in the multimedia field to investigate how diverse design interventions (e.g., spoken vs. written text) affect processing of complex visual presentations (Van Gog & Scheiter, 2010). The idea that user' features such as cognitive abilities and personality are affecting the effectiveness of information visualization techniques is continuously growing.

2. Objectives of the study

1. Explore whether cognitive abilities can be identified through eye-tracker and EEG devices as new objective ways of measurement.
2. Examine the relationship between FD/FI and visual creativity as an additional attribute of the FD-I dimension
3. Introduce a new approach of assessing and evaluating students' cognitive abilities through ambiguous images and cutting edge technologies.

3. Methodology

For the purposes of this research study, eye-tracker and EEG technologies will be utilised to reflect the complex nature of cognitive abilities and aims to provide rich information and a more concrete picture of this concept.

3.1 Population

Students will be recruited via the SONA systems who sign up for course credit. Approximately 60 participants (20 per group) will be enrolled. This number is based on previous individual differences research and should be sufficient to detect medium sized effects. Finally, there are eligibility requirements for participation and these include:
Normal or corrected-to-normal vision and hearing, right handed with no history of neurological problems (e.g epilepsy) or language related disorders (e.g. dyslexia)

3.2 Materials

The upcoming exploration will be carried out using three different methods: a) psychometric tests (Hidden Figures Test- HFT; and Torrance Test of Creative Thinking – TTCT; both have been ordered and permission to use has been requested and gained from the person in charge at the Psychology Test Library of the School of Psychology, Faculty of Health and Human Sciences), b) eye movements' analysis through eye-tracking, and c) brain signals via EEG/ ERP measurements to capture how different cognitive groups of individuals behave through visual stimuli problem solving tasks. A number of ambiguous images will serve as the visual stimuli of the research (approx. 45; 15 in each one out of the three categories) and will be scaled to the same dimension and equalized for intensity.

The research tools are listed below:

- Approx. 45 Ambiguous images (15 for each category out of the three)
    - 15 content
    - 15 figure/ ground
    - 15 perspective and
- 15 normed stimuli (As to control the ambiguous images)
- Hidden Figures Test (HFT)
- Torrance Tests of Creative Thinking (TTCT)

3.3 Procedure

The experimental design of the research will be conducted in three parts:

Part A - Hidden Figures Test (HFT)

Participants level of field independent will be measured with the use of the Hidden Figures Test and participants will have 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 find one of the 5 simple figures embedded in a more complex pattern. The cut-off scores were decided taking into consideration how other researchers determined the cut-off scores in their studies (Daniels & Moore, 2000; French, Ekstrom & Price, 1963). Therefore, individuals who score 10 or lower will be categorized as FD, those who possess a score from 11 to 17 will be classified as FM or FN, and as FI those who score 18 or higher.

Part B - Torrance Tests of Creative Thinking (TTCT)

The researchers will administer the TTCT to the participants as a way to measure their level of visual creativity. The TTCT- Part I Figural contains 3 non-verbal activities: Picture Construction, Picture Completion and Lines and Circles (repeated figures). Ten minutes are required to complete each activity with a total working time of 30 minutes.

Part C – Eye-tracker and EEG experiment

Users' interaction and cognitive behaviour will be examined with the aid of the eye-tracker and EEG recording device. Participants will be asked to perform a computer-based task while wearing a head-mounted EEG recording device during ambiguous figure perception task viewing. While performing the tasks their eye-movements and brain activity will be unobtrusively measured. A number of ambiguous (45) and normed images (15) were pre-selected and will be presented (approx. 55) for a specific time in ms. Participants task is to identify the two interpretations that are embedded in each ambiguous figure. Participants will have to click on the finding task as to indicate their response and answer a multiple choice question per stimulus. Specifically, they will be asked to perform a computer-based task while wearing a head-mounted EEG recording device during ambiguous figure perception task viewing. While performing the tasks their eye-movements and brain activity will be measured. This EEG procedure is the recording of electrical activity along the scalp. The headset includes an elastic fabric cap fitted closely to the scalp which involves the placement of small electrodes on different parts of the brain on the scalp. This soft electrode elastic cap will be fitted on the participants head and will cover their hair. The recording is obtained by placing electrodes on the scalp with a conductive, electrolyte paste/gel, usually after preparing the scalp area. In order to ensure protection from harm, openness and honesty of the investigator towards the participants, they will also be asked to fill in an EEG/ERP Safety Questionnaire to ascertain information on faculties related to health and handedness (Appendix III). A trial-testing evaluation of the environment will take place as a medium to measure the subject’s response time to the target stimuli in order to set up the presentation time of each ambiguous figure.

4. Data analysis

Eye movements will be recorded with the aid of the SMI iViewX model eye-tracking software and the EEG device during the tasks processing. The visual stimuli recording mode of the SMI BeGaze analysis software will be used to capture not only the eye movements, but also mouse clicks as a way of detecting users’ task time completion. The qualitative data will be then analysed with the use of the BeGaze 3.1 software. The quantitative data will be statistically analysed using the Statistical Package for the Social Sciences (SPSS), BESA Software and MatLab.

5. Significance of the study

Empirical studies are in need to determine the link between FD/FI, ambiguous images and visual creativity which currently remains unknown. The upcoming research, will attempt to examine the role of ambiguous images as a tool in identifying FD/FI cognitive construct style and its association with visual creativity. Brain activity will be recorded (EEG) while participants perform visual stimuli tasks in order to investigate the neural correlates of visual creativity.

Since the influence of cognitive abilities on HCI implications becomes critically important, the findings of the study will enrich our understanding regarding user cognitive characteristics and HCI, finding out valuable ways to improve users’ online experience and performance. Finally it will enable instructional designers to consider the nature of the user population related to their cognitive differences and be able to tolerate personalized environments based on how individual cognitive features relate to interface design.

References

Boksem, M., Meijman, T., & Lorist, M. (2005). Effects of mental fatigue on attention: An erp study. *Cognitive Brain Research 25*, 107–116.

Daniels, H. L., & Moore, D. M. (2000). Interaction of cognitive style and learner control in a hypermedia environment. *International Journal of Instructional Media, 27*, 369–384.

Dragon, K. (2009). *Field dependence and student achievement in technology-based learning: A meta-analysis.* Master thesis, University of Alberta, Alberta.

French, J. W., Ekstrom, R. B., & Price, L. A. (1963). *Kit of reference tests for cognitive skills. Educational Testing Services.* Princeton: NJ.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin, 124*.

Van Gog, T., Scheiter, K. (2010). Eye-tracking as a tool to study and enhance multimedia learning. *Learning and Instruction 20*, 2, 95–99.

6. Where you are providing information sheets for participants please INSERT a copy here. The information should usually include, in lay language, the nature and purpose of the research and participants right to withdraw:

7. Ethical Protocol:

Please indicate how you will ensure this research conforms with each clause of Plymouth University's Principles *for Research Involving Human Participants.* Please attach a statement which addresses each of the ethical principles set out below. Please note: you may provide the degree of detail required. Each section will expand to accommodate this information.

(a) **Informed consent:**

i. How will informed consent be gained?

All participants will be asked to complete a consent form after reading the participation sheet. The Consent Form is encompassed in Appendix II.

ii. Are there any issues [e.g. children/minors, learning disability, mental health] that may affect participants' capacity to consent? If so how will these be resolved?

Not applicable.

iii. Will research be carried out over the internet? If so please explain how consent will be obtained

No.

(b) **Openness and honesty:**

i. How will you ensure that participants are able to have any queries they have answered in an open and honest way?
The participation sheet and the informed consent form.

ii. Is deception being used? If so, please indicate which of the following is relevant to its use

Not applicable.

Deception is completely unavoidable if the purpose of the research is to be met	☐
The research objective has strong scientific merit	☐
Any potential harm arising from the proposed deception can be effectively neutralised or reversed by the proposed debriefing procedures	☐

iii. *(If deception is being used) please describe here why it is necessary for your research*

Information sheet, consent form, debriefing procedures and safety questionnaire for the EEG involvement are provided. These will ensure the openness and honesty of the investigator against the participants.

(c) **Right to withdraw:**

i. *Please indicate here how you will enable participants to withdraw from the study if they so wish [where this is not research carried out over the internet]*

Before each experiment participants will be informed that their participation is voluntary and that they are free to withdraw at any time.

ii. *Is the research carried out over the internet? If so please explain how you will enable participants' withdrawal.*

No.

(d) **Protection from harm:**

Indicate here any vulnerability which may be present because:

- *of the participants (they may <u>for example</u> be children or have mental health issues)*
- *of the nature of the research process. Indicate how you shall ensure their protection from harm.*

The involvement of the eye-tracker and the EEG equipment are considered safe and will not provide any harm or risks against the participants' health.

Participants will be briefed on the involvement of the eye-tracker and the EEG equipment in the Information sheet and also an ERP Safety Questionnaire will be administered to ascertain information on faculties related to health and handedness.

I am also seeking cover under the terms of University's insurance arrangements for students conducting research.

***Please note** - researchers contacting children as an aspect of their research must be subject to DBS/CRB checks. These can be arranged through Human Resources.*

Does this research involve:

Vulnerable groups ☐

Sensitive topics ☐

Permission of a gatekeeper for initial access ☐

Deception or research which is conducted without full and informed consent ☐

Research that will induce psychological stress, anxiety or humiliation or cause minimal pain ☐

Intrusive intervention (eg, the administration of drugs, vigorous physical exercise or hypnotherapy) ☐

Not applicable.

Will your samples include **students whose coursework will be assessed by the researcher(s**) (for example you are recruiting students for your study which includes some that will be assessed by you as part of their degree/diploma)?

Yes ☒
No ☐

If **Yes,** please answer the following

(1) Student participation in research for pedagogic purpose
Where recruitment of the research sample involves participants who are being academically assessed by the researcher but whose participation forms part of the overall assessment for their degree/diploma

(i) *does participation in the research form part of the students' own assessment as part of their degree/diploma (e.g. psychology students who can opt to participate in a research project as part of their assessment for their degree)?*

Yes

(ii) *If this is the case please describe how assessment follows from this research and alternative arrangements available for those who decide not to participate*

As part of the requirements for PSY 154 and PSY 259 Psychology modules students are asked to gain some experience of the variety of form of psychological research through participation in approved studies carried out by final stage project students, research staff and lecturers. Participation is recorded in form of participation points. Students get 1 point for a study lasting up to 30 minutes, 2 points for an hour and so on. Students will need to collect 22 points by the deadline at the end of the academic year. Getting the required points is part of the module assessment.

The research is separate from the assessment. Research participation and/or performance will not prejudice any form of assessment as details of the research are separate from details of assessment. Research is anonymous, clearly highlighted on the information sheet and consent form. Students can withdraw at any point during the experiment. Withdrawal will not affect assessment. This is clearly stated in the information sheet and consent form. Assessment is carried out according to clear criteria provided to staff and students, and is subject to both internal and external checks.

Participating in studies is not compulsory. If students are unwilling or unable to act as a participant, as an alternative they can write an extended essay on ethical principles in

Psychology research. The deadline for submission of the essay is the same as that for completion of the points requirement.

It is entirely up to the students which assessment they choose: participation points or essay. They are informed about this on the according module sites, in the handbook, and in the lecture in the beginning of the according academic year. Thus, an informed decision is made beforehand which assessment option to choose.

(2) Student participation in research for non-pedagogic purposes

Where recruitment of the research sample involves participants who are being academically assessed by the researcher but whose participation does not form part of their assessment for their degree/diploma
Please state where and how you will ensure students understand that their participation is entirely voluntary and that they can participate or withdraw at any time without prejudice to their relationship with the University or any staff, and without prejudice to their assessment of academic performance.

(e) **Debriefing:**
Describe how you will debrief participants

Please see attached debrief (Appendix IV).

(f) **Confidentiality:**
How will you ensure confidentiality and security of information?

The project will be handled with confidentially against all the respondents. All the collected data will be kept confidential and used only for research purposes. Names of participants will not be included and participant ID will be written instead of participants' name.

Specifically, participation ID will be assign to each participant instead of their full name as a mean of breaking the link between data and identifiable individuals and be able to safeguard confidentiality. During the data analysis procedure and where the links need to be preserved in order to match data sets, these coding frames including participant personal identities will be kept securely on the hard drive of the investigator, separately from the experimental data to ensure data storage security and confidentiality purposes. Electronic data will also be stored on a password protected computer. Any other form of data will be stored in a locked filing cabinet in the office. This will also enable data withdraw and consists forms of participants that are not willing to continue the experiment.

(g) **Anonymity**
How will you ensure anonymity of participants?

No participants' names need to be collected on the information sheets and consent forms as a medium to secure anonymity. Therefore, participation code (Participant ID) will be assign for each participant instead of their real names and this will be written on both information sheet and consent form. Participants will only be requested to indicate their age and gender on the information sheet for research analysis purposes.

(h) **DBS/CRB Checks**
Do researchers require DBS/CRB checks? If so, how will this be managed?

Not applicable

(i) **Professional bodies whose ethical policies apply to this research:**
The British Psychological Society and the Faculty Ethics Committee.

8. Researchers' Safety

(a) **Are there any special considerations in relation to researchers' safety?**

I am not putting myself in any risk since the conduct of the research study will take place at the research laboratories of the School of Psychology.

(b) **If so what provision has been made *(for example the provision of a mobile phone, or a clear recording of movements)***

Contact details of the experimenter such as email address and mobile phone.

9. Declaration:
To the best of our knowledge and belief, this research conforms to the ethical principles laid down by Plymouth University and by the professional body specified in 6 (g).

Principal Investigator: Ms Efi Nisiforou	Signature E. Nisiforou	Date 07/11/2014
Other staff investigators: Dr. Marina Wimmer	Signature M. Wimmer	Date 07/11/2014
Director of Studies (only where Principal Investigator is a postgraduate student):	Signature	Date

APPENDIX F

Permission to use the Psychometric Tests

Order Form

Complete this form and mail it to the address below or fax it to the fax number below.

Mail to: ETS Research & Development (16R)
Educational Testing Service
Rosedale Road
Princeton, New Jersey 08541

Fax to: 1-609-734-5010
Attn: *Kit of Factor-Referenced Cognitive Tests*

Phone: 1-609-734-1055

SHIP TO:
(same as Bill)
Fiona McChrystal
Plymouth University
Link Building Room 113
Drakes Circus
Plymouth, Devon
PL48AA, United Kingdom

BILL TO:
Fiona McChrystal
Plymouth University
Link Building Room 113
Drakes Circus
Plymouth, Devon
PL48AA United Kingdom

Unless otherwise specified, all shipments within the United States will be sent postage paid SPECIAL FOURTH CLASS BOOK RATE. Shipments outside the United States will be billed F.O.B. Princeton, New Jersey. Unless purchasers request otherwise, materials will be sent A.O. or AIR PARCEL POST.

	SUBTOTAL
Send me _______ *Kit(s) of Factor-Referenced Cognitive Tests* (with manual)................@ $45 each	$
Send me [redacted] *Kit(s) of Factor-Referenced Cognitive Tests*....................................@ $20 each	$
Send me _______ *Guides to Factor-Referenced Temperament Scales*.........................@ $15 each	$
☐ Amount Enclosed $ _________ ☐ BILL ME TOTAL	$

Please make check payable to: EDUCATIONAL TESTING SERVICE

Agreement for Use

I understand that the test in the *Kit of Factor-Referenced Cognitive Tests* and the tentative marker scales in the *Guide to Factor-Referenced Temperament Scales* are research instruments not intended for use in selection or counseling. I warrant that I and those to whom I may provide these instruments to will use them and the resulting scores properly.

_________________________ FACULTY CO-SIGNATURE FOR STUDENT USE

_________________________ SIGNATURE

(See reverse side for Licensing Agreement)

SCHOLASTIC TESTING SERVICE, INC.

Celebrating Achievement Since 1953

PERMISSION TO RESEARCH MATERIAL

Date: October 31, 2014

From: Scott A. Rich, J.D.

Sales Director
Scholastic Testing Service, Inc.
480 Meyer Road
Bensenville, IL 60106-1617
Phone: 800-642-6787
Fax: 866-766-8054
srich@ststesting.com

To: Efi Nisiforou

PhD Candidate
School of Psychology
Plymouth University
Plymouth, Devon PL48AA
United Kingdom
Phone: +44 01752 584840
nisiforous.efi@gmail.com

This agreement hereby grants permission to purchase and research certain material (hereinafter referred to as "Material") owned by Scholastic Testing Service, Inc. (hereinafter referred to as "Publisher"), for subsequent use in a research study conducted by Efi Nisiforou within the School of Psychology, Plymouth University, United Kingdom By executing this agreement, the undersigned agrees to abide by all terms, conditions, and provisions as stated herein.

1. The Name of the Material which permission to research is being sought:

   "Torrance Tests of Creative Thinking, Thinking Creatively with Pictures, Figural Edition Form A; and ancillary materials including but not limited to manuals of direction, norms-technical manuals, and manuals of scoring and interpreting," by E. Paul Torrance, Ph.D.

2. That the Publisher's copyright to and ownership of the Material shall be maintained by Efi Nisiforou throughout the term of this agreement, in accordance with the US Copyright Act, 17 U.S.C. § 101 - 810.
3. That the undersigned hereby agrees to appropriately administer, securely hold, and securely store the Material at all times.
4. That the use of the Material shall be limited to research purposes only.
5. That the undersigned hereby acknowledges that Scholastic Testing Service, Inc., solely holds the copyright to the Torrance Tests of Creative Thinking Test Booklets, Manuals of Directions, Manuals for Scoring and Interpreting Results, Norms-Technical Manuals, and any additional ancillary materials, all of which have been provided and/or sold to Efi Nisiforou for research purposes, according to the scope of research stated in writing by Efi Nisiforou.
6. That no portion of the Material may appear outside of the Material in any form, or in any other paper, report, summary, article, or piece, published or unpublished by Efi Nisiforou.
7. *That the Material shall not be shared, copied, published, circulated, distributed, listed for sale, or sold.*
8. That no electronic version of the Material shall come into existence at any time.

9. That upon completion of the research, the undersigned shall destroy all original Material provided by the Publisher that may remain in the possession of the undersigned.

The Undersigned Hereby Further Agrees As Follows:

A. To restrict the use of the Material specifically as stated in this agreement. For any future research, permission must be requested.

B. To send one (1) gratis copy of any reports, papers, synopsis of research, data analysis, or articles regarding said research, published or otherwise, to Scholastic Testing Service, Inc.

C. Any and all permission fees associated with this agreement are hereby waived in consideration of the undersigned having purchased outright the materials for the study.

D. Permission to Research shall terminate automatically within Twelve (12) months of the date of this application. Thereafter, the undersigned hereby agrees to cease any use, work, or research pertaining to the Material named hereinabove, and may request an extension of said teminiation date in writing. This agreement may be terminated by Scholastic Testing Service, Inc., at any time without prior written consent.

E. The undersigned hereby agrees to be solely responsible for complying with Copyright Law of the United States as to the Material name hereinabove. In all instances, the undersigned agrees to defend, indemnify and hold Scholastic Testing Service, Inc., and its employees and agents, harmless against any and all claims arising or resulting from the use of the Material.

Efi Nisiforou

Agreed: Date: 31/10/2014

Efi Nisiforou (Print Name)

Signature:

Efi Nisiforou (Sign Name)

Scholastic Testing Service, Inc:

When signed by an authorized representative of Scholastic Testing Service, Inc., this form constitutes permission for use of the Material as set forth above, subject to payment of applicable permission fee.

Signature: ______________________ Title: Sales Director Date: _________

Scott A. Rich

Scholastic Testing Service, Inc.'s,

October 29, 2014

Dear members of the Scholastic Testing Service, Inc.'s (STS);

Subject: Torrance Tests of Creativity Thinking (TTCT) Permission request

This is to verify that your testing instrument; Figural test (Response Booklet A) of the Torrance Tests of Creativity Thinking (TTCT) will be supervised and that it will be held securely at all times.

Her research topic entitled "Assessing users cognitive dimensions via Electroencephalography and Eye-Tracking", seeks to understand the association between users' cognitive abilities and creativity by the time it receives visual stimuli.

I believe that by providing Miss Efi Nisiforou with the permission to use the requested test for her PhD study will facilitate her work and further enrich her knowledge in creativity.

Sincerely,

Dr Marina Wimmer
School of Psychology
Plymouth University
PL4 8AA

http://www.marinawimmer.co.uk/

Office: Portland Square A202

APPENDIX G

Request for Technical Assistance (programming/manufacturing)

Request For Technical Assistance

(programming/manufacturing)

Name for Project (Less than 30 chars please)

Individual differences in cognitive ability

Stage 4 Project students please submit this form through your supervisor.
Staff/PGs please email direct to techoffice@psy.plymouth.ac.uk
Please feel free to contact the Technical Office if you would like to discuss your project before completing this form.

Is this part of an externally funded project? No

Section 1 Researcher Details

Name	Efi Nisiforou
Contact phone no.	07840419298
Email	enisiforou@plymouth.ac.uk
Supervisor	Dr. Marina Wimmer

Section 2   What is the purpose of this project?

The idea that users' features such as cognitive abilities and personality are affecting the effectiveness of information visualization techniques is continuously growing. It is therefore important to understand how individual cognitive features relate to interface design in order to model human behaviour by designing suitable personalized learning environments based on the assumption that individuals learn differently. We assert that knowing how cognitive abilities can be detected through eye-tracking technology we can lead to solutions that improve users' online experiences.

The aim of this study is to measure behavioural data as a medium to gain new insights into the processes that underlie the integration of the Field Dependent-Independent cognitive ability and investigate its association with visual creativity.

Field Dependence/Independence dimensions are formed based on the individual's reliance on the context to extract specific meaning and describe three contrasting ways of processing information; the Field-Dependence (FD), Field-Independence (FI) and Field-Neutral or Mixed (FN/FM) individuals' distinct approach. The Field-Dependents find it difficult to identify a simple geometric figure that is embedded in a complex figure, while Field-Independent learners can identify the separate parts of a whole.

A sample of sixty participants (approximately 60 - 20 per cognitive group) will enrolled in this study and their level of Field Independence and visual creativity will be measured via the Hidden Figures Test and Torrance Test of Creative Thinking (TTCT). Their eye movements will be recorded via an SMI eye-tracker device while performing an ambiguous figure perception task.

Section 3

Please explain in detail what you require the programme/equipment to do, (in plain English that can be understood by a non-psychologist). Continue on separate sheets as required.

Description

Users' interaction and cognitive behaviour will be examined with the aid of the eye-tracker device. Participants will be asked to perform a computer-based task during ambiguous figure perception task viewing. While performing the tasks their eye-movements will be unobtrusively measured. A total number of thirty images (30) will form the stimuli of the experiment. Twenty (20) ambiguous figures and ten normed images (10) were pre-selected and will be presented for a specific time in ms (see Figure 2). Each image will followed by a blank page inter-stimulus interval (ISI).

The procedure of the experiment is divided in three phases and the instructions as below:

- Instructions
- Phase1. Practice/Trials;
- Phase 2. Main experiment and
- Phase 3. Questionnaire and are described below.

At the beginning of the experiment, instructions will be displayed on the screen (see section 4 for the specific Dropbox folder). These include:

You will see different images, one at a time. You will see a total of 30 images.

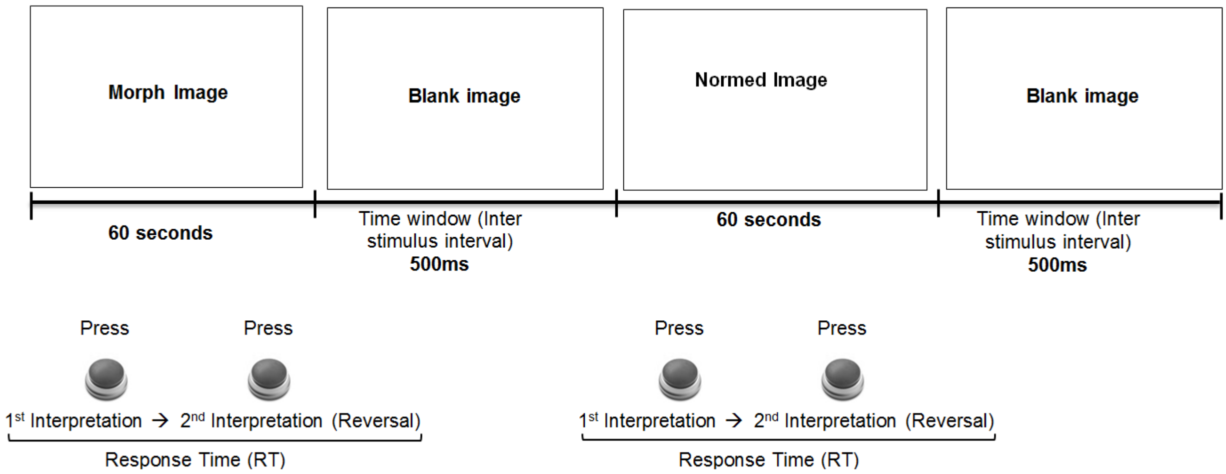
Each image will appear for a maximum of 60 seconds.
Your task is to press the button as soon as you can tell what the image is.

If you see the image changes into something else, you press the button again. The image might change or might not change.

Please press the "SPACE" button to proceed.

Phase 1. Practice/Trials

Subsequently, the trial part (***Phase 1)*** will take place and the images of this phase can be found in: \Dropbox\ Efi_Marina_Pilot study\Trials-Practice Images (see Section 4).
During the practise/trial phase (see Figure 1) one morph image and one normed image will be presented for 60 seconds each followed by a 500ms inter-stimulus interval (ISI) - time window, showing a blank screen. This phase aims to introduce the subjects into the experimental procedure (learn when to press the button) as well as to familiarize themselves with the concept of change without introducing them to ambiguous figures. The presentation order of the images included in this phase needs to be randomized across the participants as to achieve counterbalanced between participants and avoid order effect (participants always see a changes stimulus first).



Important Note to the programmer:

Please enable "ENTER" or "SPACE" button after the instructions presentation so the participant can proceed to Phase 1 not immediately but on a self-pace basis when fully comprehension of the instructions has been achieved. This needs to be time-free since the comprehension level of each individual differs significantly.
Please also add a fixation point ("+" sign) in the center of each blank image.

Phase 2. Main Experiment

Phase 2 consists of the main experiment. Participants' task is to identify the two interpretations that are embedded in each ambiguous figure and capture their response time. They will be asked to press the button when they see the first interpretation and press again if they see the content of the image changing into something else (second interpretation). We therefore have the below two scenarios followed by their respective consequence:

Scenario 1. The participant sees both interpretation, thus, button is pressed two times.
Consequence 1. If second button is pressed then it moves onto the next stimulus immediately.

Scenario 2. The participant sees one interpretation, thus, button is pressed only one time.
Consequence 2. If the second button is not pressed it moves onto the next stimulus after 60 seconds.

The presentation time of each figure will remain the same as that of the Practise/ Trials Phase 1. Each one of the thirty (30) images will be presented for 60 seconds in random order across participants. A blank page with a fixation point will appear in the centre of the screen for a time-window of 500 ms between the presentation of the first image and the second. The presentation order of the stimuli needs to be randomized across participants.

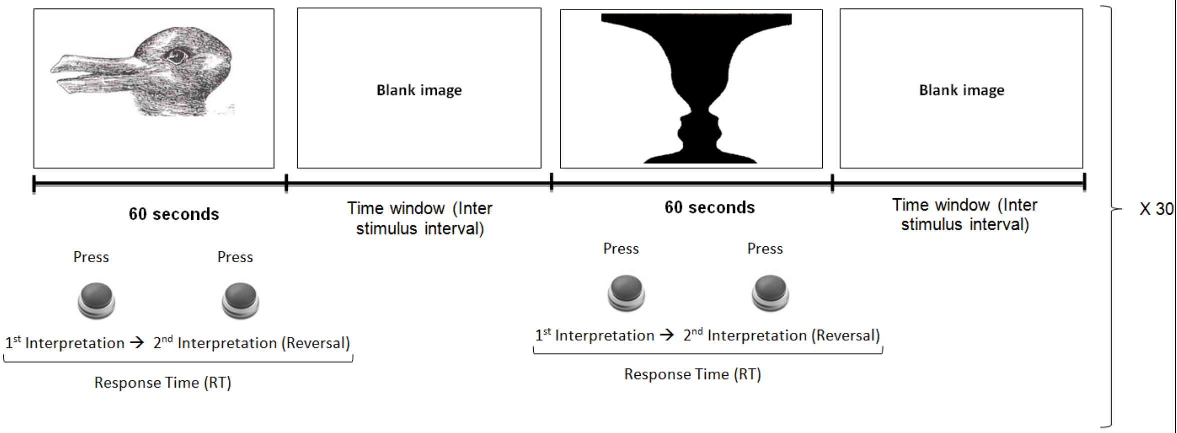


Figure 2. An illustration of the experimental paradigm and examples of the stimuli.

Important note to the programmer:

Please enable “ENTER” or “SPACE” button after the practice/trial Phase 1 so the participant can proceed to Phase 2 (main experiment) not immediately but on a self-pace basis when fully comprehension of the instructions has been achieved. This needs to be time-free since the comprehension level of each individual differs significantly. Please also add a fixation point (“+” sign) in the center of each blank image.

Phase 3. Questionnaire

At the end of the experiment participants will have to respond to a close ended questionnaire as a medium to report their familiarity and to check for naivety on the ambiguous images stimuli of the experiment.

Only small images of the twenty (20) ambiguous figures will be included in the questionnaire.

For an example please advise the below structure.

Question 1: Have you seen this image before?

	Yes	No
Image 1	○	○
Image 2	○	○
Image 3	○	○
Image 4	○	○
Image 5	○	○

Question 2: Would you describe yourself as a creative thinker?

No Maybe Yes

Question 3: What cognitive type you believe that you are?

Choose one of the following answers

Please choose

If you are "Field Independent", you will be able to focus on the relevant details and not be distracted by unnecessary details.

If you are "Field Dependent", the information structure in the environment plays an important role in your understanding or learning. In a distracted environment you will face difficulties in finding out what you are looking for as you cannot identify the separate parts of a whole.

If you are "Field Neutral", you will be able to focus on the relevant details in a mild distracted environment. You sometimes behave as FD and sometimes as FI according to the learning situation.

*Please select your participant code

The code should be given to you by the researcher. If you do not have a participant code you cannot continue any further please contact the researcher for a participant code.

Summary of the information that needs to be presented to the participants:

- Present instructions to the participants.
- Press “ENTER” or “SPACE button after the presentation of the instructions.
- Start with the practice/ trial phase and then continue to the main experiment.
- Press “ENTER” or “SPACE button after the practice phase to proceed.
- Random presentation of the images.
- Set presentation time of each image for 60 seconds.
- Fixed time window at a level of 500ms.
- A total of 30 images will be used including ambiguous figures and normed images.

Section 4

Please provide any drawings/illustrations of how you would like the screen/object to look. (If an object to be made, please include measurements). Use separate files as necessary. Either list filenames and brief description of contents here, or attach paper copies. If you need to provide hand-drawn illustrations then note here and send them with a printout of this form in addition to emailing.

- All images are made as to fit in a window of 700x700 pixels.
- All images must be presented in the centred of the screen.
- All the images can be found in the shared Dropbox folder called Efi_Marina_Pilot study.

Name of each folder along with a brief description:

\Dropbox\ Efi_Marina_Pilot study\Instructions
\Dropbox\ Efi_Marina_Pilot study\Content Ambiguous Figures
Ten figures are included in this folder. Size is set.
\Dropbox\ Efi_Marina_Pilot study\Figure-Ground Ambiguous Figures
Ten figures are included in this folder.
\Dropbox\ Efi_Marina_Pilot study\Normed Images
Ten figures are included in this folder.
\Dropbox\ Efi_Marina_Pilot study\Trials-Practice Images
In this folder you will find two normed images (saved as Normed 1, Normed 2) to be presented in the trial phase of the experiment. Another subfolder named “Morphs” is included in this folder and contains 4 images (pair of two) for you to create the morphs. The images for morph one (1) are saved as morph 1 and morph1-1 and the images for morph two (2)are saved as morph 2 and morph 2-2.

Section 6   Please list output data that the programme needs to record/produce.

See task specific instructions for every task individually.

- Age
- Gender
- Response time for each stimulus button press
- Number of button presses for each stimulus
- Eye-movements from one image to the other
- Timestamp subjects responses when button is pressed

Section 7 Researcher

Please make sure you have filled in all parts of this from to the best of your ability and explained in as much detail as you can. For student projects this should be a complete and final specification. For staff/PG research this may be a preliminary spec for discussion, prototyping and further development.

Researcher Signature: Date: 23/10/2014

If you submit the form by email from your university email account then a physical signature is not required. Project students should submit this to their supervisor for approval prior to forwarding to the TechOffice.

Section 8 Supervisor (for Stage 4 projects)

Name :   Internal Tel No: __________

Please sign below to confirm that you have read this specification and that it is correct and will meet the needs of the student's project data collection.

Signature: ____

If you submit the form by email from your staff university email account then a physical signature is not required

Section 9 Technical Office

Date Received: ______________ Signed __________________________________

Technician assigned:

APPENDIX H

Letter of Confirmation for Erasmus+ Placement

Erasmus+

Cyprus University of Technology

ERASMUS+

Letter of Confirmation

To be completed by the Host Institution/Company:

It is hereby certified that

Ms: Efi Nisiforou

Has spent an Erasmus Placement Period at our Institution/Company

Name: Plymouth University

between the following dates

	10/01/2014		**and**		**28/02/2015**		
day	month	year		day	month		year

In the field of:

Psychology

Date **28/02/2015**

Stamp and Signature

RESEARCH WITH PLYMOUTH UNIVERSITY
The Graduate School
Plymouth University
Drake Circus
Plymouth PL4 8AA United Kingdom

Name of the signatory: CATHERINE JOHNSON

Function: DTC ADMINISTRATOR

APPENDIX I

Alpha Coefficient tests for each study

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,868	,862	32

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,873	,880	32

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,850	,851	32

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
,862	,869	32

APPENDIX J

Ambiguous Figures – Experimental Stimuli