Measuring User Perception and Acceptance by Eye Tracking, in Web-based End-User Development

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Abstract

In the recent years in the End-User Development (EUD) research there is a shift from the study of tools that focus on desktop graphical applications, to the development of EUD for web environments and the Internet of Things (IoT). To this end mouse and eye tracking methodologies are used to implicitly monitor the end-user behavior in real time. In this paper we examine the potential correlation between eye movements and end-user perception and acceptance in modern web-based EUD environments. The aim is to find out whether end-users' perception and acceptance attributes can be reflected on their eye behavior when interacting with a web-based, database-driven EUD system. To check out our research hypotheses we have conducted a field test using a prototype EUD tool based on a natural language approach (named 'simple talking'), to assist end-users in creating database-driven mobile applications. The results of the field test show significant correlations between eye behavior and acceptance and perception. Self-Efficacy is correlated to fixations of any kind. Risk-Perception is correlated to the increment of the pupil size. Perceived Ease-of-Use is correlated to fixations that turned into clicks and to the increment of the pupil size. And Perceived Usefulness is correlated to fixation duration.

Keywords: End-User Development (EUD); Eye-tracking in EUD; Eye-tracking in Human Computer Interaction; Perceived Ease of Use; Perceived Usefulness; Self-Efficacy; Risk Perception.

1. Introduction

In the recent years in the End-User Development (EUD) research area we have experienced a shift from the study of tools that mainly focus on desktop graphical applications, to the development of EUD techniques for web environments (Paternò, 2013). According to Barricelli, and Valtolina (2015) the definition of the end-user has been deeply changed in the last decade. The main reason of this evolution is the complex ecosystem of Internet of Things (IoT) that has transformed the traditional role of the end-user to that of end-user developer. EUD is mainly defined as a set of methods, techniques, and prototype applications that allow users of software systems, who are acting as non-professional software developers, at some point to create, modify or extend a software artefact (Lieberman et al., 2006). In other words, people who are not professional developers can use EUD applications to create or modify software artefacts and complex data objects without significant knowledge of a programming language.

EUD is inherently different from traditional software development and should be examined differently. Burnett and Scaffidi (2011) declare that trying to support EUD by simply mimicking traditional development approaches will possibly lead to unsuccessful outcomes. According to Rode et al. (2005) "we can build better End-User Development tools if we know how end-users think". Many studies have emphasized the existence of different mental models between programmers and

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non-programmers, as well as of different priorities and motivations: they follow different approaches and reasoning strategies to modeling, performing and documenting the tasks to be carried out in a given application domain (Costabile et al., 2008; Blackwell and Morison, 2010). Analyzing the end-users' behavior while interacting with EUD environments is important to design effective EUD tools, especially today when EUD is becoming more and more dominant in the IoT ecosystem of the end-users' computer-related activities.

End-user perception and acceptance have been outlined by many studies (e.g.Beckwith, et al, 2006; 2007; Beckwith et al., 2005; Burnett, 2009, Burnett et al., 2008; 2010; 2011; Beckwith and Burnett, 2007; Chen and Corkindale, 2008; Cyr et al., 2007; Lee, 2008; Sun and Zhang, 2008) as important Human Computer Interaction (HCI) human factors and have been shown to affect user performance in EUD tasks. Hence, the analysis of the end-users' perception and acceptance is crucial to design tools and methodologies that assist end-users' to enhance their developing performance. It is important for the EUD community to design and implement new approaches in order to capture and analyze the end-users' perception and acceptance while interacting with today's EUD environments.

Mouse and eye tracking methodologies are ideal to implicitly monitor the end-user behavior in real time. Especially eye tracking, can provide with cognitive and psychological user data, helpful to deeply analyze the users' behavior and internal situation during the whole user-system interaction (e.g., Ball et al., 2003; Just and Carpenter, 1976; Yoon and Narayanan, 2004). However, most existing user-centered EUD research has been conducted via questionnaire surveys, think-aloud or retrospective verbal protocols, interviews or focus groups and real time observation by humans. In Human Computer Interaction (HCI) analysis of eye movement data has been mainly studied to evaluate usability issues since eye-movement tracking represents an objective technique that can offer useful advantages for the in-depth analysis of interface usability (Poole and Ball, 2005).Unfortunately, despite its important HCI contribution eye tracking has not been widely integrated in the behavioral research area of EUD.

The lack of such significant research results triggered our interest to use eye tracking to examine the potential correlation between eye movements and end-user perception and acceptance in modern web-based EUD environments. This work aims to study whether end-users' perception and acceptance attributes can be reflected on their eye behavior while interacting with a modern web-based EUD environment targeted at the development for database-centric mobile applications.

Our research question is: are there any significant correlations between eye movements and perception and acceptance of end-users of similar expertise level, when interacting with a web-based, database-driven EUD system? To achieve the paper's research goal the concepts of perception and acceptance have been broken down into a set of attributes (variables) to be analyzed, based on a set of research hypotheses. Because of the limited relative previous eye tracking research, we were 'inspired' from user experience metrics and mouse tracking patterns to establish suitable eye tracking measures in EUD behavioral research.

The main ambition of this work is to provide the EUD research community with a basic background knowledge and a motivation to study further and understand end-user developer eye movement correlation to behavioral human-side factors (such as perception and acceptance) in today's web-based and web-targeted EUD systems.

This paper is organized as follows. The second section presents a theoretical foundation of perception and acceptance factors in EUD, focusing on the attributes of Self-Efficacy, Risk-Perception, Perceived Ease of Use and Perceived Usefulness. These attributes are derived by the basic behavioral EUD research and the main components of the Technology Acceptance Model (TAM). EUD Then, it presents some basic eye tracking research and related metrics in HCI, outlining the need for similar research in the EUD area as well. In the end of the second section a list of useful eye tracking metrics for user experience is presented. The third section presents the research hypotheses that need to be examined. There is a set of eye-related hypotheses for every perception and acceptance item. The fourth section describes the evaluation methodology which is composed of five main steps: the prototype web EUD tool that was used for the field test, the field test preparation and procedure that was followed, the eye tracking technology (hardware and software),the feature extraction method, the measured variables and the resulted questionnaire, and finally the data analysis methodology chosen. The fifth section shows the results. Then a discussion section follows that presents an analysis of the results and explains the study's issues and limitations. Finally, the conclusions and future research are presented. Annex A presents the questionnaire used for the survey.

2. Literature Review

2.1. Perception and Acceptance in End-User Development

End-User Development

According to Lieberman et al. (2006), End-User Development (EUD) is 'a set of methods, techniques and tools that allow users of software systems, who are acting as non-professional software developers, at some point to create, modify or extend a software artifact'. . What characterizes end-user developers is that they express a need to modify on their own the computer systems they use and to gain more control over their computer applications (Lieberman et al., 2006; Repenning and Ioannidou, 2006).

EUD is inherently different from traditional software development. Burnett and Scaffidi (2011) declare that trying to support EUD by simply mimicking traditional development approaches will possibly lead to unsuccessful outcomes.

Fortunately, there are many remarkable EUD approaches, most of them presented in details in the work of Spahn et al. (2008) and Paternò (2013). Indicatively, such approaches include programming using visual attributes, programming by demonstration (PBD), programming by specification, programming with text, interface customization, natural programming, visual programming, spreadsheets, etc.

Many EUD technologies have been designed according to the abovementioned approaches. For instance, PBD-based tools are available for creating animations and are often used in combination with visual or textual languages. According to programming by specification, Liu and Lieberman (2005) implemented a system that accepts specification in natural language and generates a corresponding program written in Python. Some systems, like the Topes System of Scaffidi et al. (2008) provide a forms-based visual interface, restricting the user's specifications to only those that can be handled by the tool. The CoScripter (Scaffidi et al., 2010) tool is a good example of combining visual with textual specifications, since it uses a textual language to represent a web macro, which is a script that directs a web browser to navigate the web and manipulate websites in a particular way (Burnett and Scaffidi, 2011).

While thefirst EUD tools were mainly focused on desktop graphical applications, in recent years a considerable amount of work has been carried out to apply the EUD approach to web environments (Paternò, 2013). According to Rode et al. (2005), web EUD tools can be categorized to three main categories: database-centric tools that are primarily intended to help end-users put databases online for viewing and editing purposes, form-centric tools that are intended to help end-users create forms for collecting data and website-centric tools whose primary purpose is assisting the user with the creation of static or dynamic websites. Some examples of database-centric EUD tools are PhpClick(Rode et al., 2005; 2006), FORWARD (Ong, 2010), Visque (Borges and Macías, 2010), XIDE (Litvinova, 2010), CRIUS (Qian et al., 2010) and Simple-Talking (Protogeros and Tzafilkou, 2015). There are also some query-centered approaches for mobile systems, such as Query by Zoom (Silveira, 2010) and Query- by-Object (Akiyama and Watanobe, 2012).

End-User Perception and Acceptance

Many studies have emphasized the existence of different mental models for programmers and non-programmers, and the existence of different priorities and motivations. End-users follow different approaches and reasoning strategies to modeling, performing and documenting the tasks to be carried out in a given application domain (Costabile et al., 2008; Blackwell and Morison, 2010). In this context, research in Human-Computer Interaction (HCI) has put considerable effort over the past decades to build theories and models which attempt to explain end-users' perception while using computer software to customize, program and/or develop artefacts.

A series of end-user behavioral theories that shed light on perception and acceptance factors in HCI and EUD research have been developed. Some of the most dominant theories in the EUD community are: Self-Efficacy Theory (Bandura, 1977; 1986), Attention Investment Theory (Blackwell, 2002), and Technology Acceptance Theory (Davis, 1989).

According to Self-Efficacy theory studies, Self-efficacy (SE) conveys an individual's level of confidence to execute courses of action in a given situation. Self-efficacy has been studied in depth by Bandura (1977; 1986) who found that it can be influenced by environmental situations, cognitive and personal factors as well as demographic characteristics. Social cognitive theory (Bandura, 1986, 1997) posits self- efficacy as a key determinant of skill acquisition and task performance.

Computer self-efficacy is an extension of self-efficacy that is specifically related to computer usage (Compeau and Higgins, 1995). Pajares (2002) argues that self-efficacy can affect task effort, persistence, expressed interest, and the level of difficulty of goals users will strive to attain. Stated in Blackwell et al. (2009) point out that being a challenging task, software development renders a person with low self-efficacy may be less likely to persist when a task becomes challenging. Moreover Self-efficacy is tightly linked to positive physiological and emotional states in the aftermath of a successful execution of certain behavior (Shea and Bidjerano, 2010).

Analysed in Blackwell's Attention Investment Model theory (Blackwell, 2002), Risk-Perception (RP) is considered to strongly influence the end user's behavior through their cost/benefit evaluation. According to Blackwell (2002), risk is the probability that no pay-off will result, or even that additional future costs will be incurred from the way the user has chosen to spend attention. If users decide that the costs and/or risks are too high in relation to the benefits they may choose not to follow through with the action. Perception of risk thus plays an important role in a user's decision making about whether to use particular application features (Beckwith and Burnett, 2004).

The Attention Investment Model predicts that higher perception of risk can lead to differences in actual behavior. Risk-Perception can strongly influence computer related behavior (e.g. Willingness to learn, Self-Efficacy, etc.) since it determines the whole 'confidence and security' the end-user feels while interacting with the computer environment.

Low Risk-Perception has been shown to be positively related to performance during computer related tasks. High Risk-Perception renders users less likely to make use of unfamiliar features (Beckwith et al., 2005) eliminating their 'high performance' possibilities and the successful task completion. High perceived risk results in avoidance behavior (not using features that might help them in their task), then the result could be lower task performance, or a higher cost (in time) to accomplish the desired computer task (Beckwith and Burnett, 2004).

As regards to end-users' acceptance theories, the original Technology Acceptance theories, developed by Davis (1989), do not necessarily focus on end-users as their primary audience, and the technologies studied are general software technologies. Nevertheless, there are strong ties to the more specific research of end-user problem solvers (Beckwith and Burnett, 2007).

The main purpose of Technology Acceptance Model (TAM) (Davis, 1989), is to explain and predict IT acceptance and facilitate design changes before users have experience with a system. TAM is considered one of the well-known models related to technology acceptance and use since it has shown great potential in explaining and predicting user behavior of information technology (Park, 2009).

TAM predicts user acceptance based on two specific behavioral beliefs which determine an individual's behavior intention to use an IT (Davis, 1989). According to TAM, when users are presented with a new technology, two key factors influence their decision about how and when they will use it: perceived usefulness and perceived ease of use (Venkatesh and Morris, 2000). TAM suggests that perceived ease of use and perceived usefulness are the two most important factors in explaining system use. Additionally, the End-User Computer Acceptance (EUC) theory introduces the most relevant human factors affecting the end-users' overall behavior and performance including perceived ease of use and usefulness (Chen and Corkindale, 2008; Cyr et al., 2007; Sun and Zhang, 2008).

Following we describe the meaning and terminology of the two above mentioned key acceptance factors:

Perceived Ease of Use (PEOU) is defined as the degree to which a person believes that using the system would be free of effort (Davis, 1989). Given that effort is a finite resource, an application perceived to be easier to use than another is more likely to be accepted by users (Davis, 1989).

Its role is crucial in EUD tasks and it can affect users' performance, as mentioned in many researches (e.g. Beckwith, et al, 2006; 2007; Beckwith et al., 2005; Burnett, 2009, Burnett et al., 2008; 2010; 2011).

Perceived Usefulness (PU) is determined as the degree to which a person believes that using a particular system will enhance his/ her job performance (Davis, 1989). Davis (1989) describes a system high in Perceived Usefulness as one for which a user believes in the existence ofa positive user-performance relationship. The user perceives the system to be an effective way of performing the task(s).

A strong influence of PU on performance and other perception attributes (e.g. perceived playfulness) has been found by many studies (e.g. Lee, 2008; Ong and Lai, 2006; Terzis and Economides, 2012; Van Raaij and Schepers, 2008).

2.2. Eye tracking research in Human Computer Interaction and related work

Eye tracking has generated a great amount of interest in the HCI and user experience (UX) research since the beginning of the twenty-first century when the technology started becoming more widely accessible. Today, eye tracking is frequently employed to help evaluate and improve designs at various stages of the development cycle (Bojko, 2013).

According to Poole and Ball (2005), eye-movement tracking represents an important, objective technique that can afford useful advantages for the in-depth analysis of interface usability.Eye-movement recordings can provide an objective source of interface-evaluation data that can inform the design of improved interfaces. Also, eye movements can provide a window onto so many aspects of user cognition and human factors especially on problem solving, reasoning, mental imagery, and search strategies (e.g. Bal et al., 2003; Just and Carpenter, 1976; Yoon and Narayanan, 2004).

According to Just and Carpenter (1976), what a person is looking at is assumed to indicate the thought "on top of the stack" of cognitive processes. This "eye-mind" hypothesis means that eye-movement recordings can provide a dynamic trace of where a person's attention is being directed in relation to a visual display. Measuring other aspects of eye movements, such as fixations (moments when the eyes are relatively stationary, taking in or "encoding" information) can also reveal the amount of processing being applied to objects at the point-of-regard. Common eye metrics such as fixation duration and pupil size (diameter)have been correlated to perceived web page relevance(Gwizdka and Zheng, 2015).In practice, the process of inferring useful information from eye-movement recordings involves the HCI researcher defining "AOIs" (areas of interest) over certain parts of a display or interface under evaluation, and analyzing the eye movements which fall within such areas. In this way, the visibility, meaningfulness and placement of specific interface elements can be objectively evaluated and the resulting findings can be used to improve the design of the interface (Goldberg and Kotval, 1999).

Although traditional HCI eye tracking research was focused on measuring usability and interface design issues, recent HCI eye-tracking research also focuses on measuring the overall user-experience. User experience expands usability in a sense that it studies not only the interface efficiency but also the end-user from a human side. That is, eye tracking can also measure the end-user's perceived items, such as perceived ease of use, hesitation, perceived playfulness, cognitive and mental load, etc. and thus it can provide with a basic knowledge of the users' internal situation while interacting with a computer system.

The main measurements used in eye-tracking research are fixations and saccades. Saccades are quick eye movements occurring between fixations. Although there are a few more types of eye movements, saccadic eye movements, consisting of saccades and fixations, are most common to user experience (UX) research. Fixation is a metric of great interest in HCI and UX because even though eye tracking only captures foveal vision, it provides useful information about visual attention because, in most cases fixation coincides attention (Bojko, 2013). There are also a multitude of derived metrics that stem from these basic measures, including "gaze" and "scanpath" measurements. Pupil size and blink rate are also studied. For instance, the metric of pupil dilation has been associated with mental effort and attention (Onorati et al., 2013). Oliveira et al. (2009) and Gwizdka (2014) found that for text documents and images pupil dilated for more relevant stimuli.

In Jacod and Karn (2003) (mainly focused on usability) and in Holmqvist et al. (2011) the authors document all the existing eye tracking metrics. Suggesting eye movement as a cognitive load in HCI, Chen and Epps (2014b) state that end-users' perceptual load should be considered in cognitive load measurement using pupil diameter and blink measure. Pupil diameter and blink rate have been associated to cognitive load in many HCI research studies. For example they were also studied for task analysis to improve HCI (Chen et al., 2014a;2013;Haapalainen et al, 2010; Iqbal et al., 2005) and for constructing effective and user-personalized training (Chen et al., 2011). Furthermore, pupil diameter and/or blink measures have been found useful to the system usability (Nakayama and Katsukura, 2007; Kozsa, 2011).Chen and Epps (2014a) encourage eye tracking research in HCI to infer cognitive load, since as they suggest "knowing the type and level of load that is generating user mental effort will benefit the diagnosis and remedy formulation processes in human-centered design".

Although its UX and usability-centered HCI implementation, eye tracking has not been widely adopted in end-user behavioral or more generic EUD research. In particular, end-user behavior, perception and acceptance have not been examined through eye tracking methodologies in current web-based EUD environments. The research described in this paper differs from the efforts above because it attempts to integrate the eye-tracking methodology in EUD research and to provide with existing and/or new eye metrics to measure or deeper understand the end-users' behavior while performing developing tasks.

Eye tracking has not been widely used to detect and analyze the end-users' perception and acceptance attributes, such as Self-Efficacy, Risk-Perception, Perceived Ease of Use and Perceived Usefulness, which are important to the end-users' developing performance according to the EUD literature.

Regarding perceived self-efficacy, limited research works have been found to use eye tracking as a self-efficacy measure. In particular, in Eachus et al. (2008) the authors have correlated eye tracking data with Internet self-efficacy. In contrast, mouse tracking research has deeply examined mouse movements as reflecting self-efficacy and confidence levels of the user. In particular, the straight pattern (Lee and Chen, 2007) or else called as ‘confident movements’ a user’s self-efficacy can be expressed by a pause before a direct movement towards a target, since "once traced the desired feature (or link) users move the mouse straight to it". This mouse behavior implies the user feels certain about his/her actions (Rodden et al., 2008).
Regarding risk-perception, no research works have been found to use eye tracking as a risk-perception or hesitation measure. Although hesitation has been studied in mouse tracking research and a hesitation pattern has been defined (Mueller and Lockerd, 2001; Ferreira et al., 2010), no eye tracking research has been conducted to examine possible correlations between eye movements and hesitation or risk levels while end-users interact with EUD or other software environments.
Regarding perceived usefulness and ease of use, most eye tracking HCI research focuses on measuring usability and user experience. Yet no eye tracking research has been conducted to measure perceived usefulness and ease of use on web-based EUD environments. However, there are plenty of existing user experience eye metrics are HCI that they can also be used to examine user interaction with EUD environments, since according to Bojko (2013), the same measures can represent different cognitive phenomena in the context of different stimuli and goals. Fortunately, the lack of EUD-targeted eye metrics does not prevent us from analyzing the existing eye-metrics (e.g. form user-experience or other research area) in the EUD scope. Based on Bojko’s (2013) methodological work on how to conduct eye tracking research for measuring the user experience we have aggregated in Figure 1 a list of eye-tracking (fixation and pupil)metric categories and metrics many of which could be useful for our webEUD-oriented research as well.

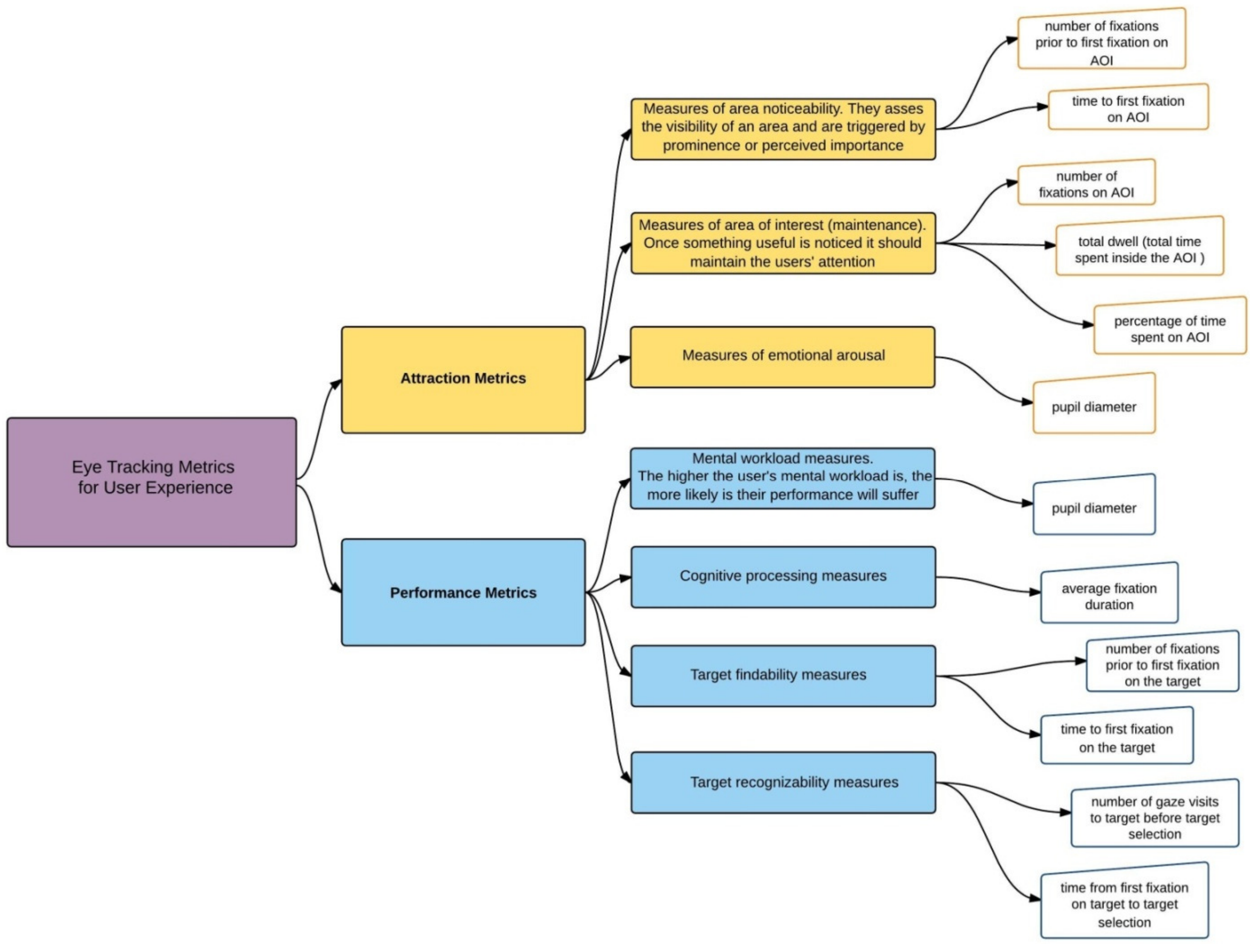

Figure1. List of eye user experience metrics according to the taxonomy of Bojko (2013)

3. Research hypotheses

In this section we construct a set of research hypotheses to examine the potential correlations between user acceptance and perception items and eye behavior in EUD tasks. However, since eye-tracking in EUD is a new research area and there is no previous research methodology we should consider the following before the hypotheses formation:

- A EUD system does not consist of static pages (like most eye-tracking studied environments); instead it is composed of many dynamic pages and in some cases of SPA (Single Page Applications). Thus we will measure the average eye-behavior during the time needed by a user to complete a development task. This time is different for every user and is defined as 'EUD task duration'. We consider that users are working on different pages (URLs) at the same timestamp. That is, we could not compare users' behavior based on specific timestamps but based on common URLs.
- Since we will measure the user-side situation (perception and acceptance) and not the system interface design and usability, we will not integrate in our methodology any areas of interest (AOIs). For this reason we have excluded from our research most of the AOI-oriented eye metrics listed in Figure 1 and we will use only the most generic and user-oriented ones, i.e. the ones that are appropriate for testing the user 'internal situation' while interacting with a system and not the noticebility, finadability and attraction of specific AOIs in the user interface.

- Since there is a considerable correlation between eye and mouse movements (Chen et al., 2001), when literature eye related background is 'missing' we suggest and use as EUD eye metrics some related mouse patterns that could also be reflected by eye behavior as we explain.

Eye measuring Self-Efficacy

Since there is not a rich eye tracking literature for successfully measuring self-efficacy levels in end-users, and more specifically there is not any eye tracking self-efficacy research in web-based multi-page EUD environments, we have considered the mouse-eye correlation showed in many research works (e.g. Chen et al., 2001;Guo and Agichtein, 2010; Huang et al., 2012;Navalpakkam et al., 2013; Rodden et al., 2008)and decided to use mouse behavioral patterns in order to define and test self-efficacy eye metrics for EUD environments.

Many researchers have concluded that the 'direct mouse movements' can determine self-efficacy levels. Defined as "straight pattern" (Lee and Chen, 2007) the users' 'confident movements' are characterized by a pause before a direct movement towards a target, since "once traced the desired feature (or link) users move the mouse straight to it". On presence of this pattern, researchers infer that there is an earlier decision and the user feels certain about his/her mouse movement. This use of mouse defines direct movements that occur once the user has decided which action to take (Rodden et al., 2008), and this undoubtedly reveals task-oriented self-efficacy. In the context of interaction with web applications, direct movement is characterized by "a direct movement toward a target whit no big pauses" (Ferreira et al., 2010).

In terms of eye-tracking self-efficacy, the mouse pattern can be interpreted as following: the user needs first to eye detect the target before moving the mouse straight towards it. The usefulness of the fixated target is determined by the user's decision to click or not to click on it. This logically means that a fixation must occur on every desired target before the mouse click. Hence, any fixation that turns into click could reveal the users' confidence that the fixation area is the desired one. For this reason our first hypothesis is:

H1.1: Self-Efficacy is significantly related to the number of fixations that turned into clicks during the EUD task.

According to Bojko (2013),once a desired target is noticed it should maintain the users' attention and this is expressed by the total number of fixations on these areas. Based on this, we assume that the more the fixations the higher the users' certainty that he/she has detected the desired/useful item. Hence, our second hypothesis is:

H1.2: Self-Efficacy is significantly related to the total number of fixations during the EUD task.

Eye measuring Risk-Perception

The most commonly used eye tracking measure of mental workload is pupil diameter. According to Bojko (2013) pupil gets larger with high processing demands. The author suggests that the higher the user's mental workload is, the more likely is their performance will suffer. According to Tsang and Wilson (1997), mental workload for a given task depends on the amount of effort a person dedicates to the task and their spare mental capacity. According to Tevel and Burns (2000) perceived-risk can be one important factor that contributes to mental workload. The authors showed that there is a relationship between subjective risk assessment and mental workload in HCI.

For this reason the next hypothesis is:

H2.1: Risk-Perception is significantly related to the average increment of the pupil's diameter during the EUD task.

Eye measuring Perceived Ease of Use

One of the measures of cognitive processing difficulty is the average fixation duration. According to Bojko (2013), longer fixations mean more effort to extract information and more difficulty in general. Since PEOU is defined by Davis (1989) as the degree to which a person believes that using the system would be free of effort, the next hypothesis is:

> H3.1: Perceived ease of use is significantly related to the number of fixations that turned into clicks during the EUD task.

Exploring pupil diameter to index cognitive load has been an active research line in several application domains (Chen and Epps, 2014a). The difference with mental workload, mentioned in H2.1 is that cognitive load can be seen as an effect that users experience, whereas mental effort is a unit that users actually exert in response to the load (Jong, 2009). Chen and Epps (2014a) showed in their cognitive load experiment that pupil diameter change was larger during the high perceptual load task than the low. The authors concluded that participants exerted more mental effort to deal with the high perceptual load task. For this reason we assume that in EUD environments where the users have to 'face' a developing task, high perceptual load can be reflected to low perceived ease of use. Hence, our next hypothesis is:

> H3.2: Perceived ease of use is significantly related to the average increment of the pupil's diameter during the EUD task.

Eye measuring Perceived Usefulness

As already mentioned, longer fixations mean more effort to extract information. Hence, longer fixations reveal ambiguity and hesitation to take a specific action (i.e. to click on the fixated point). This also may reveal a difficulty to perceive a system as useful since there are doubts on the predicted outcome/performance if the specific action (click) is completed. That could imply that the more the fixation duration over a specific point the more the ambiguity on the performance outcome. Hence our last hypothesis is:

> H4.1: Perceived usefulness is significantly related to the average fixation duration during the EUD task.

4. Evaluation methodology

4.1. Prototype web EUD tool

The prototype EUD tool we used for our experiment is the one used in a recent research work of Protogeros and Tzafilkou (2015), where the authors designed a natural language approach ('simple talking') to assist end-users creating database-driven mobile applications. The authors also developed a prototype wizard-based web EUD tool to integrate and evaluate their EUD approach. The end-users' high performance results indicated the validity of the EUD approach and the efficiency and usefulness of the tool. A detailed presentation of the particular EUD approach for database-driven web applications can be found in Protogeros and Tzafilkou (2015).

Figure 2 presents the overall concept of the prototype the web EUD tool.

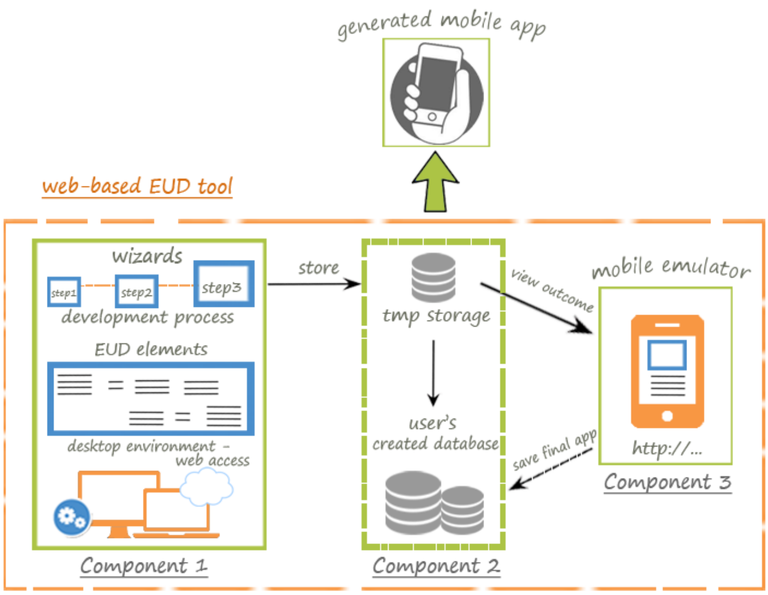

Figure 2. Overview of the web EUD tool concept and architecture

As depicted in Figure 2, the EUD concept is divided in three logical components/areas (from left to right). The first component presents the concept of the EUD tool wizard-logic interface, its 'user-friendliness' (i.e. user-centered design elements, such as clear buttons, examples, instructions, etc.) and web accessibility. The second component shows the database storing creation procedure. In particular, the end-users' developed/constructed items in Component 1 are stored in a temporary database storage in Component 2. The end-user can then review the created components and modify/update/delete them. When he/she finishes, he/she can proceed with the application creation which will create both the final database and the user interface for mobile devices. As presented in the Component 3, the end-users can then view the constructed application via a mobile emulator and they can save it in the final database (of the second component). Finally, the mobile application is generated and the end-users can access and use it via their mobile devices. To edit their application, the end-users need to login again in the web tool via their desktop device (Component 1).
To explain the end-user development process and present the interface environment of the prototype web EUD tool, we provide the following descriptions and interface screenshots:

- Participants (end-users), need to follow a step-by-step wizard process (see Figure 3) to create their own database-driven (based on an abstracted relational schema) application in order to manage their business. In every step they can create a basic database item, such as a table or a relationship and define the attributes' (fields) data types, the integrity constraints, the relationship's type (e.g. one-to-many, many-to-many, one-to-one), etc.
- In the end, they can select the generation of their application. A generated link is provided to each user, and they can view their application via their mobile device or a mobile emulator.
- Via their mobile device they can access all the constructed items and insert, edit, delete and search their records (see Figure 4).

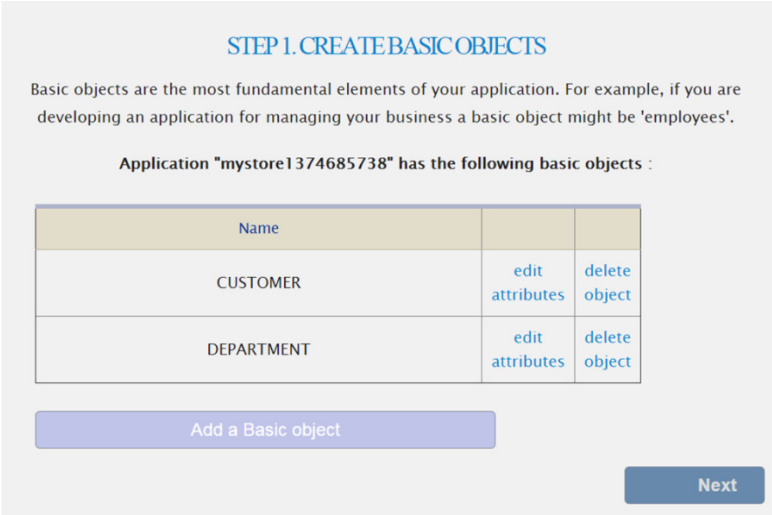

Figure 3. EUD interface (example of wizard-step 1)

Figure 4. Mobile interface of the generated application

4.2. Participants and procedure

There were 10 volunteers (3 male and 7 female). Eight of them (2 male and 6 female) successfully completed the tasks in three different days. Participants were tested individually and each one spent around 40 minutes to complete the EUD task.

All the participants had been informed that their eye movements would be recorded and they were asked to use lens instead of glasses and remove any eye makeup such as mascara. They were also asked to inform us on any serious eye-health issues they might have. The calibration tests were successfully fulfilled by 8 out of the ten participants.

Additionally, since pupil diameter was decided to be a measured and analyzed, lab moderators made sure that the lighting did not interfere with eye tracking.

Prior to the EUD task the participants had to answer a short questionnaire regarding their experience level on database concepts, programming, World Wide Web and overall computer use. The experience level was measured in a scale from 1 to 5, as depicted in Figure 5.

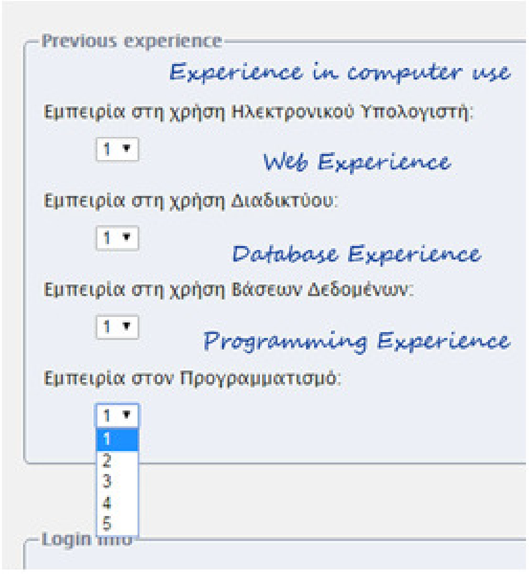

Figure 5. Web questionnaire prior to EUD task, regarding the user previous experience (translation in English is provided in hand-written fonts)

The measured mean value of the participants' database familiarity was 1,62, revealing that they could be 'safely' considered as non-professional/non-expert end-users in database-development tasks. Additionally, their programming experience was 1,87, their familiarity with web was 3,.37 and their general familiarity with computer use was 3,12 (see Table 1). These mean values satisfy our target group (end-users) requirements, i.e. users that are non-experienced programmers, with no or limited knowledge on database concepts but with efficient familiarity with web interaction and computer use in general.

Table 1 Participants' experience level

Measured Item	Users (N=8)		
	mean (0-5)	St. Deviation	St. Error
Database Experience	1,62	0,91	0,41
Programming Experience	1,87	1,18	0,54
Web Experience	3,37	0,91613	0,32
Computer Use Experience	3,12	0,83452	0,29

The participants were calibrated using a standard 9-point calibration where the point was set to move between the positions at a slightly higher speed than normal. The calibration points were red dots with a central black dot shown on a neutral gray background. An automated calibration procedure was used, which was initiated by the moderator.
Before the beginning of the development procedure, the participants were provided with a pfd document with instructions on the user task. The user task was based on a real world problem, small enough to be resolved in a limited time by the end-users. The example was based on a DVD store and the management of customers and DVD rental. It is simple and comprehensive since it is familiar to most end-users and its database structure encompasses the creation of all the basic database (relational) items: tables, fields and relationships. The exercise given to the participants was to develop a simple database-centric mobile application, to record, edit and retrieve movie DVD rentals and customer data.

In particular, the participants were provided with the following task description:

"*The exercise refers to the case of a* ***DVD store*** *which rents movie DVDs.*
You need to create an application to store and organize all the available DVDs and all the customers and also to manage and keep record of the status-of-rent for every DVD and every customer."
To help them develop the appropriate database structure we also provided the following information:

- *Every customer can rent many DVDs.*
- *A DVD can be rented by many customers.*
- *For every customer we want to store their name, last name and, email.*
- *For every DVD we want to store their title and duration.*
- *We also want to store the date every customer rented and returned a DVD.*

The user task was designed to enclose the creation of all the basic database items as following:

- Main entities (DVD, CUSTOMER, CUSTOMER-DVD).
- Fields for every entity (DVD: title, duration | CUSTOMER; name, email | CUSTOMER-DVD: date rent, date return).
- Many-to-many relationship (a CUSTOMER can rent many DVDs –a DVD can be rented by many CUSTOMERS).

What we expected from the users was to efficiently design the database schema of Figure 6, (which of course was not presented to them):

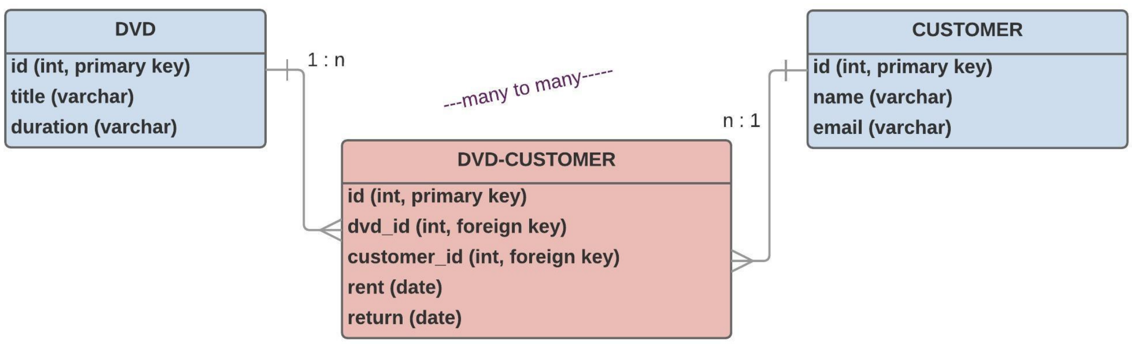

Figure 6. Entity Relationship Diagram of the expected database schema (solution)

A few more explanations were added by the moderator and the developing task could begin. Some of the participants needed to receive some extra help on the EUD task.
After completing the above-described user task, each participant had to answer a questionnaire-based survey consisted of 19 items measuring a set of perception and acceptance variables (see Annex A). The questionnaire was provided to the users as an online survey form, embedded in the last page of the EUD application.
The participants had no previous training on how to use the EUD tool. The use of the prototype tool (the web-EUD system) was simple, following a wizard-based logic and the interface text was translated in Greek.

4.3. Measured variables and questionnaire

The following list contains the set of user-oriented (perception and acceptance) and eye tracking variables (metrics) measured for each user.

- Self Efficacy (SE)
- Risk Perception (RP)

- Perceived Ease of Use (PEOU)
- Perceived Usefulness (PU)
- Number of fixations (NumFixations)
- Number of fixations that turned into clicks (FixToClicks)
- Average duration of fixation (FixDuration)
- Pupil size -average increment from initial state (PupilAvg)

The questionnaire survey consisted of 19 questions (items) which measure the five independent above-listed variables. A five point Likert-type scale with 1 = ‘‘strongly disagree’’ to 5 = ‘‘strongly agree’’ or 1 = ‘‘never’’ to 5 = ‘‘many times’’ was used to measure the items. Our questionnaire structure was based on previous research of computer perception and acceptance related questionnaires (e.g. Compeau and Higgins, 1995; Davis, 1989; Moon and Kim, 2001; Venkatesh et al., 2003; Thompson, et al. 1991; Wang et al., 2009) but we adjusted and extended the questions in order to cover all the under survey attributes. The original questionnaire was in a Linker scale form consisted of a prompt, ‘‘during the usage of the EUD tool I felt that I was totally confused, or I was bored, or I was confident" etc. (see Annex A).
As presented in Annex A, five items were used to measure Self-Efficacy, Risk-Perception and Perceived Ease of Use and four items were used to measure Perceived Usefulness. The internal validity and reliability of the questionnaire is presented in Table 2 in the next section.

4.4. Eye tracking technology and feature extraction

The eye tracking software and hardware that was used was the Tobii eye tracker, a commercial platform for the recording and analysis of eye gaze data. The hardware was composed of a Tobii monitor with an integrated eye tracker device in the front side. Although the software provides with ready for analysis metrics (such a fixation duration, total fixations, time spent on an Area of Interest, etc.) we used raw excel data which were exported by Tobii and imported in a MySQL database. Via SQL queries we retrieved the needed data in the desired mode.
Due to the dynamic nature of the EUD environment, the eye tracking software needed to be adjusted to recognize the stimuli as ‘Web stimuli’ in order to treat each URL as a static image.
The software’s eye tracking filter was set to fixation and the software generated only fixation related data (no saccades or blinks were captured). The raw data provided all fixations, clicks and time information as well as the coordinates (x,y) of every fixated point in every URL. If a URL was missing it would be impossible to calculate some ‘page-dependent’ variables like the number of fixations that turned into clicks, since we need to group by URL to guarantee the screen point(x,y) under fixation belongs to same page (URL) when it was clicked and not to another one.pupil diameter values for both eyes were also provided in detail.
The eye tracker also produced gaze video recording including gaze plots (‘scanpaths’). Scanpaths are the ‘paths’ that the aye follows to retrieve information over the visual item (Jacob and Karn, 2003; Poole and Ball, 2005). Scanpaths describe a sequence of saccade-fixation-saccade depicting them as lines (saccades) and dots (fixations) toward the target (Goldberg and Kotval, 1999). Scanpaths can also give important qualitative eye metrics such as the scanpath length (e.g. short scanpaths reveal sufficient search strategy), duration, normality, etc.
In order to extract information by the end-users’ scanpaths in EUD tasks we should isolate different video gaze timestamps, (through screenshots, examples are shown in Figure 7) for the same URL.

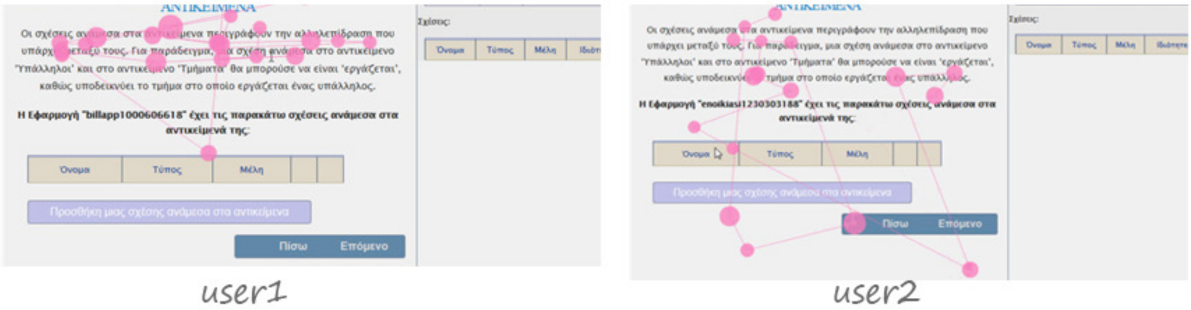

Figure 7. Example of gaze video timestamps/scanpaths of 2 different users in the same EUD system page (URL)

4.5. Analysis

In order to measure the correlations between the measured variables we used the Pearson correlation. . It is the appropriate method to define the strength of the association among a small set of continuous variables. Moreover, taking into account the small sample size, Pearson is preferred over other parametric or non-parametric correlation testing methodologies (e.g. Spearman's) that assume normality.

In order to evaluate the questionnaire internal consistency we calculated the value of Cronbach alpha (α).

Finally, to present the general results concerning every variable we used descriptive statistics.

5. Results

Construct validity and reliability have been tested to ensure that the results are reliable and consistent. Calculating Cronbach's alpha coefficient we tested the construct reliability. This measures the internal consistency by indicating how a set of items are closely related and forming a group (Moola and Bisschoff, 2012). Nunnally (1967) suggests that a Cronbach alpha value of 0,70 is acceptable, were a slightly lower value might sometimes be acceptable as well.

In Table 2 and Table 3, Cronbach's alpha values for all factors are equal or above 0,70, indicating that all measures employed in this study demonstrate a satisfactory internal consistency and the measurement model is supported.

Table 2.Results for validity of the measurement model

Construct Item	Cronbach α(>=0.70)
Self-Efficacy	0,89
SE1	
SE2	
SE3	
SE4	
SE5	
Risk Perception	0,70
RP1	
RP2	
RP3	
RP4	
RP5	

Ease of Use Perception	0,76
PEOU1	
PEOU2	
PEOU3	
PEOU4	
PEOU5	
Usefulness Perception	0,71
PU1	
PU2	
PU3	
PU4	

Table 3. Results for reliability of the measurement model

Cronbach's Alpha	Cronbach's Alpha based on Standardized Items	N of Items
0,80	0,78	5

Table 4. Descriptive statistics of user questionnaire measured items

	Mean (0-5)	Std. Deviation
SE	3,30	0,48
RP	3,20	0,63
PEOU	4,00	0,73
PU	3,00	0,81

Diagram in Figure 8 gives a general overview of the measured eye-behavior of each user.

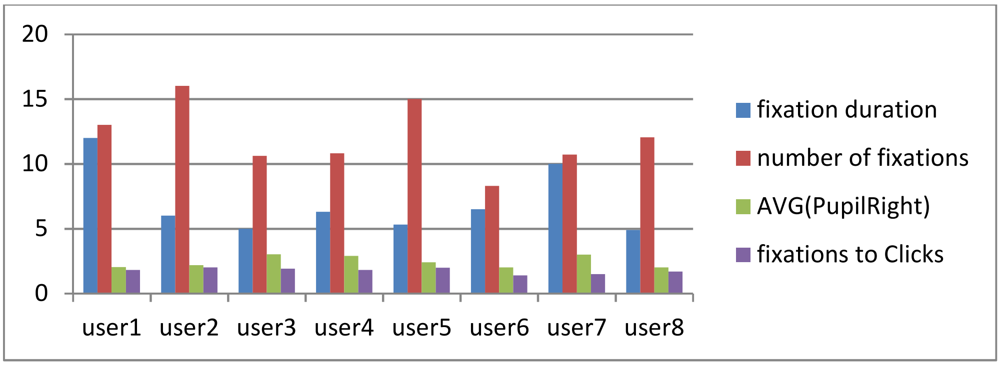

Figure 8. Eye behavior for every user

Table5 shows the correlation coefficients between pairs of the measured variables for the user sample. As the results show there are some significant correlations between eye behavior and perception or acceptance items (where sig. = p-value).

Table 5. Descriptive statistics of user questionnaire measured items

		FixToClicks	NumFixations	PupilAvg	FixDuration
SE	PearsonCorrelation	**0,65**[*]	**0,66**[*]	0,22	0,24
	Sig.	0,041	0,04	0,30	0,29
RP	PearsonCorrelation	0,41	0,4	**0,79**[**]	0,35
	Sig.	0,16	0,17	0,01	0,20
PEOU	PearsonCorrelation	**0,86**[**]	0,56	**0,80**[**]	0,05
	Sig.	0,00	0,07	0,01	0,46
PU	PearsonCorrelation	0,44	0,02	0,07	**0,65***
	Sig.	0,13	0,48	0,43	0,04

*. Correlation is significant at the 0,05 level.

**. Correlation is significant at the 0,01 level.

6. Discussion

The experimental results showed that our hypotheses are confirmed since there were a number of significant correlations between eye behavior and acceptance and perception while users interacted with the web-based EUD environment for database-driven mobile applications.

In particular, the results in Table 5 show the following significant correlations:

- Self-Efficacy is significantly correlated to both, the total number of fixations and to the number of fixations that turned into clicks.
- Risk-Perception is significantly correlated to the average increment of the pupil size.
- Perceived Ease-of-Use is significantly correlated to both, the number of fixations that turned into clicks and the average increment of the pupil size.
- Perceived Usefulness is significantly correlated to the average duration of fixation.

Based on the eye-tracker's generated gaze videos we were also able to extract some visual information by the end-users' scanpaths in EUD tasks. To do this, we isolated screenshots of the same URL for different users.

By discussing with the participants after the completion of the EUD task we noticed that they faced difficulties in the EUD step of creating the relationship between two entities. Isolating the video part recording the URL of this particular step for every user we noticed (for the majority of the participants) long fixations over the form that was asking them to enter the name of the relationship. The creation/naming of a relationship was perceived as the most difficult task according to the participants' later explanation. Indeed such long fixations were not noticed in any other URL of the EUD system.

Our quantitative analysis showed that users' longer fixations reflected ambiguity and hesitation to take a specific action. According to Bojko (2013) this behavior can also be interpreted in low perceived usefulness. To help bring this result to life, one representative gaze plot was selected to be shown (see Figure 9). This conclusion could also mean that qualitative analysis of scanpath several correlations between eye behavior and perception in EUD systems.

Figure 9 depicts two examples of different users' scanpath videostamps for the relationship creation step (same URL). As we can see the fixation is obviously longer over the form where the user has to type the name of the relationship.

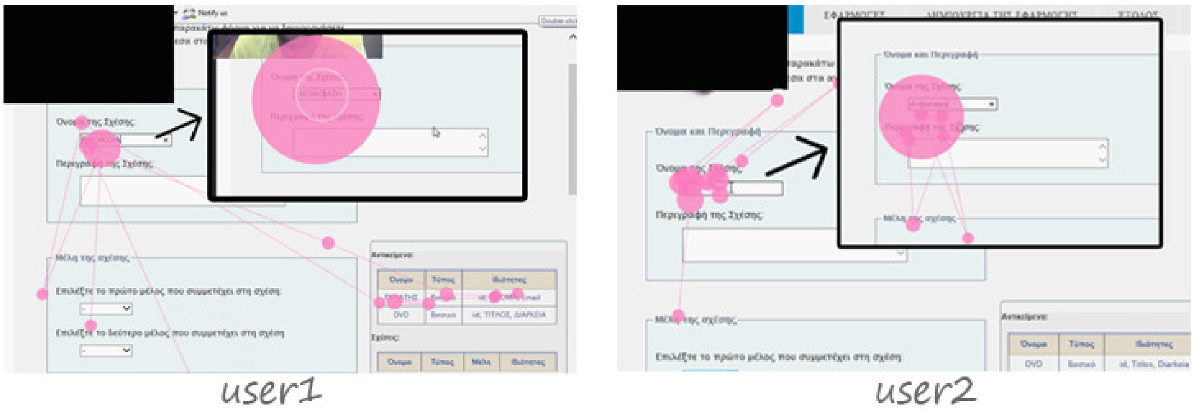

Figure 9. Scanpaths used as examples illustrating the significant correlation between average fixation duration and perceived usefulness of the EUD task.

We did not conduct any more visual confirmation analysis of scanpaths since our work is primarily targeted at the statistically quantitative anaysis of generic correlations between eye behavior and acceptance/perception. In similar future works, videostamps of scanpaths can be used as an analytical tool (both in quantitative and qualitative works) to examine more correlations by measuring e.g. the length of the saccades' path, normality, duration, etc.

Possible issues and limitations

Since this research is the first in the area of eye tracking analysis in web-based EUD environments for database driven mobile applications there are some limitations.

First, the approach involves a limited number of variables and there are a number of other important variables that could be added in future studies.

A second limitation is imposed by the self-efficacy evaluation method. Many self-efficacy studies conduct both a pre-test and a post-test self-efficacy questionnaire, to track changes over time in participants' perceived levels of self-efficacy. In this study we used a post-test for all the measured items, including self-efficacy, since the users in our sample had approximately the same experience in programming, database, web and computers in general. According to the theory of self-efficacy (Bandura, 1997), prior experience is the strongest influential factor to self-efficacy. For this reason we did not include a self-efficacy pre-test in our survey

A third limitation is due to the sample size. Even if Pearson correlation does not assume normal distributions, the sample size is not large. The visual analysis though, based on gaze plots/scanpaths could be further used (as it was used in the case of fixation duration) to confirm and reinforce the statistical results. Additionally, it is admitted that in eye tracking research there is no "one sample size fits all". Especially in usability-targeted research, according to Bojko (2013), eye tracking as a research tool improves the problem discoverability and the more improved the problem discoverability, the fewer participants are needed.

Finally there may be another possible limitation involved by the wizard-based design of the prototype tool. Wizard-logic has been proved to be preferred by female users (Beckwith et al., 2005; Burnett et al., 2010) and it can positively affect their perception and acceptance. Also, this can possibly lead to differentiated results in future web-EUD research that will be conducted on non-wizard like interface designs.

7. Conclusions and future work

In this paper we examined the correlation between eye movements and end-user perception and acceptance in a modern web-based EUD environment. Our aim was to find out whether end-users' perception and acceptance attributes can be reflected on their eye behavior when interacting with a web-based, database-driven EUD system.

The measured variables for perception and acceptance were: Self-Efficacy, Risk Perception, Perceived Ease of Use and Perceived Usefulness; and for the eye movements were: number of fixations, number of fixations that turned into clicks, average duration of fixations and average increment of pupil size.

To evaluate our research hypotheses we have conducted a field test using a prototype EUD tool based ona natural language approach (named 'simple talking') to assist end-users in creating database-driven mobile applications. Eye tracking data from 8 participants (out of 10) were analyzed. Two participants were excluded due to calibration difficulties

The conducted filed test showed that there are some significant correlations between eye movements and acceptance and perception items. In particular, significant correlations were detected between Self-Efficacy and total number of fixations, Self-Efficacy and number of fixations that turned into clicks, Risk-Perception and average increment of the pupil size, Perceived Ease-of-Use and number of fixations that turned into clicks, Perceived Ease-of-Use and average increment of the pupil size, and finally Perceived Usefulness and average duration of fixation.

Additionally, some example analysis work on video-based gaze plots/scanpaths confirmed our hypotheses (e.g. duration of fixation) and revealed that correlations between eye behavior metrics and perception can also be extracted using visual gaze plots/scanpaths. Hence, future EUD oriented works can use gaze videos as an analytical tool to examine more correlations by measuring e.g. the length of the saccades' path, normality, duration, etc.

An interesting future research direction could also be to examine the users' behavior by combining mouse monitoring and eye tracking methodologies. For instance, combined mouse and eye-tracking data can help EUD researchers understand what happened in between clicks and reveal more about the users' cognitive process. Also, by capturing the users' development behavior, user-modeling techniques could be developed to adapt/personalize the EUD environments, aiming to enhance the end-user performance.

In our opinion the main contribution of this work is to provide the EUD research community with interesting research results that could motivate researcher to further study and apply eye tracking for measuring end-user perception and acceptance in today's complex ecosystem of IoT.

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Annex A. Questionnaire

Table 6. Survey Questionnaire

Constructs	Items	Questions
Perceived Usefulness		
	PU1	The system is useful.
	PU2	The system makes me more productive.
	PU3	The system makes me save time.
	PU4	The system satisfies my needs and requirements.
Perceived Ease of Use		
	PEOU1	The system is easy to use.
	PEOU2	I do not need to try too hard to use the system effectively.
	PEOU3	I can use the system without written instructions.
	PEOU4	I can learn how to use the system easily and fast.
	PEOU5	I can easily correct my mistakes while I use the system.
Self-Efficacy		
	SE1	I felt confident while I was using the system.
	SE2	I believed that I could perform well.
	SE3	I felt I had the control of the task.
	SE4	I felt that everyone else knew what to do but me.

	SE5	I felt confused while using the system.
Risk Perception		
	RP1	It was taking me time to decide how to move while using the system.
	RP2	I felt nervous every time I took an action (e.g. pressed a button).
	RP3	I checked well my actions before moving to the next steps.
	RP4	I had no hesitation to take an action.
	RP5	I had no difficulty to try which feature (among other) to use.