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Monitoring Mouse Behavior in e-learning Activities to Diagnose Students' Acceptance Items of Perceived Usefulness and Ease of Use

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Abstract: This study investigates students' mouse behavior during their interaction with a web-based experiential learning environment for Computer Science courses. The research focuses on the detection of correlations between the monitored mouse metrics and students' technology acceptance items of perceived usefulness and ease of use. Findings reveal several significant correlations; in particular, metrics of mouse clicks and hovers can be associated with students' perceived ease use and perceived usefulness. The findings of this work show an interesting research direction towards the analysis of learners' mouse behavior during their interaction with interactive and web-based tutoring systems.

Keywords: *experiential learning; Iinteractive web development courses; Mmouse tracking; Sstudents' perceived acceptance; Web-based tutoring systems*

Introduction

Computer Science courses of programming and web development are usually perceived as difficult by students, especially from female students who tend to perform lower or not getting involved in this type of courses (Oestean, 2019). Modern learning theories attempt to leverage learners' engagement in 'difficult' perceived courses by providing interactive and experiential learning environments offering to students a hands-on and reflective learning experience which helps them to acquire new skills (Marin, 2014). Hence, experiential and creative learning approaches have been integrated in e-learning activities to increase learner's engagement in web development and programming courses (e.g. in Tzafilkou et al., 2015). However, diagnosing learners' mental states during the learning process (i.e. system interaction) remains a strong challenge for the learning community.

Monitoring mouse behavior can reflect specific users' behavior patterns and also be used to model users' behavior (Hinbarji et al., 2015). Several mouse-tracking studies suggest the existence of a typology of users based on observed cursor behavior (Leiva et al., 2008; Rodden & Fu, 2007). Mouse movements have been used as input data also for user authentication and there are a number of mouse-based authentication systems that do not use biometric devices but only a common mouse device authentication (e.g. Hinbarji et al., 2015; Nakkabi et al., 2010). As a fact, mouse behavior monitoring is a vital part since it can implicitly and dynamically provide useful information about the users' state of mind and perceived user experience. Despite its contribution to diagnose user mental and cognitive states, mouse behavior has not been extensively analyses by the research community. In their work, Khan et al. (2008) correlated mouse and keyboard usage to the outcome of personality tests. Also, Zimmermann et al. (2003) examined mood through mouse and keyboard and Dijkstra (2013) investigated the diagnosis of self-efficacy levels in simple question-based e-learning environments. Tzafilkou et al. (2014) examined the diagnosis of self-efficacy and hesitation levels in order to improve user experience in web-based activities, and Tzafilkou and Protogeros (2018) examined the correlation between mouse patterns and users' perception/acceptance items in End-User development tasks.

Drawing from the above, our main objective is to explore potential correlations between measurable mouse movements and technology acceptance items for students when interacting with a web-based tutoring system during a web development course. To answer this question, we conduct an experimental study where students interact with an experiential learning environment and their mouse related behavior is monitored via a mouse tracking mechanism. This study mainly contributes in exploring mouse patterns and their correlation to students' perception. The findings of this study may

provide the e-learning research community with background knowledge and a motivation to further examine the learners' mouse behavior in today's tutoring systems, aiming to deeper understand learners' state of mind and provide them with personalized strategies or adaptive learning features.

This paper is organized as follows. The second section presents the research hypotheses, the third section describes the evaluation methodology and the fourth section presents the results and the sixth section discusses the main findings. Finally, the last section presents the main conclusions and potential future research directions.

Research Hypotheses

Mouse movements and Perceived Ease of Use: 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).

Tzafilkou and Protogeros (2017; 2018) showed that eye fixations and hence mouse hovers that turned into clicks are correlated to perceived ease of use in web-based tasks. Also, since mouse clicks can be interpreted into choice decisions (Slanzi et al., 2016), we assume that the more a user clicks on elements the more decision they make about their choices and knows how to perform the task.

For these reasons our next hypotheses are:
H1.1: Mouse hovers (count) that turned into clicks are significantly related to learners' perceived ease of use.
H1.2: Total mouse clicks (count) are significantly related to learners' perceived ease of use.

Additionally, the defined 'random' mouse pattern (Ferreira et al., 2010) is characterized by movements "without any specific intention, just playing around and doing random movements whit short pauses or not". Hence, we assume that direct and fixed movements would reveal less perceived difficulty and hence they could be correlated to perceived ease of use.

For this reason, our next hypothesis is:
H1.3: Number of straight lines (i.e. direct moves) is significantly related to learners' perceived ease of use.

Mouse movements and Perceived Usefulness: 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 of a positive user-performance relationship.

Recent research findings (Tzafilkou and Protogeros, 2018; 2017) revealed that perceived usefulness is correlated to eye fixation duration in web based development tasks.

For all these, our next hypotheses are:
H2.1: Duration of mouse hover before mouse click is significantly related to learners' perceived usefulness.
H2.2: Total number of mouse hovers is significantly related to learners' perceived usefulness.

Methods

Learning and Monitoring Tools

The prototype e-learning platform was designed to assist students in understanding web development and relational databases concepts via an interactive and experiential learning approach, similar to the one suggested in Tzafilkou et al. (2015). In particular, students were asked to create a set of objects and build the corresponding web forms by constructing and editing one by one the various types of form fields. They could also edit some design elements (colors, font sizes, button styles, etc.) and preview the generated outcome.

A JavaScript based mouse monitoring tool was developed to capture mouse events and store them in a MySQL database in real time, during the user-system interaction. The monitoring tool was developed to capture mouse coordinates (x, y), timestamps (in ms) and JavaScript events like mouse hovers, clicks and moves and send them in a database via web sockets (using Socket IO). The examined mouse patterns (e.g. time durations, total numbers of clicks, etc) were extracted from the database via PHP programs.
The monitoring tool was integrated to the learning platform in order to monitor the students' mouse behavior while working on their learning by

development task. Both the learning platform and the monitoring tool were hosted in the university's server and all data could be locally collected.

Participants and procedure

A population of 42 university students voluntarily participated in the experiment. Of those, 30 (18 male and 12 female) successfully completed the task. The experiment was conducted during an under-graduate e-Commerce/web development course in a Greek university. The participants were given a web development learning task to solve in the form of an exercise demanding the description and construction of a simple web form. In the end, the participants needed to fill out a web-based questionnaire form regarding their perceived acceptance items. Short instruction was providing in the beginning of the process and the prototype tool was briefly presented by the researchers. No technical issues occurred and the experimental process lasted about 30 minutes.

Survey model and mouse metrics

The questionnaire survey was consisted of 9 questions (items) measuring two technology acceptance 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. The questionnaire structure was based on previous research of computer perception and acceptance related questionnaires in Tzafilkou and Protogeros (2018; 2017) and Protogeros and Tzafilkou (2015).
As presented in Annex A, five items were used to measure Perceived Ease of Use and four items were used to measure Perceived Usefulness.

The survey model has been validated and reformulated in terms of internal consistency according to Cronbach's a result, as depicted in Table 1.

The mouse metrics captured by the monitoring tool included the following:

- Number of mouse clicks (NumOfClicks)
- Number of mouse hovers (NumOfHovers)
- Number of mouse hovers that turned into clicks (NumOfHoversToClicks)
- Duration of mouse hovers before mouse clicks (AvgTimeHoverToClick)

Table 1
Cronbach's Internal Consistency

Construct Item	Cronbach α (>=0.70)
Ease of Use Perception	0,76
PEOU1	
PEOU2	
PEOU3	
PEOU4	
PEOU5	
Usefulness Perception	0,71
PU1	
PU2	
PU3	
PU4	

Sample characteristics and data analysis

A Shapiro-Wilk test (Shapiro and Wilk, 1965) for normality was conducted on the whole sample. As the results show in Table 2, the values of Perceived Usefulness (PU), Perceived Ease of Use (PEOU) come from a normal distribution.
Hence, in order to examine the bivariate correlations between the measured variables we used the Pearson correlation analysis since it is an appropriate method to define the strength of the association between pairs of continuous variables.
To present the general results concerning every measured variable we used descriptive statistics.

Table 2
Normality test- Shapiro-Wilk

	Statistic	df	p
Perceived Usefulness	,956	30	,248
Perceived Ease of Use	,934	30	,065

Results

Table 3 presents the descriptive statistics' results of the examined acceptance variables for the whole sample.

Table 4 depicts the Pearson correlation coefficients for the examined pairs of variables/metrics.

Table 3
Descriptive statistics of user questionnaire measured items

Measured item	N	Mean (1-5)	SD
Perceived Usefulness	30	3,78	0,60
Perceived Ease of Use	30	4,09	0,70
Valid N (listwise)	30		

Table 4
Correlations between measured items (N=30)

		PU	PEOU
NumOfClicks	r	-0,229	**-0,311***
	p	0,112	0,047
NumOfHovers	r	**-0,311***	-0,284
	p	0,047	0,064
NumOfHovers ToClicks	r	-0,266	**-0,440***
	p	0,077	0,007
AvgTimeHover To Click	r	**0,591***	0,285
	p	0,000	0,063

Discussion

This study shows that mouse tracking methodologies can be efficiently used to monitor learners' behavior and to diagnose levels of acceptance items during experiential e-learning activities. Most of our research hypotheses were confirmed since the analyzed data showed a number of significant correlations between mouse metrics and acceptance items while students interacted with an experiential and interactive learning environment.

Mouse movements and Perceived Ease of Use: All hypotheses regarding mouse movements and perceived ease of use (H1.1, H1.2, and H1.3) were confirmed. In particular, as predicted, the number of straight lines, the number of mouse clicks and the number of mouse hovers that turned into clicks are significantly related to perceived ease of use. This finding comes to accordance with the previous findings of Tzafilkou and Protogeros (2017) who revealed a similar behavior in end-user development tasks. Also, according to Slanzi et al. (2016) mouse clicks can be interpreted into choice decisions. Hence our findings could reveal the correlation between the number of clicks and the number of decisions to take specific actions, revealing increased levels of perceived ease of use.

Mouse movements and Perceived Usefulness: All hypotheses regarding mouse movements and perceived usefulness (H2.1 and H2.2) were confirmed. In particular, similarly to previous literature findings (Tzafilkou & Protogeros, 2017), the duration of mouse hover before mouse click and the number of mouse hovers are significantly related to perceived usefulness. Also, this finding implies that mouse movement patterns can be linked to eye movement patterns, like being described in Bojko (2013). In particular, according to Bojko (2013), longer eye fixations mean more effort to extract information and reveal ambiguity and hesitation to take a specific action. However, this assumption needs further investigation to be statistically proved.

Additionally, no significant gender differences were observed between the participants. The findings though come in line with previous works (e.g. Arapakis et al., 2014) and suggest that knowledge of the user gender is not very important in mouse gesture analysis. However, gender plays an important role in learning and getting engaged in computer science courses (EC, 2019), hence further analysis might be necessary.

To this end, mouse tracking seems to be a promising methodology in capturing and analyzing learners' behavior during experiential learning activities. Mouse tracking implementation can be regarded as a contributing step in the deeper understanding students' mental situations and hence in the design of more user-centered and efficient tutoring tools and approaches.

Conclusions and Future work

In this study we examined the correlation between mouse movements and learners' acceptance in terms of perceived ease of use and perceived usefulness, in a web-based experiential learning environment for web development courses. The mouse metrics we captured and examined were the number of mouse clicks, number of mouse moves, number of mouse hovers, number of mouse hovers that turned into clicks, duration of mouse hovers before mouse clicks, number of straight lines,

number of clicks in straight lines, average pause time, and average time between clicks.

Via an experimental field test on 30 students participating in the course of e-commerce/web development, we revealed several significant correlations between mouse metrics and acceptance items.

The main contribution of this work is to provide the learning research community with a basic background and a motivation to further examine the learners' mouse behavior during their interaction with in e-learning environments.

Combined eye tracking methodologies or monitoring touch related behavior in mobile devices during mobile learning tasks could be implemented in the future to extend the research findings of the current work. Such findings can be used to diagnose or predict learners' perceived items and mental states, in order to provide with learner-centered, supportive and/or adaptive learning environments.

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Annex: Questionnaire

Table 5. 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		
	PE1	The system is easy to use.
	PE2	I do not need to try too hard to use the system effectively
.	PE3	I can use the system without written instructions.
	PE4	I can learn how to use the system easily and fast.
	PE5	I can easily correct my mistakes while I use the system.

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