The Influence of Cognitive and Personality Characteristics on User Navigation: An Empirical Study

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Abstract. An empirical study aiming to investigate the influence of cognitive and personality characteristics on user web navigation is presented in this paper. Individual cognitive abilities and personality dimensions were identified and validated, and expected correlations with results of objective variables were postulated. Effectiveness, efficiency and orientation within a web site were the measured objective variables. Measures of spatial ability and extraversion were correlated with objective accomplishment measures and orientation. A high statistically significant correlation was found between spatial ability measure and orientation measure. Conversely, no other correlations were supported. Future work will be significantly improved by employing new variables, measures and instruments, especially for user personality dimensions.

Keywords: spatial ability, extraversion, user navigation, orientation, empirical study.

1 Introduction

Research in the field of Human-Computer Interaction (HCI) places the individual as the focus of all theoretical and practical advances, stressing the importance to design technologies for human needs. The role of adjustable interactions, suited to various and complex ways of human mind, demands and expectations, is a goal not easily set. To reach such a goal a large amount of work has to be done in understanding human behavior towards computers in their everyday interaction. Identification of cognitive and personality characteristics that influence the way people interact with computers is the first and crucial step.

One of the things which make successful human-computer interaction difficult is the large range of tasks which a computer can perform and the diversity of system users [1]. Namely, users with a wide variety of background, abilities, motivations and goals are using computers for quite diverse purposes. In general, HCI research acknowledges that differences among individuals in the terms of personal user profiles or characteristics have an affect on interaction. Concerning user navigation in particular, individual differences have been shown to lead to different navigation styles, e.g. [2]. Explicitly, cognitive characteristics, ranging from differences in various cognitive abilities, significantly influence the way that people navigate through web, e.g. [3; 4].

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On the other hand, data on personality dimensions effect often failed to validate those intuitions, *cf.* [5].

An empirical study aiming to investigate affect of user cognitive abilities and user personality in modeling user web navigation is presented in this paper. We have identified user individual cognitive and personality characteristics, validated them and detected potential correlations with results of objective variables. Effectiveness, efficiency and orientation within the chosen web site were the measured objective variables.

The work described in this paper is significant in a number of respects. First, the results of the conducted experimental work add importance to the growing awareness of the crucial role of individual differences in the HCI field. Particularly, our results suggest that specific cognitive ability (i.e. spatial ability) is on the whole important cognitive characteristic of users which has a significant effect on the quality of navigation. Second, the proposed approach could be applied on various user samples and on a range of different web sites.

The paper is organized as follows. In Section 2 we provide a short outline of basic concepts and a state of the art concerning an affect of cognitive and personality characteristics on user navigation. Detailed design of the empirical study is presented in Section 3, while subsequent Section 4 brings achieved results and the discussion of findings. Finally, Section 5 concludes the paper.

2 Background to the Research

2.1 Basic Concepts

Numerous definitions of cognitive characteristics were given throughout many years of research on individual differences. Guilford's Structure of Intellect (SI) Model is widely accepted theory which claims that human cognitive abilities could be described on three dimensions (cubic form): operations (cognition, memory, divergent production, convergent production and evaluation), content (figural, symbolic, semantic and behavioral) and products (implications, transformations, systems, relations, classes and units) [6]. Sternberg [7] has focused on just three main components of intelligence: practical intelligence (the ability to adapt to and to shape one's environment), experiential intelligence (the ability to deal with novel situations and to think in novel ways) and componential intelligence (the ability to process information effectively). The very last component includes metacognitive, executive, performance and knowledge-acquisition components that help to steer cognitive processes. Conversely, Gardner [7] has proposed a Theory of Multiple Intelligences, identifying eight components of intelligence. He argues that these intelligences are relatively distinct from each other and that each person has some level of each of these eight intelligences. One of those intelligences, *spatial intelligence*, he defined as the ability to know where you are relative to fixed locations, the ability to accomplish tasks requiring three-dimensional visualization and placement of your hands or other parts of your body. *Spatial ability* is a cognitive characteristic that gives a measure of the ability to conceptualize the spatial relationships between objects [8]. Consequently, spatial skills/ability is considered important for navigating in the real world and in an abstract information space such as hypertext [9].

Personality can be defined as a dynamic and organized set of characteristics possessed by a person that uniquely influences her/his cognitions, motivations and behaviors in various situations [10]. Eysenck [11] has claimed there are two main personality factors: neuroticism as the tendency to experience negative emotions and extraversion as the tendency to enjoy positive events, especially social events. Alternatively, Cattell has defined personality as traits or stable tendencies to respond to certain classes of stimuli or situations in predictable ways [6]. He proposed the existence of 16 distinct traits such as "cool-warm", "practical-imaginative", "shy-bold", "submissive-dominant" and so on which he derived through factor analysis of rater inter-correlations.

2.2 Related Work

A number of empirical studies have attempted to investigate how cognitive and personality characteristics like spatial ability/intelligence and personality traits influences peoples ability to navigate through web.

In a significant review article, Egan [5] summarized related research suggesting that the ability to navigate through information search systems depends on certain cognitive abilities (e.g. spatial ability) in such way that people with lower abilities are less capable in those activities. Conversely, results of studies dealing with personality traits and user navigation often showed no correlation at all (*ibid.*). Benyon and Hook [12] presented some experimental work of authors dealing with influence of spatial ability on navigation. They emphasized correlations found between spatial ability and navigation in a database, spatial ability and user's ability to navigate a large file structure as well as correlation between users' abilities on tests involving a mental rotation of images and their task completion time.

Ho [13] performed preliminary data analysis to draw a linkage between web customers' characteristics (such as personality traits) and their browsing behaviors. Author investigated whether there are correlations between users' click streams and their personality traits. He found small but significant correlation between personality trait called "need for cognition" (similar to extraversion) and web browsing. In their recent work Ho, Davern and Tam [14] set objective to understand the role of personality in choice behavior in the context of preference matching.

Recent studies are focused on whether cognitive abilities and attitudes influence component search processes, as well as overall accuracy and speed. Gugerty, Treadaway and Rubinstein [15] conducted a study with 180 participants to evaluate whether individual differences in basic cognitive abilities (i.e. spatial and verbal ability), attitudes towards computers and prior experience with computers influence peoples' ability to search for and find information on the Internet. According to the results, spatial and verbal ability, in addition to attitudes towards computers, affected the accuracy and speed of Internet search. Sharit, Hernandez, Czaja and Pirolli [16] carried out an experimental task consisted of six realistic search problems, all involving information seeking on web which varied in degree of complexity. The results indicated that though necessary, Internet-related knowledge was not sufficient in explaining information-seeking performance and suggested that a combination of both knowledge and key cognitive abilities is important for successful information seeking.

Melguizo, van Oostendorp and Juvina [17] have introduced a term "lostness" as the measure of web orientation. Namely, websites represent non-linear information allowing users to selectively visit only relevant pages. Hence lostness is derived from the number of links accessed by users performing information retrieval tasks and the deviations from the optimal pathway. This property however also increases the cognitive load and can cause users to feel "lost in hyperspace". Lostness, or the tendency to lose one's sense of location, is the most common problem users experience while navigating and affects user's performance and satisfaction (*ibid.*).

With the intention of providing additional insight into different ways people navigate through web sites as well as to investigate which user individual differences contribute more to those diversities, we have conducted the empirical study presented in the following.

3 Empirical Study Design

An experimental procedure adopted to find the influence of cognitive and personality individual differences on user navigation included some previously defined cognitive and personality tests which selected group of participants had to undertake. Achieved results were analyzed together with participants' navigation scores in order to find influence on defined navigation measures.

3.1 Participants

A homogeneous group of randomly chosen 25 participants was involved in the experimental procedure. They were all computer science students, sharing nearly equal knowledge and abilities in web usage and Internet literacy. Group was consisted of 15 males (60%) and 10 females (40%). The age of all participants varied from 18 to 23, with a median value 20. The distribution of gender, age and study group is presented in Table 1.

Table 1. The distribution of age, gender and study group

	Study group			Age		
	Graduate	Postgraduate	Total	18 - 19	20 - 21	22 - 23
Male	6	9	15	4	3	8
Female	8	2	10	6	3	1
Total	14	11	25	10	6	9

3.2 Instruments and Measures

Spatial ability, as one of the crucial cognitive characteristics that has influence on user navigation, was measured with spatial ability test TOS-S composed of 80 tasks requiring three-dimensional visualization. *Extraversion*, as a personality characteristic, was assessed by employing Eysenck's Personality Questionnaire (EPQ). A web site of the University of Split (www.unist.hr), as the site which provides information equally attractive to a broad student population, was involved in the study. Fig. 1 illustrates university web site user interface.

Fig. 1. Screenshot of the University of Split web site interface

User navigation is represented by measures of objective accomplishment (effectiveness and efficiency) as well as orientation. Effectiveness and efficiency were grouped under the label *fulfilment* which denotes task success (effectiveness) obtained with minimum error rate (efficiency). Orientation measure labeled as *lostness* is defined through minimum navigation steps and usage of help buttons ("back" button in the browser or "home" button on the chosen web site). The experimental procedure of the conducted empirical study is illustrated in Fig. 2.

3.3 Procedure and Hypotheses

During a two week long preparation of the study we conducted several pilot tests with participants who shared similar background with our selected group. Pilot testing was insightful in many ways providing information about individual and group duration of the testing, additionally offering particular answers to all technical requirements of the study.

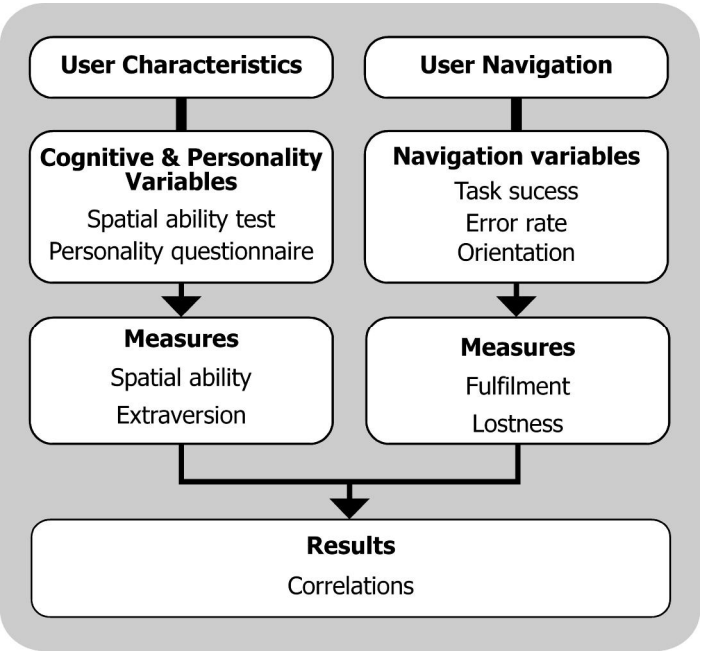

Fig. 2. Experimental procedure of the empirical study

The evaluation procedure was carried out in two steps with precise timetable for all participants' activities. First step started with a week reserved for meeting with all participants and introducing to them purpose of their involvement, at the same time also acquiring very important information about their knowledge and abilities in Internet usage. In the second week 25 participants were divided into three groups and during three testing sessions they all completed the spatial ability test and personality test. For all participants time limit for completing the spatial ability test was 20 minutes. Personality test had no time limit but average time participants spent completing it was approximately 30 minutes.

In the second step of the experimental procedure every participant had to accomplish three assigned tasks while navigating through chosen web site. Participants had to complete selected typical tasks whose structure and location on the web site was not changed over time. The tasks covered different topics, offering to the participants a similar opportunity for finding task-related information. The procedure was carried out individually with each participant, using a personal computer with Internet access in addition to software and hardware support for tracing and recording users' actions and navigation. Estimated time for assigned tasks was 15 minutes. Due to specific experimental situation and individual activities for every participant involved, the second step was carried out in another two subsequent weeks.

In order to examine effect of users' cognitive and personality differences on their navigation we set four hypotheses:

- H1: Participants' score on extraversion measure will correlate with both measures fulfilment (objective accomplishment measure) and lostness (orientation measure).
- H2: Participants with high score on spatial ability measure will have low (i.e. better) result in orientation measure of lostness.
- H3: Participants with high result in fulfilment measure will achieve better results on score in spatial ability test.
- H4: Participants' scores on fulfilment measure and lostness measure will negatively correlate.

Factors that have an affect on web navigation behavior were identified from the results of measured variables.

4 Results and Discussion

Descriptive statistics for both spatial ability and extraversion as cognitive and personality measures respectively, along with a number of participants (N), minimum and maximum scores, arithmetic means and standard deviations are presented in Table 2. Significance levels K-S (Kolmogorov-Smirnov coefficient) for normality of distribution showed no statistical difference in the distribution of the results from the expected normal distribution.

Table 2. Descriptive statistics of the cognitive and personality measures

Measures	N	Minimum	Maximum	Mean	Standard Deviation	K-S
Extraversion	25	3.00	20.00	13.88	4.400	0.620
Spatial ability	25	42.00	79.00	62.04	10.330	0.959

Descriptive statistics of the navigation measures fulfilment and lostness, together with a number of participants (N), minimum and maximum scores, arithmetic means and standard deviations are offered in Table 3. Although relatively large standard deviation of fulfilment results could point otherwise, Kolmogorov-Smirnov coefficient did not show any statistical difference in the distribution of the navigation measures results.

Table 3. Descriptive statistics of the navigation measures

Measures	N	Minimum	Maximum	Mean	Standard Deviation	K-S
Fulfilment	25	51.67	461.30	152.47	110.588	0.060
Lostness	25	1.50	9.00	5.14	2.339	0.623

With the aim of testing our four hypotheses, bivariate correlation method was performed using SPSS 16.0 software statistical package. Pearson's correlation coefficients for participants' results in the achieved cognitive, personality and navigation measures are shown in Table 4.

Table 4. Pearson's correlation coefficients of overall results

Correlation of results	r
Spatial ability - Lostness	-0.73**
Spatial ability - Fulfilment	0.31
Fulfilment - Lostness	0.08
Extraversion - Fulfilment	0.02
Extraversion - Lostness	0.03

** significant correlation at level of $p < 0.01$

A statistically significant correlation ($r = -0.73$; $p < 0.01$) was found between spatial ability and orientation measure lostness. Negative correlation confirms our second hypothesis (H2) implying that participants with better score on spatial ability test achieve lower lostness result, i.e. better orientation while navigating through the web site. It seems that higher spatial ability enables users to create clearer mental pathways of the web site allowing them to navigate through without constantly returning back. This finding again stresses important influence of spatial ability on user navigation, in particular navigation throughout a web site, and is in line with most of the related work presented in the second section.

No statistically significant correlation was found between spatial ability and objective accomplishment measure fulfilment, thus not supporting our third (H3) hypothesis. Although unexpected, this result could indicate that participants with lower spatial ability use different navigation style without affecting their effectiveness and efficiency.

Furthermore, no significant negative correlation between fulfilment and lostness measures is in line with previous findings, accordingly not supporting our fourth (H4) hypothesis. These results point out the fact that participants with diverse spatial abilities achieve similar scores in objective accomplishment measure. Consequently, we concluded that participants' different navigation style does not affect their success in task completion.

Personality measure extraversion did not show any correlation with neither fulfilment nor lostness navigation measures, for that reason not supporting our first (H1) hypothesis. It seems that difference in this particular personality dimension has no influence on the way participants navigate through web site. Moreover, majority of reported findings does not support influence of personality characteristics on user navigation as well [5]. Even though some authors [13; 14] tried and succeeded to determine correlations with some specific personality dimensions, our results failed to support those findings. Nevertheless, further examination of specific personality dimensions should be considered, the research which could provide better insight into personality influence on users' navigation.

5 Conclusion

The objective of the presented empirical study was to provide additional insights on the role of particular user individual characteristics in user interaction with computers. In this paper we present empirical data and findings on the relationship between cognitive and personality characteristics on the one hand, and user navigation on the other. The measures of spatial ability and extraversion were correlated with the

objective accomplishment measures and orientation within a chosen web site. Consequently, in order to find significant correlation between our variables we set four hypotheses. Although only one of the hypothesis was confirmed (H2) and the other three rejected (H1, H3 and H4), our results convey insightful information. Identified high correlation between spatial ability and orientation on the web site confirms significant role of this cognitive characteristic in user navigation.

The conducted empirical study along with obtained results is quite motivating for our upcoming work related to the identification of major individual factors which contribute to user's successful navigation. Nevertheless, our future work could be significantly improved by employing new variables, measures and instruments, especially for user personality dimensions.

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