Individual Differences in Internet Search Outcomes and Processes

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CHI 2006, April 22–27, 2006, Montréal, Québec, Canada.
ACM 1-59593-298-4/06/0004.

Abstract
A study was conducted, 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. Spatial and verbal ability, as well as attitudes towards computers, influenced the accuracy and speed of internet search. Current analyses are focusing on whether cognitive abilities and attitudes influence component search processes, as well as overall accuracy and speed.

Keywords
Information search, internet search, individual differences, cognitive abilities

ACM Classification Keywords
H5.4. [Information interfaces and presentation (e.g., HCI)]: Hypertext/Hypermedia---User issues.

Introduction
Disparities in internet access due to income and education-level have decreased in recent years but have not been eliminated [12]. In an influential review article, Egan [9] summarized research suggesting that the ability to perform computer tasks such as

information search depends on certain cognitive abilities (e.g., spatial ability), such that people with lower abilities are less capable at these computer tasks. These findings suggest that access to and fluency at computer-based tasks may be distributed unequally across groups defined by income, education and cognitive ability. This situation presents a serious problem, especially when the computer-based tasks with less than universal access are basic work and life tasks, as many computer-based tasks are becoming. For example, many people use the internet to search for jobs or for health-care information. It is certainly socially and politically unacceptable to provide unequal access to this type of information.

If Egan's suggestion of unequal access to computer-based tasks based on cognitive skills is true, then providing more universal access becomes an important goal. Egan and others have suggested that this could be done by re-designing computer interfaces so that they are less dependent on specialized cognitive skills, or by providing personalized or adaptive interfaces that accommodate to individual differences [3][9]. However, prior to these interfaces changes, more work needs to be done to document the extent to which current computer-based tasks actually depend on specialized cognitive skills. Some of the individual differences studies cited by Egan focused on interfaces that are now out of date, e.g., command-line text editors. Others have conducted similar studies based on current-day interfaces and tasks, such as information searching in databases [1][2][6] [13][14] or the internet [11]; and all of these studies have provided limited support for the conclusion that performance on these newer interfaces is still overly dependent on individual differences in cognitive ability. However, most of the studies on this topic contain methodological flaws that limit their validity. These flaws include very small and overly narrow samples (e.g., college undergraduates), measuring a narrow range of cognitive abilities, measuring particular cognitive abilities inadequately (e.g., with only a single test), not measuring other psychological factors that may mediate the effect of cognitive abilities (such as personality, attitudes, and prior task experience), and not using appropriate multivariate methods of data analysis. An additional problem with these studies is that they have usually not identified the particular components or stages of the computer-based task that are affected by differences in cognitive skill [9]. Understanding the particular computer-task components that are overly dependent on cognitive abilities helps designers focus their redesign efforts.

The situation described above leaves interface designers in an untenable situation. It could be that computer interfaces are limiting access to some groups based on cognitive skills, and thus should be redesigned to avoid this. But we are not sure if this is the case, and we do not have a clear idea of what cognitive abilities (or other psychological factors) may be limiting access, or of what components of computer tasks these abilities are affecting.

The purpose of this proposed project was to conduct a large individual differences study that rectifies some of the problems described above and provides useful and precise information to interface designers. In this study, 180 college students performed a series of internet search tasks and also completed tests of cognitive (verbal and spatial) ability, attitudes towards computers and the internet, and prior experience with

computers and the internet. We used advanced multivariate statistics – structural equation modeling – to test a hypothesis based on research by Vicente and colleagues [14]. This hypothesis was that the effect of cognitive abilities on internet search performance would be mediated by attitudes and experience with computers and the internet. Or, more informally, people like tasks that allow them to use their cognitive strengths; and these positive attitudes cause people to spend more time doing these tasks, which leads to better performance of these tasks. In particular, the hypothesis was that verbal and spatial abilities would positively affect participants' attitudes towards computers and the internet (i.e., higher abilities leading to more positive attitudes), which in turn would positively affect the amount of prior experience with computers and the internet, which in turn would positively affect internet search outcomes (i.e., speed and accuracy of performance).

In ongoing research on this project, to be described below, we are investigating other variables that may mediate between cognitive abilities and search outcomes. In particular, we are looking at whether the processes and strategies people use during internet searching – e.g., keyword searching and browsing – are affected by individual differences, and whether peoples' processes/strategies affect their search performance. This focus on internet search processes follows from Egan's advice to investigate which components of an overall task are most affected by individual differences.

This study rectifies most of the methodological flaws identified above, in that it uses a larger sample size, measures a wider range of cognitive and non-cognitive abilities, measures each ability adequately, uses appropriate statistics, and considers how individual differences affect search task components as well as overall search performance. A limitation of the current study is that it did not address the problem of an overly narrow sample.

Methods

Two hundred and eleven college students participated in the study. After removing outliers (participants with 3 or more scores > 3 standard deviations from group mean) and dropping participants with incomplete data, 180 participants with complete data were included in the analyses. The internet search task consisted of 11 questions, such as "What was the population of Mississippi in 1930?" Participants searched the world wide web for the answers using any search engine they preferred. Once they found the answer for a particular question, they clicked the DONE button, clicked on the answer from a menu with 8 possible answers, and then received feedback. All of the participants' computer interactions during the internet search task were recorded using the Uzilla instrumented web browser [8].

Four aspects of spatial ability were assessed using tests developed by Ekstrom [10]: spatial visualization (paper folding test), spatial orientation (cube comparison test), spatial memory (building memory test), spatial scanning (map planning test). Three aspects of verbal ability were assessed using the Nelson-Denny Reading Test: reading rate, reading comprehension, and vocabulary. Participants' computer and internet attitudes were assessed by a modified version of the Technology Profile Inventory [7]. Finally, a survey was developed to assess participants' prior experience with

computers and internet. Participants completed these tests during a 2.5 hour session.

Results: Individual Differences and Search Outcomes

The measurement model had a good fit to the data [χ^2 (75)=87.944; CFI=.983; SRMR = .046; RMSEA = .031; RMSEA confidence interval - (0.000-0.058)]. This showed that the tests assumed to measure spatial and verbal ability, computer and internet attitudes, and computer and internet experience actually did measure individual differences on these factors.

The main variable used to measure the quality of participants' internet search performance across the 11 search tasks was accuracy, i.e., the number of correct searches.

Figure 1 shows some of the results of the structural equation modeling testing the hypothesis that cognitive abilities influenced attitudes, which in turn influenced experience, which influenced search performance. Only the relationships between variables found to be significant are shown (and some significant relationships of lesser importance are not shown). All relationships shown are positive; i.e., high scores on one variable were associated with high scores on the other. Spatial ability, but not verbal ability, had the hypothesized positive effect on computer and internet attitudes. Also, computer and internet attitudes had the

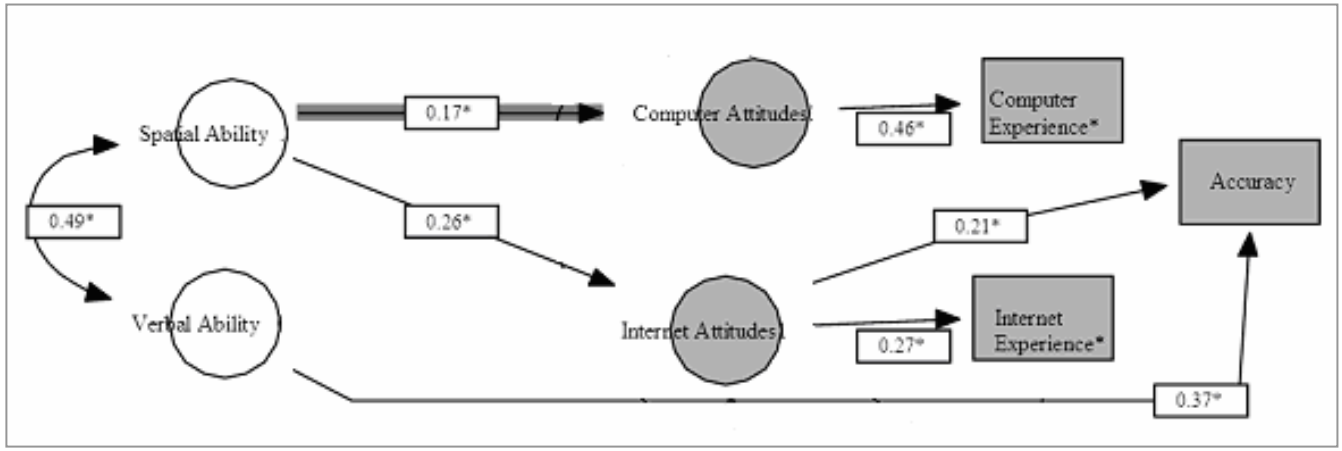

Figure 1. Effects of spatial and verbal ability, computer and internet attitudes, and computer and internet experience on each other and on the accuracy of internet search performance. Relationships between variables that are not statistically significant (and some significant relationships of lesser importance) are not shown. The gray-shaded link (spatial – computer attitudes) was marginally significant ($p < .08$). Numbers in boxes are standardized regression coefficients, which indicate the amount of change in output variable Y given a unit (1.0) change in input variable X.

hypothesized positive effect on computer and internet experience. These relationships among spatial ability, computer and internet attitudes, and computer and internet experience fit well with the overall hypothesis. However, the specific hypothesis that computer and internet experience would directly influence search performance was not supported. On the other hand internet attitudes and verbal ability had direct effects on search performance. Importantly, spatial ability had a significant indirect effect on search performance through the mediating variable of internet attitudes.

To summarize, important parts of the overall hypothesis were supported. Verbal and spatial abilities influenced peoples' internet search performance, with the influence of spatial ability on search performance being mediated by internet attitudes. The strength of the relationships in this study was comparable to other studies of how individual differences affect computer use. The overall individual differences model in Figure 1 accounted for 21% of the variance in search accuracy (i.e., $R^2 = .21$). This is a large effect size [5]. In comparison, Chen and Rada [4] found that, across three studies, spatial ability accounted for 20% of the variance in ability to use hypertext.

Current Analysis: Individual Differences and Search Processes

The analysis just reported focused on how individual differences in cognitive abilities and attitudes affects overall internet search performance, as measured by the speed and accuracy of performance. In addition to these *outcome* measures of search performance (speed and accuracy), we are interested in measuring the *processes* people use to search. For example, do people rely primarily on keyword searching via search engines, or do they also browse from site to site? When using keyword searching, how effective are people in their choice of keywords? Obviously, individual differences may exist in these search processes as well as in search outcomes.

In our current analysis of the same search data presented above, we are quantifying participants' search processes using a number of variables. The variables that focus on how people perform keyword searching include: number of searches per search task; number of keywords per search; number of search results evaluated; and rank of correct site (containing search answer) among search results. The variables that focus on how people browse include: number of sites visited by browsing; number of pages visited other than search results; time per page; and frequency of use of browser BACK button.

These (and other) variables will be measured for each of the 180 participants using the trace of search behaviors recorded with the Uzilla browser. Once these variables are measured, we will conduct factor analyses to ascertain whether the clusters of variables assumed to measure keyword searching and browsing actually represent independent behavioral factors.

Following this, we will investigate how these internet search processes are associated with individual differences in cognitive abilities, attitudes and experience. In these analyses, we hypothesize that verbal ability will be positively related to keyword searching ability, and that spatial ability will be positively related to browsing ability. Finally, we will

investigate how individual differences in these search processes are associated with internet search outcomes (i.e., overall speed and accuracy).

Conclusion

Understanding these relationships between individual differences in cognitive abilities and attitudes, internet search processes, and search outcomes will give more specific and effective guidance for efforts to redesign search interfaces so as to reduce the effect of individual differences.

Acknowledgements

The work reported in the results section is part of the Masters Thesis work of Craig Treadaway (in Applied Psychology, Clemson University). Permission to use the Uzilla instrumented browser [8], developed by Andy Edmonds, is gratefully acknowledged.

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