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ORIGINAL ARTICLE

The use of attention resources in navigation versus search

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Abstract Personal information management research has consistently shown navigation preference over search. One possible explanation for this is that search requires more cognitive attention than navigation. We tested this hypothesis using the dual-task paradigm. We read a list of words to each of our 62 participants, asked them to navigate or search to a target file, and then compared the number of words recalled in each condition. Participants remembered significantly more words when retrieving by navigation than by search. The fact that they performed better at the secondary task when navigating indicates that it required less cognitive attention than search. Our results also cast doubt on the assumption that search is more efficient and easier to use than navigation: Search took nearly three times longer than navigation, was more vulnerable to mistakes and retrieval failures and was perceived as more difficult on a subjective evaluation. Our results also support the folk belief that women are better than men and that younger people are better than older ones, at multitasking.

Keywords Personal information management · File retrieval · Attention · Dual-task paradigm

1 Introduction

Personal information management (PIM) is an activity in which an individual stores his/her personal information items in order to retrieve and use them later. Such information items include files, emails, Web favorites, contacts, and notes. In today's personal computers, the two main ways in which items can be retrieved are hierarchical folder navigation and queries using a search engine. Although search is more flexible than navigation and does not require creating or remembering a prior structure, research has consistently shown that users prefer navigation over search [1–4]. Even when using highly advanced search engines, people tend to use navigation for the majority of their file retrievals and use search only as a last resort in those cases where they do not remember the location of their files [5].

One possible reason for the preference for navigation is that the search process may require more cognitive attention. File retrieval is typically performed in the context of a larger process carried out before and after retrieval (e.g., a chemistry student who is writing a seminar paper retrieves a file called "Table of Elements" in order to continue to work on the seminar paper). Therefore, it is reasonable to prefer the option that requires less attention and allows the users to keep the larger process in mind, instead of having to concentrate on the retrieval process itself and then attempt to resume and trace back their thinking.

The main goal of this research is to test the hypothesis that search indeed requires more cognitive attention than navigation. In order to test it, we asked our 62 participants to search and navigate to their files while doing a secondary task which was a free recall task. We read a list of words to the participants, asked them to navigate to or search for a target file, and then compared the number of words they recalled from the list in each condition.

1.1 Theoretical background

This section has two parts. In the first, we report on theoretical literature and empirical research that compared navigation to search; in the second, we report on the dual-task paradigm which we use in our study.

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1.1.1 Navigation versus search

Hierarchical navigation ("navigation" for short) is a two-phase process. First, users manually traverse their organizational hierarchy until they reach the location in which the target item is stored (be it a directory or a folder). Second, they locate it within the directory or folder (either actively by sorting the items by attribute or by using the system default). Search is a process in which users first generate a query specifying some property of the target item, including at least one word related to the name of the information item and/or the text that it contains (full-text search) and/or any attribute relating to that item (e.g., when the item was modified). The search engine returns a set of results from which the user selects the relevant item [5]. Navigation, in contrast to search, generally requires hierarchical storage; that is, users need to create folders or directories and to store the information items in them, in preparation for future retrieval and use.

Through most of its long history, the hierarchal method has met with criticism. One disadvantage is that classifying information can 'hide it' from the user and therefore reduce the chances of rapid retrieval [6–8]. In addition, the act of categorization itself is cognitively challenging; users may find it hard to categorize information that could be stored in more than one category [7, 9]. Categorization is also difficult because it requires that people anticipate future usage; moreover, that usage may change over time [6, 8]. At retrieval time, users also need to recall how the information was classified, which can be difficult when there are multiple categorization possibilities [10]. These problems were illustrated in a study of email categorization by Whittaker and Sidner [8]. They found that users with many categories found it harder to file items and were more likely to create spurious unused folders.

These arguments gave rise to the *search everything* approach to PIM, which suggests that search should replace navigation as the main method for retrieving personal information [11]. The *search everything* approach is deeply rooted in current human–computer interaction literature [e.g., 10, 12–15]. It asserts that search suits user requirements better than navigation because it simplifies the retrieval process, offering more efficient and flexible ways for users to specify their retrieval needs; in addition, it eliminates the need to construct and maintain complex folder hierarchies that anticipate future retrieval needs. These arguments against navigation have been bolstered by recent developments in Web access, where the use of navigational systems such as Yahoo categories has been almost completely superseded by search engines such as Google [16].

One of the ways to test the *search everything* approaches is to investigate users' retrieval preferences. In each retrieval, users can choose to navigate, search, or use other options (such as the Recent Documents list). This is an individual choice and is likely to be affected by organizational structure (i.e., less organized users would tend to search more than 'neat' ones). Moreover, the same user can change his/her retrieval strategy over time or even within the same retrieval (e.g., search for a file after it is not found via navigation). However, information behavior science investigates general tendencies by using measures of central tendencies (e.g., mean) and measures of diversity that account for these individual differences (e.g., standard deviation). The validity of the results increases if they recur in several independent studies or observations. In 1995, Barreau and Nardi [1] observed an "overwhelming" preference for navigation over search. This observation was found in several independent studies over the years [2–4, 17, 18]. In 2008, Bergman et al. [5] conducted a large-scale study ($N = 519$) and a longitudinal study (7 months) to test users' retrieval preferences. Their participants assessed that on average they used navigation for 56–68 % of file retrieval events (SD = 27–32 %) and searched in only 4–15 % of events (SD = 9–22 %). The search engine used, whether advanced (Google Desktop, Spotlight) or old (Windows XP, Sherlock), had no effect on their retrieval preferences. The study also indicated that search was used mainly as a last resort, when users could not remember the file location. Finally, the results showed no evidence that improved desktop search engines lead people to change their filing habits and become less reliant on hierarchical file organization.

Why do people prefer navigation to search, regardless of the evidence that, at least for email retrieval, search is substantially faster [19]? One possible reason for the navigation preference is that it requires less cognitive attention than search. In navigation, users use their own familiar folder structure and they become more familiar with it each time they navigate. Moreover, navigation is based mainly on *recognition*—where each step down the hierarchy provides incremental visual and contextual feedback about navigation success as well as clues to the next choice of folder [4]. This may allow users to retrieve their files in cognitive automation (similar to an experienced driver who is familiar with the driving procedure and does not need to give it particular attention), which allows them to split their attention while navigating and maintain their thoughts on whatever they are doing at the time (like an experienced driver who can simultaneously drive and converse with a passenger). On the other hand, search may require more cognitive attention: first because thinking of a search term is a *recall* task which is known to be more difficult than recognition and second, because there are several search options for retrieving the same file, and the list of search results may be new and unfamiliar to users, thus requiring their attention.

Our hypothesis, therefore, is that navigation requires less attention than search. We tested this hypothesis using a *dual-task* paradigm, discussed in the next section.

1.1.2 The dual-task paradigm

The concept of dual tasks can be demonstrated through the example of the chatty driver. Imagine an experienced driver who is driving while having a conversation with her passenger. Driving the car is the driver's *primary task*, and having a conversation is her *secondary task*. The fact that she can concentrate on the conversation indicates that she does not need to pay a lot of attention to the driving procedure itself; she can perform it with a high degree of cognitive automation. Suddenly, she sees a child running out onto the road in an attempt to catch a ball. At that moment, all of the driver's attention is focused on her driving; she pays no attention whatsoever to what her passenger is saying. In other words, the fact that at that moment the driver did not hear a word the passenger said (low results on the secondary task) indicates that all of her attention was needed for the primary task (driving).

The dual-task paradigm has been widely used in cognitive psychology for several decades [20, 21] and was already put to use in information behavior science [22, 23]. Gwizdka [22] asked his participants to perform a secondary task at different stages of a Web search. He found that their performance on the secondary task was lower in the query formulation stage than in later stages of the search (scanning the search results and viewing individual Web pages). This indicates that thinking of a search word is more cognitively demanding than later stages of the search process.

In order to be effective, the secondary task should use the same cognitive resources as the primary one [24]: People have a limited set of mental resources of different types; when demands on the primary task are high, the resources committed to that task become unavailable to the secondary one, provided that it uses the same mental resources. These resources can be either verbal (the *phonological loop*) or visual (the *visuospatial sketch pad*) [25]. As retrieval is mainly a verbal process, our secondary task also needed to be verbal. In addition, we wanted our secondary task to be *realistic*, and in real-life situations, people are typically engaged in tasks of a verbal rather than a visual nature before and after file retrieval. The secondary task we chose was a delayed free memory recall task, widely used in cognitive psychology research.

Recall tasks: In the free recall task, participants are given a list of words and their task is to recall as many words as they can in any particular order. In an immediate free recall task (i.e., when participants are asked to recall the words immediately after hearing them), participants tend to remember 7 ± 2 words [26]. In a delayed free recall task (where participants hear the words, wait, or do an unrelated task and only then are asked to recall them), the number of words recalled decreases and is negatively correlated with delay time and the difficulty of the intermediate task [20, 21]. In order to keep the words in short-term memory during the intermediate task, participants needs to use their phonological loop (a short-term memory component that keeps traces of words from decaying by rehearsing them); however, they are very limited in doing that when carrying out another verbal process at the same time. In our experiment, retrieval was the intermediate task: participants were given a list of words and asked to retrieve the file and only then to recall as many words as they can remember. In order to do that, participants needed to use their phonological loop and repeat the words in their mind while retrieving the file. The more attention-demanding the retrieval is, the less attention is available for the phonological loop. Therefore, the number of words remembered is an indication of the amount of attention required by the primary task. Our research used the number of words recalled in the secondary task to investigate which retrieval method demands more attention—navigation or search.

2 Research questions

1. *Which retrieval method demands more cognitive attention—navigation or search?*

This was measured by the number of words remembered after the use of each retrieval method.

2. *Which retrieval method is more efficient and easier to use—navigation or search*?

We tested the *search everything* approach assumption that search is more efficient and easier to use than navigation by comparing the two retrieval methods *without* the additional free recall task. We measured and compared retrieval time, number of mistakes, number of failures, and subjective difficulty.

3. *Do gender and age differences affect multitasking capabilities*?

This question does not directly relate to the topic of our study; however, our data allowed us to test the widespread belief that women are better than men and that younger people are better than older ones, at multitasking (tasks that require divided attention). We tested this by analyzing the effect of gender and age on the number of words remembered in our secondary task.

4. *Does folder depth affect attention allocation*?

The structure in which the folders are organized may affect the amount of attention required for the navigation process. Our hypothesis is that the deeper in the folder hierarchy the file is located, the more attention is needed for the navigation process.

3 Method

3.1 Participants

Participants were 62 users of Windows 7, half of them (31) women. Most of the participants were students at Bar-Ilan University, Israel (non-random selection). Their ages ranged from 20 to 53 ($M = 30.89$, $SD = 7.49$), and they reported a high degree of computer literacy on a 1–5 Likert scale ($M = 4.11$, $SD = 0.81$).

3.2 Procedure

In the experiment, we used two tasks: a retrieval task and a memory task. Our primary task was the *retrieval task* in which participants were asked to retrieve (using either search or navigation) documents taken from their 'Recent Documents' list. This method combines the advantages of a controlled task (as we controlled the target file and retrieval method used) with a naturalistic study (as participants use their own computers to retrieve their own files). We had successfully used this method in the past [27].

Our secondary task was a free recall *memory task* in which participants heard a list of words before the retrieval task and were asked to repeat as many words as possible (in no particular order) after the task. We used two lists of 10 words each taken from the Hebrew version of the Rey Auditory Verbal Learning Test (RAVLT).

We used a within-subject design, where all participants performed in each of four conditions: navigation without a memory task, search without a memory task, navigation with a memory task, and search with a memory task. The order of conditions, as well as the use of two lists of words, was counterbalanced. In the search conditions, participants were not allowed to copy the file name into the search box because this would not have been a realistic simulation, as in real-life search processes are clearly cognitive in nature [28]. We are aware of the fact that we placed a constraint only on the search task and not on the navigation task, and consider this limitation when analyzing our results. Notice, however, that this was unavoidable, as any information given to our participants to identify target files could have been directly used to search for these files (e.g., if we had printed the first page of a document as an identifier, we would have had to forbid participants from typing text from the document into the search box). Each condition ended with a subjective assessment of the difficulty of retrieval: participants were asked "how difficult was it for you to find the file?" and answered on a scale of 1–5 (1 very easy, 2 easy, 3 neither easy nor difficult, 4 difficult, 5 very difficult).

3.3 Reliability and manipulation check

We decided to include only participants who use the Windows 7 operating system because our pilot results showed that users of Windows XP (which comes with a less advanced search engine) needed nearly twice the amount of time for their searches, and we did not want this to be an alternative explanation for our results. Subjective difficulty was found to be a reliable variable because it highly correlated with retrieval time. In addition, [22] recommended that the secondary task should be selected such that it is large enough to affect performance on primary task but still allows close to normal performance. Indeed, our findings show that, when asked to perform the secondary memory task, participants performed slightly more poorly on the retrieval task on all retrieval parameters (retrieval time, number of mistakes, and number of failures), and they reported that it was slightly more difficult for them in the subjective assessments. However, all effects were small and non-significant as required by [22].

4 Results

4.1 Which retrieval method demands more cognitive attention—navigation or search?

We tested this question by comparing the number of words remembered after navigation with the number of words remembered after search. A paired t-test showed that the average number of words remembered after navigation ($M = 6.15$, $SD = 1.88$) was significantly larger than the average number of words remembered after search ($M = 5.47$, $SD = 1.87$) $t(61) = 2.66$, $p < 0.01$.

However, navigation retrievals were much faster than search retrievals (see the results of question 2 below), and time is known to have strong effect on the number of words remembered [20, 21]. Therefore, an alternative explanation for these results is that participants remembered more words after navigation than after search simply because navigation took less time than search.

In order to eliminate this alternative explanation, we filtered in only pairs of retrievals where the difference in retrieval time between search and navigation for that particular participant was less than 10 s. Of the original 62

Table 1 A comparison of efficiency and subjective difficulty for search and navigation

	Navigation	Search	Test	p
Retrieval time (in seconds)	$M = 17.75$	$M = 50.11$	$t = 3.8$	<0.001
	SD = 17.51	SD = 62.83		
Number of mistakes	$M = 0.56$	$M = 1.28$	$t = 2.45$	<0.05
	SD = 1.09	SD = 2.03		
Failures	$N = 1$ (1.6 %)	$N = 7$ (11 %)	W = 2.12	<0.05
Subjective difficulty	$M = 1.64$	$M = 2.4$	$t(56) = 3.98$	<0.001
	SD = 0.88	SD = 1.25		

pairs of retrievals, 27 met this criterion. The average navigation time for these 27 pairs ($M = 10.45$ s, SD = 4.98 s) was not significantly different and very similar to their average search time ($M = 12.13$ s, SD = 5.81 s).

When comparing results only for these 27 participants, we found that the number of words recalled after navigation ($M = 6.48$, SD = 1.85) was larger than the number of words recalled after search ($M = 5.74$, SD = 1.68), $t(26) = 2.39$, $p < 0.05$. Note that on this test, the difference in the number of words remembered cannot be explained by a difference in retrieval time.

To conclude, our results show that, irrespective of differences in retrieval time, our participants performed better at the secondary task when navigating than when searching for their files. These results suggest that search requires more cognitive attention than navigation.

4.2 Which retrieval method is more efficient and easier to use—navigation or search?

This question was tested by comparing retrieval time, number of mistakes, percentage of failed retrievals, and subjective difficulty of search and navigation. All comparisons were made between navigation with no memory task and search with no memory task. Comparisons of retrieval time, number of mistakes, and subjective difficulty used a paired t-test, and comparison of percentages of success used a Wilcoxon's signed-rank test. Table 1 presents our results.

Table 1 indicates that navigation is faster than search and results in fewer mistakes and failed retrievals and that navigation was subjectively easier than search. Notice also the large effects—for example, on average, search retrievals took nearly three times as long as navigation retrievals,[1] and participants failed to find seven of their files when searching, compared to only one when navigating. However, one must be careful when considering the implications of these findings: in the experiment, we prevented the participants from searching by using the file name (as it was given them by the tester). We asked our participants to what extent the restricted search was more difficult than search retrievals that they typically perform. On a scale of 1–5, the average answer was 3.65 (SD = 1), which was significantly different from the midrange (3—"neither easier nor more difficult"), $t(53) = 5$, $p < 0.01$. Though our additional constraint added only a little difficulty to the search retrievals (0.65), this could serve (at least partially) as an alternative explanation of our results.

4.3 Do gender and age differences affect multitasking capabilities?

Our study allowed us to test the common belief that women are better than men and younger people are better than older ones, at multitasking, by testing the gender and age effect on the number of words recalled in the secondary task.

Gender effect: We tested this using an independent t-test that compared the number of words recalled, for men and women, for both navigation and search. While the difference between the number of words recalled after navigation for women ($M = 6.29$, SD = 1.94) and men ($M = 6$, SD = 1.84) did not reach significance, there was a significant difference between the words remembered after search between women ($M = 5.94$, SD = 1.63) and men ($M = 5$, SD = 2), $t(60) = 2.02$, $p < 0.05$. In other words, when conducting a search (which was shown to be subjectively more difficult than navigation), on average, women remembered nearly one whole word more than men. This result indicates that there may be truth in the common belief that women are better at dividing their attention (multitasking) than men are.

Age effect: We tested age effect using a Pearson's correlation test. Again, results did not reach significance for navigation $r = (-0.19)$ but reached significance for the search condition $r = (-0.39)$. When conducting the subjectively more difficult condition (search), age had a negative effect on performance in a divided attention task,

[1] Similar results regarding navigation retrieval time were obtained in [27].

supporting the common belief that the younger generation performs better when multitasking.

4.4 Does folder depth affect attention allocation?

We tested this research question by correlating folder depth (the number of folders the participant needed to open in order to reach the target file) with the number of words recalled from the word list. A one-tailed Pearson's correlation test showed significant negative correlation $r = (-0.23)$, $p < 0.05$. This indicates that the deeper the participants need to navigate to reach their files, the more attention the retrieval requires.

5 Discussion

Our research compared navigation with search. We tested which retrieval method demands more cognitive attention and which retrieval method is more efficient and easier to use. We also tested for gender differences regarding multitasking abilities.

5.1 Use of attention resources

Our participants remembered significantly more words in the free recall task when navigating to their target file than when searching for it. The fact that when navigating participants did better on a secondary task than when conducting a search, regardless of retrieval time differences, indicates that navigation requires less cognitive attention than search. True, our secondary task required a verbal cognitive resource (the use of a phonological loop), which may interfere with the verbal process of finding a search word more than if we had given a visual secondary task. However, as the majority of computer users are mainly busy with verbal processes before and after their retrievals (with the exception of users with visual-related jobs such as illustrators and architects), we think that this is rather a small limitation on the interpretation of our findings.

These results partly explain the strong preference found for navigation over search found in [1–5]: Computer users typically retrieve information items while in the midst of doing something else and intend to continue doing that after the retrieval. To do so, they need to keep whatever they were previously doing in mind, so as to eliminate the need to spend time and cognitive effort on recalling it. It is therefore rational to prefer to use the retrieval option that demands less attention.

Navigation may demand less attention because users are typically very familiar with their folder structure. Not only did they create it according to their own categorizations and subjective needs, but also each time they navigate to their files, they become more familiar with the structure. Therefore, navigation can be performed semi-automatically, leaving the mind free to think of other tasks at hand. Search, on the other hand, requires thinking of a search word, which has been shown to be an attention-demanding task [22]. Moreover, there are several different possible options to use in queries (e.g., different search words), which give different result lists, and this does not contribute to familiarity.

Another possible reason why navigation requires less attention than search is that virtual file navigation may use the same part of the brain that humans have been using for millions of years to navigate in the physical world. Using a designated area of the brain (namely, the posterior part of the hippocampus) may free other parts of the brain to attend to other tasks at hand. We are currently testing this hypothesis in a follow-up study using an fMRI scanner device.

We can conclude that even if search does not take more time than navigation as found in [19] for email retrieval, computer users may prefer navigation to search because it demands less of their attention.

5.2 Retrieval efficiency and ease of use

Our results showed that search took nearly three times more time than navigation; search is vulnerable to more mistakes and retrieval failures and is perceived as more difficult in subjective evaluation. Some of this effect may be attributed to the fact that we did not allow our participants to type the target file name in the search box (as it was given them by the tester), without putting a similar restraint on navigation. However, as participants indicated that this restraint made search only slightly more difficult than their typical searches, we believe that these findings cast a serious doubt on the untested assumption regarding the *search everything* approach: that search is more efficient and easier to use than navigation. Future research using other data-gathering techniques, such as logs, should be used to shed light on this question.

5.3 Gender and age effect

Gender effect: There is a common belief that women are better than men at multitasking, as noted by [29], who examined blogs and popular articles over the Internet. However, these beliefs are not always supported by scientific evidence: Although confirming results were obtained in [30], no significant difference was found in [31]; moreover, both [32] and [29] found an opposite effect: of men's superiority over women at multitasking. Therefore, our results showing women's superiority over men are non-trivial. Ren et al. [30] used evolutionary psychology to explain this phenomenon: in a hunter-gatherer society, men had to focus all their attention on hunting, while women needed to split their attention between gathering food and looking after the children. Like all evolutionary psychology post hoc explanations, this one can be criticized for lack of ability to test or refute it, which is demanded of scientific hypotheses [33]. An alternative explanation relates multitasking differences to differences in brain function between genders [34].

Age effect: We found that age has a negative effect on multitasking performance. This can be explained by the practice effect: [35] showed that younger members of the Y generation are much more involved in multitasking (e.g., listening to music and engaging in social network activity while doing their homework) than the X generation members and baby boomers. Future research should further test these common beliefs.

5.4 Structure effect

Folder structure can have various effects on the attention allocated to the retrieval. Our results indicated that the deeper in the hierarchy the file is located, the more attention the navigation requires. This is probably due to the fact that deep navigations are more complex than flat ones. In addition, it is reasonable to assume that pilers (i.e., people with less structured collections, see [7]) are more accustomed to searching for their files, and therefore, each search requires less attention.

5.5 Navigation and search in mobile devices

We tested our research questions regarding local files in a personal computer environment. To what extent do our results hold for ubiquitous files in mobile devices such as mobile phones and tablets? In order to consider this question, imagine a scenario where mobile device users navigate and search for their ubiquitously stored files using software such as Dropbox. This interaction is different from that with a personal computer in various ways: the device is handheld, the display space is limited, users typically use their hands to directly touch the screen (or press buttons), and the external environment is typically more noisy and distracting than accustomed when using a PC. However, we believe that the same basic differences between navigation and search remain: In navigation, users need to travel down the folder hierarchy until they reach the folder in which they previously stored the file, and then locate it within that folder. And in search, users need to think of a search word, type it in a search box, and then find the file from a list of query results. If the basic actions required for navigation and search remain the same in a mobile environment, then it is likely that the cognitive processes required for them are also unchanged: In navigation, the (now ubiquitous) folder environment remains familiar to the user (who stored the file there), so retrieval can be performed semi-automatically. Similarly, since search still requires thinking of a search word, which is a recall process shown elsewhere to be attention demanding [22], it is expected to be cognitively demanding in a mobile environment as well. Our hypothesis is therefore that, like in a PC environment, search requires more attention than navigation in a mobile environment. This hypothesis should be tested by future research.

6 Conclusions

The results of this research indicate that navigation requires less cognitive attention than search retrieval. This could partly explain users' preference for navigation over search. Our results also cast doubt on the *search everything* approach hypothesis that search is more efficient and easier to use than navigation. Future research should test other possible reasons for navigation preferences and find other ways to compare search and navigation efficiency.

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