NAVIGATION IN INFORMATION SPACE: HOW DOES SPATIAL ABILITY PLAY A PART?

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ABSTRACT

Spatial implications of the commonly used 'navigation' metaphor have lead many research works to investigate the premeditated relation between individual differences and navigation. This study presents an exploratory survey on the influence of spatial ability, the most incisive aspect of individual difference for navigation, when people try to accomplish their goal in the information space. Based on the previous results, researchers, in the field, are equivocal to state that a person with high spatial ability performs better in navigation. There are still different opinions about the potential of visual mediators for people with low spatial ability that help in refraining from the state of being disoriented or lost in the avalanche of information. The findings motivated us to design a research framework that may show us the result for drawing some contributory inference on this issue. The framework is presented after the extensive discussion. At the end, we discuss on future improvement schemes for this design and also on some overtures for further works along this direction.

KEYWORDS

Hypertext navigation, spatial ability, information space, information visualization.

1. INTRODUCTION

Spatial ability is the ability to perceive spatial patterns or to maintain orientation with respect to objects in space (Ekstrom et al., 1976). It is the cognition of spatial properties of the world like location, size, distance, direction, shape, movement, etc. In the context of navigation, it is the perceptual ability on the information space based on user's previously acquired knowledge, information processing capability and motor capability on spatial properties in real world. Spatial ability is often cited as a good predictor of individual's performance in human- computer interactions (Egan, 1988; Stanney & Salvendy, 1995). The influence is more eminent in the act of browsing or navigation in an interaction space, which has somewhat spatial layout inherent in it. (Benyon & Murray, 1993; Dahlbäck et al., 1996).

Identifying the ways in which people conceptualize the whole interaction environment and the extent of spatiality in this model is yet to be resolved clearly. It is still needed to forecast the browsing patterns of people with varying spatial abilities. The basic premise behind the metaphor is that finding information in a significantly large navigation space is psychologically similar to navigating in real world space and, hence, promoting the existence of a mental architecture that conceptualize the information space in a spatial manner, may increase the affectiveness, efficiency and enjoyment of navigation. It is believed that navigation performance of people with low spatial ability can be improved by providing them with visual tool that assist in grasping the layout of the space (Robertson, 1997; Vicente & Williges, 1988). Benyon & Murray (1993) and Höök and Dahlbäck (1997) conducted studies that clearly showed that people with high spatial ability can visualize the organization of information better than people with low ability. Stanney & Salvendy (1995), found that visual tool for hierarchical representation of information is an effective means by which to accommodate low spatial individuals in information seeking tasks. But, another work by Chen (2000) revealed that it is not the spatial ability rather experience with the system that matters effectively in the performance of navigation in information space. Another interesting study (Allen, 1998) reveals that spatial organization of information helps the low ability people with their way finding but, in some cases, negatively affects the high spatial people. Dillon & Vaughan (1997) were somewhat cynical, in their landmark article on information shape, on the rationale of looking at the information systems as a metaphor of real world space. Instead, Dillon suggested the idea of *Information Shape*, which, in his view, more suitable to express the users' actual mental and physical tasks in information seeking (Dillon & Vaughan, 1997; Dillon 1995). However, the contraposition of results and divergence in opinion call for more efforts like ours on this topic.

2. NAVIGATION IN INFORMATION SPACE

Navigation is the process of moving from one location to another and knowing the relative position in order to reach the desired destination in a spatial environment. It includes understanding, partitioning an environment, exploring it and finding the right way to the end from starting point (Benyon, 2001). In order to explain *information Space*, Benyon (2001) introduced the idea of *activity space*. Activity space is the physical spatial environment where people perform a certain activity. Information space is the structured collection of information consisting of various information artifact and signs from where subjects seek information for their activity space. According to results from the study by Dieberger (1997), visualizing an information space is necessary for effective navigation. That is why people often impose metaphors to information space to give it a visual structure. Apart from the large body of information contained in it, an information space can be envisioned as a set of nodes, each of which is an information unit or sign (van Dyke Parunak, 1989). The topology of these nodes makes it resemble a space for traversing. The complete structure takes a shape like a city or town where the way-finder is not forced to take any single path to reach a destination. In this sense, hypermedia is the most notorious example of an information space. Besides, newspapers, television and even a single autonomous computer or paper document can be treated as an information space. The evolution of the World Wide Web over past several years has been astounding. Due to its huge information content and complexity in navigation, salience and structure make it the most complex information space for information users. Navigation in information space, thus, can be defined as the process where user moves through the virtual information network by following links from node to node and senses her position in the network relative to the destination node. Navigation and way finding are used as similar terms in many works when it comes in the context of electronic information space (Dahlbäck & Lonqvist, 2000). Based on the size, orientation and structure, the navigation mechanism varies from one information space to other. There are numerous definitions for navigation in information space and Dahlbäck & Lonqvist (2000) concluded it as a task rather synonymous to information retrieval.

3. SPATIAL ABILITY

Analyzing and understanding spatial ability is a complex affair in psychology. Every task that presents figural stimuli does not require spatial ability to exploit by the individual. Nor does the absence of a figural stimulus mean that there is no spatial processing (Lohman & Kyllonen, 1983). Spatial ability or thinking, in general, requires several psychological attributes such as ability to encode information, remember, transform and differentiate spatial objects (Lohman & Kyllonen, 1983). Kritchvesky's posits on spatial ability are quite acceptable to the community (Caplan & Romans, 1998). According to him, there are five broad categories of spatial functions, which are *perception, memory, attention, mental operations and construction*. The functions, all together, contain nine basic spatial skills. These are *object localization, line orientation detection, spatial synthesis, short term spatial memory, long term spatial memory, attention to left hemispace, attention to right hemispace, mental rotation and spatial construction*. Other spatial properties proposed by various authors include visual scanning, face recognition, topographical orientation, and identification of incomplete figures and detection of hidden figures. Much research has been conducted to devise appropriate psychological tests to measure these abilities. Ekstrom et al. (1976), Lohman & Kyllonen (1983) and Caplan & Roman's (1998) compilations are some of these to name few. An expansive discussion on these tests is beyond the scope of this study.

4. HOW PEOPLE CREATE MENTAL MODELS DURING NAVIGATION

Spatial ability of an individual comes to play when she performs the task of navigation in information space. For instance, authors of an information space possess a semantic structure of information pieces that primarily resides in their mind. The virtual space that is created by unifying these models of one or more authors is not more than a transient representation of the whole information. A reader or information seeker, when comes to interact with the intermediate representation, tries to develop another mental model based on what she sees or finds through the navigation. It is believed that if the information nodes are related spatially in some extent, both the authors and readers develop a space out of these nodes where they start navigating, unconsciously, during developing or traversing the virtual model (e.g. a WWW site). The shape of this space depends on the individual's various cognitive abilities where spatial ability is, presumably, the principal component (Benyon & Murray, 1993).

Based on the model a user creates, she tries to predict the hidden surfaces or parts of the space. Dillon (1991), in his article on readers' model on academic articles, showed results that support the existence of such a predictive model in each reader's mind during interaction with paper or digital journal articles. The accuracy of this prediction depends on how the reader design the structure based on her experience and various cognitive abilities. Our principal focus is on finding the influence of user's spatial ability in creating such a model and how information can be presented to user so that she can predict the original structure of information better and, essentially, enjoys effective navigation.

5. NAVIGATION AND SPATIAL ORGANIZATION OF INFORMATION

Background study as found in (Allen, 1998) shows that spatial organization of information visualization helps in learning and memory. As short term memory plays a key role in navigation sessions (Hewett, 1998), spatial organization of information, eventually, results in better navigation in information space. Again, long-term memory encapsulates experiences and habits in human brain (Tulving, 1983; Coone & Fisher, 1998). Chen (2000) identified experience with the system as the main factor for lost less navigation. Taken as a whole, spatial organization of information has received much focus in finding the exact relation between spatial ability and conceptualization of information space. Stanney et al. (1995) found that visual mediators, such as 2D and 3D organization of information, remove the discrimination of mental models between low and high spatial peoples. Similar results were found in (Allen, 1998), where Allen showed that it was not the high spatial people, but rather those with low spatial ability who got benefited from the spatial representation of information. Some of Allen's result was interesting where high spatial people's performance degraded due to the presence of spatial layout of information. Höök & Dahlbäck (1997) also studied that visual momentum in information space helps with low spatial people. It is still not established firmly that how exactly high spatial people affected by spatial representation of information.

In the next section we discuss on the framework that is designed to find answer of these questions. We choose the World Wide Web as the information space for navigation because of its complexity and enormosity.

6. RESEARCH FRAMEWORK

The purpose of this research is to gain a better understanding of how navigational tool in the World Wide Web (WWW) sites helps people in their information seeking and keep them away from the state of being *lost* (Smith, 1986). Breadcrumbs, in general, are a list of hyperlinks that "convey information to the user (about the site structure or the path they have taken), and to also give users a way to select links from the breadcrumbs (in order to go 'up' in the site hierarchy or to re-trace their steps)" (Instone, 2002). Breadcrumbs have evolved as a major navigational tool of the WWW, but there has been little research regarding their "precise concepts and terminology in order to effectively use breadcrumbs in different situations" (Instone, 2002).

Instone (2002) distinguished two types of breadcrumbs: *location breadcrumbs* and *path breadcrumbs*. Location breadcrumbs show readers where the current web page is in the hierarchy of the current website. As such, they are rather like route markers on a highway, which are consistent with author's model. Path breadcrumbs show readers the sequence of web pages that they visited at the current site to 'arrive at' the current web page. From the definition, it is clear that location breadcrumbs give user an idea of where exactly they reside in the site hierarchy. This helps in better understanding the structure of that particular information space. We chose this type of breadcrumb for our investigation due to its apparent cogency in creating a better model of the information space in user's mind. Throughout the rest of this framework, breadcrumbs generally mean location breadcrumbs if not specifically indicated.

Many examples of regular location breadcrumbs can be found in websites such as in Open Directory Project site (URL: http://dmoz.org)(Figure 1).[1]

Figure 1. Regular breadcrumb as found commonly in the web

6.1 Experimental Breadcrumb

Hochheiser et al. (1999) investigated the performance benefits of simultaneous over sequential menus. Sequential menus are better suited for information query where some kind of hierarchy exists (Hochheiser et al. 1999). In another study by Zaphiris et al. (1999), in-place expandable menus in web environment present a hierarchy of choice to users and reduce backtracking and lostness. The *experimental breadcrumb*, that we developed, provides both simultaneous and sequential features for a website which is an ideal combination for such navigation tasks. The experimental breadcrumbs look like regular breadcrumb at the first place; but there is a menu associated with each of the breadcrumbs and it pops up when user moves her mouse over that specific breadcrumb item. The menu contains all the links that are one level deeper in site hierarchy of that particular item. Figure 3 shows an instance of experimental breadcrumb.

As we discussed in previous sections, the relation between human spatial ability and spatial organization of information in an information space, we now present the credibility of experimental breadcrumb as a potential tool for future web. Neerincx & Lindenberg (1999) abridged on three types of spatial navigation

1 Source: <URL: http://dmoz.org/Health/Mental Health/Counseling Services/Online*i*>

support that help people in wayfinding in large information space. These are landmarks, history map and navigation assistant. *Landmark*s are the navigation cues that help in user in recognizing their situation in the search space. A *history map* keeps a trail of users navigation activities. A *Navigation assistant* has the knowledge of the domain and is able to dynamically provide advice to the individual user by analyzing various individualistic factors like interest, browse history, profession, education and age.

We tried to facilitate these three presumptions during the design of experimental breadcrumb. The breadcrumb trail shows the history of the user's navigation activities. The pop-up menu is dynamic in the sense that it always directs user where else she can go from that specific breadcrumb item. The definition of experimental breadcrumb, itself, contains the landmark feature of an ideal navigation tool. As the links in the menus are exactly one level down the site hierarchy, it gives user the awareness regarding her situation during navigation. Allen's (1998) work on spatial information presentation clearly shows the effectiveness of 2D spatial layout of information for low spatial ability people in their navigation in information space. The 2D representation style of the experimental breadcrumbs, hence, reduces the limitation of regular linear breadcrumbs that might be experienced by low spatial ability people. On the whole, the overall architecture seems promising for more effective navigation in web environments for people of diverse abilities.

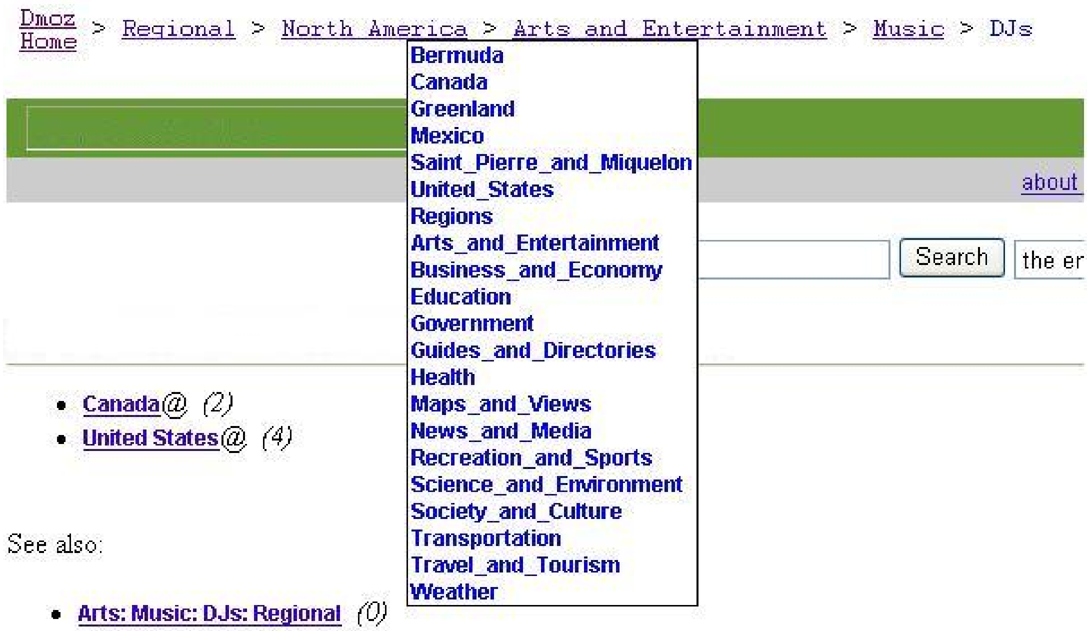

Figure 2. Experimental breadcrumb for future web

7. FUTURE WORK

The new navigation tool is ready for its evaluation tests. We hope to find interesting results from our coming experiments. Besides, some future direction for its extension is under assessment. The navigation assistant part of the tool can be improved substantially. More knowledge can be infused into the menus by using intelligent systems approaches. The contents of each pop up menu will be more dynamic and reduce disorientation of users. Some independent parameters affect spatial ability such as sex, age difference, cognitive style, personality factors (Sjolinder, 1996). The best we can do is to predict the user based on these attributes and design a user-adaptive or intelligently integrated framework for navigation. We wish to incorporate these aspects in our future designs. Another dimension of our future work is to investigate Dillon's elusive construct 'Shape of Information' and how better it answers indecipherable questions regarding spatial ability of individual and navigation in information space.

8. CONCLUSION

In this study, we have reviewed previous efforts in explaining the relation between spatial ability and navigation in information space. We have presented a promising tool for navigation in large information space and discussed on some future directions for its improvement. There are, still, some open problems to move forward in this area. It will, certainly, be interesting to find how much spatial a person's mental model is and also how all these concepts can be applied to related research paradigms like collaborative hypermedia authoring and learning. Finally, it seems clear from our discussion that additional efforts are needed to come up with more effective and usable navigation scheme for people with diverse individual differences.

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