Neural Correlates of Searching VS. Navigating / Liv Glazer

Abstract

Personal Information Management (PIM), is an information behavior in which an individual stores his/hers personal information items (e.g., files, messages, emails and favorites), in order to later retrieve them. The two main strategies for retrieving personal information on the computer are: Hierarchical Navigation (*Navigation* for short) and Search. Studies that examined retrieval methods, consistently found that users prefer to use navigation over search, when retrieving their personal items. The navigation preference is a phenomenon which require an explanation, both because navigation requires the burden of maintaining folders and directories system and forces the user to store the items inside them and because search is more flexible and enables the use of any attribute that the user might remember about the target item he seeks and also does not require to remember the exact path in which the item is located. Some researchers resolve the issue of navigation preference as no more than a habit. In this study we explored a deeper explanation to the navigation preference, which is that navigation and search uses different neurological structures.

Our research hypothesis was that during navigation to a digital information, activation will occur in the same brain structures we use to navigate in the physical world for millions of years and mainly the hippocampus, which is used for spatial perception and other supporting areas, which related to procedural memory, such as the basal ganglia, areas which take part in visuo-spatial processing, such as the parietal area and the cerebellum and areas which operate in the verbal memory and naming such as the temporal area, mostly left. On the other hand, search by term method should result in increased activation in the areas which involve creating search terms and need the use of executive function, such as pre-frontal areas.

The study was carried out with reference to the NeuroIS field, which combines neuropsychological tools and methodologies from the neuroscience, in information technology (IT) research and allows the study of human behavior through learning the brain functions and brain activity in specific regions. Our study used a functional magnetic resonance scanner, fMRI, which measures brain activity through changes in blood flow in the brain in different areas and through the blood magnetism. The subjects performed the study inside the scanner and their brain activity was recorded.

In order to test the navigation and search activities, the research paradigm was designed in a blocks structure and contained four conditions: search, navigation, control search and control navigation, of 30 seconds each. Control tasks, allows setting a baseline for the fMRI scan. Since people have constant brain activity, this activity should be subtracted from the brain activity in the different experimental conditions. Rest is not a good control mode because then participants tend to think of different things. Therefore, it was necessary to give a task, which includes basic characteristics of the tasks in the experiment. Control tasks designed to subtract visual and motor processing, but to retain the cognitive activity. Entering the baseline data is a necessary conditions for the scanner to produce calculations for brain activity. Each participant had between 3 and 4 runs. All four conditions appeared in each run twice in a semi-randomized order.

The study was conducted at the University of Sheffield, England, and therefore the participants were students from that university. 16 Participants, aged between 19 and 29, volunteered to take part in exchange for financial reward. Anyone willing to volunteer could, but they had to meet the following conditions: Since the

study design makes use of the participants' personal files and computers, they must have a laptop and must agree to bring it to the research. Also, as participants performed the research
tasks in an fMRI scanner, they needed to be with a dominant right hand, and suitable for testing inside MRI machine (with no claustrophobia and in healthy physical and mental state).

Throughout the entire experiment, the participants lay in the fMRI scanner and carried out the research tasks within it. The view on their personal computer was made possible through a mirror that was placed inside the scanner. Due to the magnetism of the fMRI, we weren't able to insert magnetic objects and so we could not use a regular keyboard and mouse. Therefore, we used a virtual keyboard and an MRI- compatible mouse. Participants' brain activity was recorded during the tasks and their computer screen was documented. This documentation enables to correlate between the actions of the participants and the results of the scan, to check wrong behaviors tasks (such as using navigation during search task) and thus invalidate some information, allow division of the task into smaller parts (e.g., search task was divided into 3 parts: the thought of a search word, writing the word and selecting the correct item within the search results) and thus make fine-tuned analyzes of parts of various tasks and finally to perform behavioral analysis.

When processing the data which arrived from the scanner, brain activity was tested in two levels. First, brain activity was examined for each participant individually and this was later used to do a second level analysis for all participants together. The second analysis was conducted by one sample *t*-test. In order to find out which areas of the brain were active in each experimental condition (e.g. , which regions were active during navigation), a reduction of the task, from its matching control task was carried out (e.g., brain activity that observed in the navigation task, subtracted from the brain activity in the control navigation task). Also, in order to find out which brain regions were significantly active between the search and navigation task (e.g., which areas of the brain were significantly active in navigation, compared to search), a reduction of a task from the other task was carried out (e.g., the brain activity that was observed in the navigation task, subtracted from the brain activity in the search task).

Analysis of the results and according to our hypothesis, found that during navigation, which was reduced from its control condition, brain activity occurred in areas taking part in visuo-spatial processing, such as the right parahippocampal gyrus, parietal lobe and the right precuneus. Activity was also observed in brain areas which take part in both memory such as the frontal limbic system, and spatial memory such as the posterior cingulate and the left side the middle and superior frontal gyrus, in regions used for visual processing, such as the occipital lobe and for visual verbal processing, such as the left fusiform and the lingual gyrus. During search, which was reduced from its matching control, we found active regions responsible for memory, such as the limbic lobe and the left cingulate gyrus, areas responsible for identifying visual verbal information, such as the left fusiform gyrus and also, activation in the left parahippocampal gyrus.

Although it would appear that there is an overlap between the areas found during search and navigation, their differences can be observed when we performed the reduction of a task from a task to see which regions were significantly active in each of the tasks. Reduction of search from navigation, seemed to show significant activity during search only in the inferior / superior parietal lobe. This area is known for its involvement with integration between sensory information and motor actions. However, the reduction of navigation from search, seemed to show significant activity during navigation in regions, which comes together with our hypothesis, that take part in memory, spatial memory and spatial navigation, such as the limbic lobe, in the posterior cingulate area, the parietal lobe, in the procuneus area the frontal lobe, in the middle/superior frontal gyrus and the occipital lobe, which associated with visual verbal detection.

Our findings suggest that navigation, in contrast to search, relies mostly on areas that are not unique to the human brain and their activity requires relatively little attention, such as regions participating in spatial navigation and visual information processing. It seems that navigation in the computer, is similar to real life navigation. Possibly, this reduces the cognitive load and facilitates its use. These results are important for basic science (which is lacking for PIM) and it may be able to assist in making more informed decisions regarding the development of future PIM systems. Beyond that, it is one of the first studies to use the NeuroIS paradigm, which can expand the selection of research tools for researchers when they investigate behavioral information.