The Neuropsychology of Stroke in the Back of the Brain: Clinical and Cognitive Aspects

Great progress has been made over the past century in our understanding of how the brain works but we still know surprisingly little about how the brain processes vision. The aim of my PhD project was to learn more about how the brain recognises things in our environment such as objects, faces or words. For decades, it has been widely accepted that faces and written words are recognised differently and using different parts of the brain, with written words being recognised by areas in the left side of the brain (left hemisphere) and faces being recognized by areas in the right side of the brain (right hemisphere). The results from my PhD provide evidence against this and suggest that both sides of the brain contribute to our ability to recognise faces and to our ability to recognise words. By learning more about how the brain processes vision, the results from my PhD, together with other results from the field of neuropsychology, will hopefully enable the development of more efficient rehabilitation methods for patients who, following brain injury, have problems with their vision.

Stroke and visual problems

Stroke is the leading cause of brain injury worldwide. Every year in Denmark alone, there are approximately 12-14.000 people, who have a stroke. Approximately 20% of patients die within the first weeks after their brain injury, and while some survivors recover fully from their stroke, most have to live the rest of their lives with some form of disability. Some of the most well-known consequences of stroke include paralysis of one side of the body (hemiparalysis), as well as problems in producing and understanding language (aphasia). Stroke can also lead to a large range of other disabilities that are not as prominent, but that can be just as devastating. Problems related to vision are an example of a disability that is common in stroke survivors but that is often neglected in the health care system.

While one might assume, that our eyes are responsible for vision, our brain is in fact the main processing machine enabling us to make sense of what we see. When looking at a mug, our eyes have no idea what they are looking at. They simply detect differences in intensities of light in our surroundings. This information is then sent to the back of our brain for further processing. Our brain then identifies and recognises basic shapes and colours in our surroundings and then, after some complicated processing, recognises what we are looking at; in this case a mug. As our visual sense is so highly developed, we have a large proportion of our brain dedicated to it. This means, however, that an injury to the brain can easily affect vision. In fact, it is estimated that 60% of stroke survivors have problems related to their vision.

The devastating consequences of visual problems after a brain injury

Some years ago, at the Department of Psychology at the University of Copenhagen, we were contacted by LB, a 80-year-old man, who following a stroke, had lost the ability to recognise faces. He could no longer recognize celebrities on TV, struggled to recognise friends at social events, and regularly failed to recognise his wife. Before his stroke, he had been an expert in recognising faces. During his career as head of various large firms, he had been dependent on being able to recognise collaborators and employees. One particular episode illustrated the extent of his problems after his stroke. He had gone to a large store to buy clothes and on his way out, he had walked down a corridor and seen someone coming towards him from the other direction. The two of them got closer until they finally were standing opposite each other. Trying to avoid each other, they both took a step in one direction, and then in the other. Finally, LB barged straight ahead and … smashed his head into a mirror. The person that he had been trying to avoid was not a stranger but his own reflection in a mirror.

LB had lost the ability to recognise faces, a condition called prosopagnosia, caused by damage to some of the areas that are responsible for vision in the back of the brain. His knowledge about famous people was intact but he had lost the ability to recognise them based on their faces. His problem was so severe that he could not even recognise his own face in a mirror. This had devastating consequences on his social life. He had previously enjoyed participating in all sorts of social events but now avoided them at all costs, as he would end up introducing himself to the same person numerous times during a single event. We assessed LB and it turned out that he also had other visual problems. He could no longer perceive colours and saw the world in shades of grey, which affected his mood deeply. He had been a prolific reader and now, his reading was slow and required massive effort.

Despite vision being the sense that we as humans rely the most heavily on, we have a tendency to take our vision for granted. When compromised, the importance of our vision becomes blatantly apparent. Research has shown that visual problems after brain injury have negative effects on patients' quality of life and on their ability to function independently. While there are many rehabilitation methods available for helping patients with motor or language problems after stroke, there are currently no efficient rehabilitation options available for treating visual problems after stroke. One of the reasons for this is that we do not fully understand how the brain processes vision. In order to repair a car that has stopped working, a mechanic needs to identify which part of the motor is damaged and needs fixing. In order to help a patient with visual problems after a brain injury, clinicians needs to be able to figure out which part of brain system is damaged and needs to be targeted with rehabilitation.

The aim of my PhD was to increase our understanding of how the brain enables us to recognise things in our environment, more specifically, which processes are involved in visual recognition and how they are organised.

Patients with brain injury can provide us with useful information about how the typical brain works

In the field of cognitive neuropsychology, we test patients who have had brain injury to learn more about how the typical brain works. By studying which abilities are preserved and which are impaired, and relating the profile to the specific location of the person's brain damage, we can say something about which parts of the brain do what. Studies of individual patients with very specific visual problems after a stroke have contributed strongly to our understanding of how the brain processes vision.

There have for example been many examples of patients with pure prosopagnosia described in the literature. These patients have lost the ability to recognise faces but can still recognise all sorts of other visual stimuli such as objects and words. Most of these patients have damage to a specific area that is located in the back of the right side of the brain, leading researchers to believe that this area is largely responsible for face recognition. There have also been examples of patients with alexia (a reading disability), who have lost the ability to recognise words but are still able to recognise all sorts of other stimuli, including objects and faces. These patients typically have brain damage to an area located in the back of the left side of the brain. That these two types of patients exist: patients with problems in face recognition and preserved word recognition, as well patients with impaired word recognition and preserved face recognition, is one of the key reasons why scientists for decades assumed that face recognition and word recognition were processed very differently in the brain and by different brain hemispheres.

This hypothesis of *hemispheric lateralisation* has however been questioned over the past decade. A research group published a study in which they reported that patients with alexia (with left hemisphere damage) also performed badly on face recognition tests and that patients with prosopagnosia (with right hemisphere damage) also performed badly on reading tests. This led the authors to suggest that faces and words, rather than being processed by different brain hemispheres, rely on common machinery that uses overlapping areas distributed across both brain hemispheres.

The debate as to the extent to which face recognition and word recognition rely on processes and brain regions that are independent or common is still ongoing. The core aim of my PhD was to contribute to this discussion by adopting a new approach.

The Back of the Brain project

Most neuropsychological studies have recruited patients according to their symptoms. Typically, patients with very specific symptoms are recruited and studied in depth with many tests. While these single case studies of patients can be very informative they have two core problems. Firstly, the patients in question are very rare and are not at all representative of typical stroke patients. It is possible, that the findings from these studies have led to inaccurate conclusions about how face and word processing is organised in the brain. Secondly, as very different tests are used in each individual patient study, it is difficult to compare results across studies.

My PhD was part of a large project called the Back of the Brain (BoB) project that took a different approach. Instead of recruiting patients according to their symptoms, we recruited patients purely according to where their lesion were. To be included in the project, patients had to have a stroke in the visual areas that are located in the back of the brain. We tested all patients with the same 32 tests assessing a wide range of visual abilities including low-level visual perception (e.g. visual acuity and colour perception), intermediate visual perception (e.g. ability to integrate elements into a whole), as well as high-level visual perception (e.g. face, word and object recognition). Brain scans were also performed so we could see where their lesions were. In all, 63 patients were included making the BoB project the largest study investigating visual perception in patients with stroke in the back of the brain.

We wanted to test the traditional hypothesis that face recognition and word recognition are carried out by different brain hemispheres. We compared the performance of the 32 patients with left hemisphere brain damage to the performance of the 21 patients with right hemisphere brain damage, on tasks that assess face and word recognition. If face recognition is carried out in the right hemisphere and word recognition in the left hemisphere, then the patients with a left hemisphere stroke should be much worse at recognising words than patients with a right hemisphere stroke, and patients with right hemisphere stroke should be much worse at recognising faces than those with a left hemisphere stroke.

Both hemispheres are involved

Both groups of patients performed worse than the group of participants without brain injury on both types of tasks (reading and face recognition). Interestingly, the group of patients with a left hemisphere lesion did not perform worse than the group of patients with a right hemisphere lesion on the word recognition tasks and the group of patients with a right hemisphere lesion did not perform worse than the group of patients with a left hemisphere lesion on the face recognition tasks. This has lead us to conclude that face and word recognition, contrary to what is stated in current textbooks, may rely on processes that are distributed across both brain hemispheres. Hopefully, the findings from

our project will provide some of the building blocks needed for the development of efficient rehabilitation methods for people like LB, whose lives have been turned upside down by their brain injury.