Overview of the consequences of cognitive neuropsychology

The ability to study and understand the brain has evolved dramatically since people were first interested in the brain's seemingly miraculous capacities. However, comprehending the input/output nature of the brain (and everything in between) has always been limited to behavioral tasks of healthy individuals. Unfortunately for science, a machine that can't be reverse engineered cannot be fully understood. To truly make sense of the diverse functions of each part of the brain, it is necessary to see the importance of studying individuals with brain damage.

The field of cognitive neuropsychology occupies itself precisely with this concept. More or less, it offers the analogy of the brain as a sort of appliance, perhaps a television with lots of wires plugged into it. Assuming that none of the cables' functions are labeled (as is obviously the case with the brain), the best way to discover which cable controls each part of the television is to unplug each cable one at a time and observe which parts of the television stop functioning. This analogy works well, given that a lesion in the brain is small enough to only effect a certain function. More diffuse brain damage is like more cables being removed at once; it becomes more difficult to declare, with precision, which cable controls which function.

As non-invasive methods of imaging the brain have improved over the decades, it is no longer necessary to limit studies to healthy individuals, non-human animals, and less precise guessing as to the localization and diffusion of brain damage in patients. Techniques like magnetic resonance imaging (MRI) allow researchers to pinpoint where brain damage exists in patients, and, from further behavioral experiments, determine how the damage has affected the brain and, moreover, for which behavioral aspects the damaged part of the brain used to be responsible.

Additionally, another technique, transcranial magnetic stimulation (TMS), allows researchers to simulate a momentary “ lesion” on superficial portions of the cortex. Clearly finding a patient with brain damage for every part single part of the brain is a scientific pipedream. Thus, by following the previous analogy, TMS offers the possibility to “ remove a cable” and witness the effects without causing any permanent damage to the brain.

This paper will show three cases of brain damage studies from the past, before such technology was available, and three from the present to contrast the difference in techniques and what the studies contributed to the field of neuroscience and demonstrated about brain function.

No discussion of brain damage studies is complete without mentioning the case of Phineas Gage. Occurring in the 1840’s, and arguably one of the most famous cases of all time, Gage’s face, skull, and brain were penetrated, through-and-through by a 3cm thick, 109cm long tamping iron. He was “ momentarily stunned but regained full consciousness immediately thereafter. He was able to talk and even walk with the help of his men” (Harlow, 327). John M. Harlow, the doctor who looked after Gage after his accident, made observations about Gage’s behavior, such as “[Gage has] succeeded in raising himself up, and took one step to his chair, and sat about five minutes. “, and “ Intellectual faculties brightening. When I asked him how long since he was injured, he replied, ‘ four weeks this afternoon, at 4½ o’clock.’ Relates the manner in which it occurred, and how he came to the house. He keeps the day of the week and time of day, in his mind. Says he knows more than half of those who inquire after him. Does not estimate size or money accurately, though he has memory as perfect as ever." (" Passage of...", 282)

Assuming Gage had a normally developed brain, such observations essentially prove the concept of functional localization within the brain. Although it is easy to see this retrospectively because of what modern science has shown, Harlow didn't have the luxury of MRI or other techniques, apart from simple observation. By recognizing that Gage's memory, speech, movement, and ability to learn were spared, but "[h]is respect for the social conventions by which he once abided had vanished [(His abundant profanity offended those around him)]" (Harlow, 327), Harlow was later able to connect Gage's changed behavior to the frontal regions of the brain, which paved the way for further studies in seeking out the neural basis of various human capacities (ibid.). Understanding that each part of the brain does, in fact, have its own specific function was a crucial discovery in neuroscience and would have likely been impossible without patients such as Phineas Gage.

Another patient similar to that of Gage, in terms of fame and selective damage, is " Tan" (named for the monosyllabic sound the he produced when trying to speak), the aphasic patient of the French surgeon Paul Broca. In 1861, Broca observed that Tan " differed from a sane man only in the loss of articulated speech" (Broca, 343). Given Tan's symptoms, (for later in life he also presented with insensitivity on the right side, paralysis of both right limbs, weakened vision in his left eye , and incomplete paralysis of the left cheek, in addition to the lack of speech) (347), Broca claimed that “ the principle cerebral lesion had to occupy the left hemisphere ” (ibid.). Only years later during the autopsy could Broca precisely observe the extent of the brain damage.

In terms of Tan’s general behavior, however, Broca noted that “[it was] certain that Tan understood almost everything that was said to him…” (345), that “[n]umerical responses were those that he could make the best, by opening or closing his fingers” (346), and that “[t]he tongue was perfectly free…the patient could move it in all directions…The muscles of the larynx seemed in no way altered, the quality of the voice was natural, and the sounds that the patient made in pronouncing his monosyllable were perfectly clear” (345). These observations clearly indicate that Tan was still capable of expressing concepts, even if he was unable to express them strictly verbally, and that there existed a distinction between general vocal tract usage and speech production. These observations coupled with the results of the autopsy led Broca to realize that there existed of faculty of articulated language (as translated from French), lateralized to the left-hemisphere, distinct from comprehended language (356).

However, the drawback to Tan’s case is that given the extent of his brain damage, Broca was still left pondering “ whether the faculty of articulated language depends on the anterior lobe considered as a whole, or especially on one of the convolutions of this lobe” (357). Advances in technology in the next century would greatly strengthen his findings. Though in any case, Tan’s deficits led to the discovery of language in the left hemisphere and the notion that speaking meaningful words is distinct from general expression of concepts or of comprehending concepts as a whole.

The case studied by Carl Wernicke greatly added to Broca’s findings and strengthened the model of how language was processed in the brain by presenting a double dissociation between speech production and speech comprehension. Basically, Wernicke found a stroke patient in 1873 whose speech and hearing were unimpaired, but he couldn’t make sense of what he read or what was said to him (Alic, 666). As it turned out, this condition, which essentially contrasted that of Broca’s patient, Tan, was indeed localized to a different part of the brain. Upon autopsy, Wernicke “ found a lesion in the rear parietal/temporal region of the patient’s left brain hemisphere” (ibid.).

However, Wernicke regarded this facet of speech production and posited a connectionist-style theory of language production, thus he postulated that “ Broca’s area and [his] area were connected, and…damage to this connection would cause conduction aphasia, a syndrome wherein a patient could both speak and understand language, but would misuse words…” (ibid.). From this connectionist notion, Wernicke theorized more deeply about general associations of a concept with language. In 1886, he made the claim that, in order to understand the word “ bell”, “ the telegram arriving in [the speech comprehension center] must arouse in us the ‘ concept’ of the bell, i. e. the different memory images of the bell deposited in the cortex and localized in accordance with the sensory organs involved in their development. These are…acoustic…optic…tactile…and finally…motor images…the arousal of each one separately is communicated to the others and they constitute a functional unit” (Code, 15-16).

Unaided by modern neuroimaging technology, Wernicke made a big step forward in connectionist-model theories on semantic associations and language production/comprehension. Together, Broca and Wernicke set the stage for studying language in the brain by having observed patients with specific brain damages and consequently conjecturing about the nature of the healthy human brain.

Modern cognitive neuropsychology certainly follows the same principles in terms of assessing brain damage and theorizing about models of information streams. However, contemporary neuropsychologists have the benefit of computers, brain scanners, TMS, and, as seen in the next case, also infrared emitting diodes (IREDs).

This next case is another classic, albeit much more recent: the study of patient DF by Goodale and Milner. DF was a middle-aged woman who was plagued by brain damage after carbon monoxide poisoning (Goodale, 154). The researchers could localize the damage without needing an autopsy thanks to MRI, which allowed further testing and studying to occur with knowledge of which structures were afflicted: the ventral and lateral occipital region, and in the parasagittal occipitoparietal region. After beginning neuropsychological testing, the researchers discovered that DF had a visual form agnosia (ibid.). Overall she “ showed poor perception of shape… orientation…colour…intensity…stereopsis…motion…proximity…continuity, or similarity” (Goodale, 154-155).

Goodale and Milner ran several tests to discern how profoundly the visual form agnosia affected DF, and they came to realize “…a striking dissociation between [her] ability to perceive object orientation and her ability to direct accurate reaching movements toward objects…” (155). In one experiment DF had to indicate the orientation of a slot using a card by orienting the card similarly to the slot. Goodale notes that results here were “ grossly impaired” (ibid), but “ when [she] was asked to reach out and ‘ post’ the…card through the slot…her performance was excellent” (ibid.).

The researchers ran a similar test to measure grip aperture between her index finger and thumb when she would pick up a small plaque. Here they employed the IREDs to measure the distance between the fingers and have numerical data to work with. Such a simple task is rendered quantitative (and thus scientifically measurable) merely by the technology available at the time.

This second experiment had results similar to those of the first. Goodale notes that “ DF’s estimates [of her grip aperture] did not change as a function of the width of the plaques” (ibid.). However, when DF had to reach for the plaques and grab them, “ the aperture…was systematically related to the width of the object” (ibid.). This profound dissociation arising from DF’s brain damage led Goodale and Milner to suggest “ that at some level in the normal brains the visual processing underlying ‘ conscious’ perceptual judgments must operate separately from that underlying the ‘ automatic’ visuomotor guidance of skilled actions.” (ibid). Such a claim of the brain having information that lies at a subconscious level could not have been postulated at the time without the (un)fortunate brain damage that afflicted DF.

Building off of this notion of subconscious visual processing, the development of TMS has allowed researchers to test visual awareness (among other things) by momentarily disrupting parts of the brain via a magnetic pulse, effectively creating “ fake” brain damage that is reversible: the immediate benefit being a neuropsychological approach to a question without needing to wait for a patient with precisely the right brain damage to appear.

Ro discusses TMS experiments whose behavioral results are similar to those found by Goodale and Milner when testing DF. In the experiments, TMS suppressed primary visual cortex and “ despite unawareness of the orientation of a line in one experiment and unawareness of the colour of a dot in another experiment, subjects were nonetheless able to guess the orientation and colour of these stimuli presented within their TMS-induced scotomas at well-above chance levels” (111).

From this, he concludes that the results suggest “ a geniculoextrastriate pathway that bypasses V1 and projects directly from the lateral geniculate nucleus (LGN) into extrastriate cortex, likely area V4. [Such] a direct anatomical pathway from LGN to V4 has been demonstrated in lower primates” (112). However, Ro further postulates that “ information relayed through [the aforementioned] pathway is unconscious, at least without a functioning V1” (ibid.), a profound step toward the comprehension of human consciousness and what actually gives rise to the experience of awareness.

The final case discussed in this paper is that of Etcoff’s 1991 study of LH, a minister who suffered “ a severe closed head injury in an automobile accident at the age of 18. The accident and the surgical procedures it necessitated…[resulted in] bilateral lesions affecting visual association cortices…the right temporal lobe, the left subcortical occipitotemporal white matter, and bilateral perietooccipital regions” (Etcoff, 27). Etcoff remarked that predominant resulting behavior change was that “…LH can recognize most pictures of objects and most objects encountered in daily life, [but] he is unable to recognize the faces of his wife, children, friends, or members of his family of origin” (28).

Etcoff noted that in various tasks, LH found other strategies to guess the identity of the person. During a famous faces task, he recognize hairstyles, insignias, and uniforms to correctly guess whose face was presented to him, even though he couldn’t recognize the face itself (28-29). This indicates that LH still has a semantic connection between, for example Einstein’s hair and his identity, but the facial recognition portion of this association network was “ knocked out”.

More interestingly, LH was given the task of recognizing impossible faces from normal ones, i. e. duplicate facial features, strangely oriented features, etc., and consequently Etcoff commented that “ LH was able to distinguish a true from an impossible face with 97% accuracy…[he] can truly recognize faces as faces, and is sensitive not just to gross information such as number of features and relative placement, but to subtler relational information about feature orientation” (29). This shows a clear distinction between recognizing a face as an object and recognizing the semantic information that each individual face carries with it, thus the human brain must process faces specially, a process that is still studied extensively today. Etcoff even shared that “ LH likens the experience of looking at a face to attempting to read illegible handwriting: you know that it is handwriting, you know where the words and letters stop and start, but you have no clue as to what they signify” (29).

These six cases have demonstrated important discoveries about how the brain works through the lens of neuropsychology. From functional specialization and a man surviving a tamping iron blasting through his prefrontal cortex disrupting his personality, to distinct linguistic systems for producing and comprehending speech, to visual information existing in the brain without conscious knowledge of it, to the idea of primary visual cortex leading an essential role in consciousness, to faces being specially processed entities in the human brain, studying damaged brains has arguably led to understanding certain facets of the brain that otherwise might have been unimaginable. Furthermore, these six cases were only a handful of discoveries that have arisen from observing the behavioral results of brain damaged patients, used to illustrate the benefits of taking a neuropsychological approach to unraveling the mysteries of brain.

However, every methodology has some amount of drawbacks, and neuropsychology is not excluded. For example, given a lesion in some area of the brain, the resulting change in behavior must be a function of how the damaged area was affected. But what is this function exactly? Why should brain damage cause the output that it does instead of some very similar but sightly different behavioral change? If it is a question of reductionism, then it’s only a matter of time before the “ gap” between behavior and structure is solved, but at present, neuropsychology doesn’t answer this.

Secondly, brain damage tends to be accidental, and accidents can be messy (e. g. car crash). Lesions don’t tend to be as “ simple” as unplugging a single cable from the television, where only one aspect of the TV is clearly affected. Thus, finding “ clean”, precise lesions that alter only one part of the brain is far less likely then finding diffuse brain damage. Even if a patient tends to have only one predominant behavioral change, it cannot be said with full certainty that other parts of his brain weren’t affected or aren’t contributing, to some degree, to the new behavioral output, thus possibly confounding data despite very careful experimental designs.

Additionally, there is the question of neural plasticity, which Ro brings to attention in his study by mentioning that “…reorganisation of brain function…also complicate[s] examinations of sensory processing and visual awareness” (110), which is where the advent of TMS has been very helpful in that, apart from its aforementioned advantages, it “ drastically reduces or eliminates any opportunities for neural plasticity” (ibid.). The issue here is that plasticity in brain damaged patients might result in a level of “ rewiring” that is abnormal or unexpected, thus rendering the way in which parts of their brain function unique only to them.

All in all, however, every methodology has its pros and cons, and neuropsychology has provided science with a myriad of profound insights into the brain and its functions. The disadvantages it carries with it serve as a reminder as to how careful one must be when interpreting data about an entity as enigmatic and elusive as the brain.