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Class:	36209 Brain & Behaviour
Title of Coursework:	What does neuropsychology tell us about the way we understand and produce language?
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I affirm that this essay is my own work, and does not include any unacknowledged material taken from another source.

Signed: Date:

Neuropsychology, “the branch of psychology that is concerned with the physiological bases of psychological processes” (Hyperdictionary, 2003), has quite a lot to tell us about the way we produce and understand language. Language can be defined as “the speech of a country, region, or group of people, including its diction, syntax, and grammar" (Encarta, 2003). Although language also encompasses writing and purposeful sign language, and it could be argued that non-verbal communication such as hand gestures, body postures and facial movements are also a form of language, for the purposes of brevity this essay will concern itself purely with speech.

In order to understand the neurological aspects of language, language itself needs to be subjected to analysis. Languages are diverse, but linguists can categorise the components of all spoken languages into a universal structure (Kolb & Whishaw, 2003):

- Phonemes – the individual sounds that our mouths make. These are strung together to produce…
- Morphemes – the component sounds that make up words (a similar idea to syllables).
- Syntax – more popularly known as grammar, the rules of how to put words together into a meaningful sentence.
- Lexicon – the collective name for all the words in a language. People who write dictionaries are called lexicographers.
- Semantics – the meanings that apply to words in their various combinations (the word ‘left’ has different semantic meanings: a direction; or a remainder).
- Prosody – the changes in volume, pitch, intonation and timing that can add emotional impact to a sentence.
- Discourse – The combination of sentences so that they tell a story, or build an argument, that is more extensive than each individual sentence.

Not all languages use the same sorts of syntax or prosody, their lexicons are all different, and many use different sets of phonemes, but all languages can be analysed using these subdivisions.

Even back in the days of phrenology it was acknowledged that brain functions were to some extent localised (Cooter, 1984). If parts of the brain are specific to vision, emotion and audition, then it stands to reason that there are parts of the brain that deal with language.

As is usual in neuropsychology, we learn a lot about the relationship between brain systems and behaviour from people in whom these systems are not working properly, usually because of specific, localised damage. Language disorders with a neuro-psychological origin are normally known as aphasias (Gleitman, Fridlund & Reisberg, 2000).

Aphasias can be divided in two different ways: expressive and receptive aphasias; and fluent and non-fluent aphasias. Expressive aphasias are problems related to producing speech; receptive aphasias are problems related to understanding speech.

A fluent aphasia is one in which the speaker produces a stream of words and morphemes that resemble normally articulated speech, often with good prosody, but lacking syntax, semantic meaning or discursive structure. Fluent aphasias are often an inability to understand or interpret language, not just to produce it. There is usually a corresponding lack of comprehension of the speech of others. Research has linked these aphasias with damage to specific areas of the cortex (Kolb & Whishaw, 2003).

A nonfluent aphasia is one in which the articulation of words is a struggle, the structure of sentences can break down, and as a result normal prosody is impossible. Comprehension of others is usually unaffected, and the overall discourse and the semantics of their own spoken words quite often remain intact (Kolb & Whishaw, 2003).

Some fluent aphasias have been linked with lesions to the area of the brain known as Wernicke's area. Similarly, some nonfluent aphasias have been linked with lesions to an area called Broca's area. These disorders are known as Wernicke's and Broca's aphasias (Speakability, 2004).

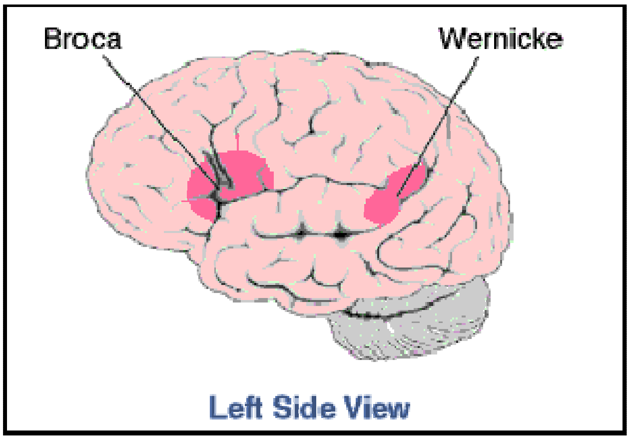

Fig. 1: Left elevation of the brain showing Broca's and Wernicke's areas (Speakability, 2004)

Broca's and Wernicke's areas, in fact many speech function areas, are located on the left-hand side of the brain in right-handed people with normal brain function. In some left-handed people, or in people with damage to the left side of the cortex, the language functions have migrated from the left side of the brain to the right, so a 'mirror image' of Broca's and Wernicke's areas would be observed, or else the duties are shared bilaterally: between the two sides of the brain (Gleitman, Fridlund & Reisberg, 2000).

Although the Broca's and Wernicke's area model, also known as the Wernicke-Lichtheim model (Martin, 2003), is very simple, it has for the most part stood the passage of time. It would seem, however, that aphasias are more diverse and have more extensive origins than originally thought.

Some Broca's aphasics have good skills in recognising an incorrect noun in a sentence, but not in recognising an incorrect syntactic structure (Caramazza & Zurif, 1976; Schwartz *et al*, 1980; quoted in Martin, 2003). This would indicate that some Broca's aphasias are a problem with understanding syntax rather than a problem with the recall of the correct word or the motor control to vocalise it. This may be supported by the large proportion of Broca's aphasics who do retain a considerable degree of comprehension. You can understand quite a lot of French, for instance, based on the lexicon picked up from school lessons or the television, but without much of the accompanying syntax you would require to speak French passably.

Similarly, Wernicke's aphasics may actually be suffering from a variety of deficits; in phoneme recognition, word construction or semantics, any one of which would prevent the production or understanding of language. Wernicke's aphasias tend to result from larger brain lesions, or indeed lesions outwith Wernicke's area (Murdoch *et al*, 1986; Dronkers *et al*, 2000; quoted in Martin, 2003). In order to better understand the localisation of these language functions, neuropsychology has a new range of tools to help track down specific brain activities.

There are three relatively new types of neuroimaging system which can be used to monitor brain activity. Event-Related brain-Potential scanning (ERP) is a way to study the electrical activity in the brain in real time, but with a low degree of spatial accuracy. ERP is measured by placing electroencephalogram sensors on the subject's scalp, and measuring the responses to test stimuli. Positron Emission Tomography and Functional Magnetic Resonance Imaging are both achieved with medical scanners, similar to CAT scanners, and are spatially accurate enough to build images with, but due to long exposure times cannot give a real time picture of brain activity for periods of less than a couple of seconds (Kutas & Schmitt, 2003).

Event-related potential information can show the brain activity in response to individual words and sentences. A study by Kutas and Hillyard (1984) has shown that ERP responses to an audibly presented test sentence change when the last word of the sentence is changed from a predictable outcome word to a related, but slightly incongruous, word, and again for a completely incongruous word. The example they used was 'He was stung by a bee / hive / mile'. It has also been used to try and deduce which parts of the brain deal with phonological information, using rhyming but semantically unrelated words; and discursive information, using pairs of syntactically correct sentences which build to an unexpected or illogical conclusion (Kutas & Schmitt, 2003).

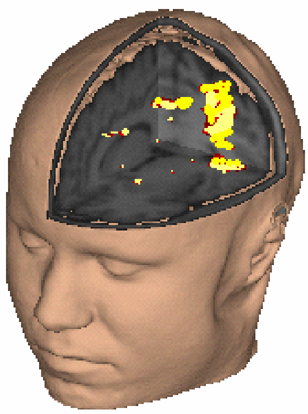

fig. 2: An image of the brain generated by fMRI with a cross-section showing the stimulated areas (M.I.T., 2001)

PET and fMRI scanning can show where blood flow is being directed within the brain, as shown in figure 2, and consequently where cognitive 'brainwork' is being done. By comparing the results of two scans taken during the performance of similar tasks, for instance reading two similar sentences with a familiar word and an unfamiliar word, researchers can observe that some parts of the cortex work on the unfamiliar word but not on the familiar one. This comparative process is known as subtraction (Gernsbacher & Kaschak, 2003).

Studies indicate that the processing of speech starts bi-laterally in the superior temporal gyrus. This part of the brain is also active in the processing of non-linguistic sound, but the left side is more active when processing the sound of a native language, with both sides being active processing non-native language and other sounds (Alavi *et al,* 1983; Petersen *et al* 1988, 1989; Frith *et al* 1991; Mazoyer *et al* 1993; quoted in Gernsbacher & Kaschak, 2003). One conclusion that could possibly be drawn from this is that the superior temporal gyrus is where the distinction between a known language and other sounds occurs.

Martin (2003) concludes from the results of several other studies that "patients with damage either to lexical phonological representations, or to the connections between these representations and semantics, all have left hemisphere damage", and that although some linguistic work occurs bilaterally, the mapping of phonetic information into semantic and discursive meaning relies on the integrity of the left temporal and parietal areas much more so than any right-brain structures.

Specific semantic information also appears to be localised. Damasio *et al* (1996) and others have reported, using PET and subtraction techniques, that specific areas of the inferior temporal lobe are activated by different categories of nouns, like tools, animals and persons. Pulvermüller (2001) disagrees to some extent with this interpretation, but does agree that semantic information about a word is recalled by the activation of a network of neurons that connects various memory functions associated with that word, even if the meaning of that word changes with time (Kolb & Whishaw, 2003).

Shaywitz *et al* (1995) reported some evidence that women and men process at least some aspects of speech in slightly different ways, with women processing phonological rhyming words more bi-laterally than men, although this has been disputed by Frost *et al* (1999) (all quoted in Gernsbacher & Kaschak, 2003). Although these studies have also shown that most language function resides in or dominates the left hemisphere, certain functions seem to be dominant on the right, for instance Buchanan *et al* (2000) reported that prosody seems to be processed in the anterior right temporal lobe. This would correlate with the lesion-based research in to aprosodia – the inability to produce or interpret the emotional or prosody content of speech.

Motor aprosodia, the inability to add prosody to speech, is associated with lesions to the right parietal lobe in an area that is the mirror-image of Broca's area in the left hemisphere. Sensory aprosodia, the inability to interpret the prosody of someone else's speech, is associated with lesions to the right temporal lobe in a mirror-image of Wernicke's area (Kolb & Whishaw, 2003). This may add weight to the folk-psychology view that the left-hand side of the brain is logical and calculating, while the right-hand side is artistic and emotional.

Studies have also shown that the inferior frontal regions (Broadmann's areas 45, 46 and 47) are activated by almost all language functions. These areas of the brain have been associated with short-term memory (Gernsbacher & Kaschak, 2003), which may tend to support theories which state that short-term memory is a verbal organisation and repetition process (Gleitman, Fridlund & Reisberg, 2000).

Language is a very complex series of processes involving a large proportion of the brain. There are strong indications that the structure of language is linked to the functions of specific areas of the brain, with these links being revealed through studies of patients with brain lesions, and also through modern scanning and monitoring techniques. The study of aphasiacs has taught us much about the way the systems of language are connected, but as usual in psychology there are differing arguments about the precise mechanisms involved. Hopefully the new scanning techniques, along with innovative experimental techniques, will be able in the not too distant future to reveal a lot more about the biological basis of our language capacity.

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