To what extent is brain function lateralized

This essay will describe cerebral asymmetry in detail and to what extent the brain function is lateralized. The topics that will be covered in this essay are, Lateralization of function, The split-brain approach, Differences between the left and right hemispheres, Three theories of cerebral asymmetry, Cortical localization of language, Evaluation of the Wernicke-Geschwind model, and Functional brain imaging and the localization of language. This essay will give a clear description of all the major aspects above and describe the main ways in which they relate to cerebral asymmetry.

It is important to start of by defining what we mean by lateralization, this refers to the activity of using one hemisphere more than another. The term " relative lateralization" is more accurate because we are usually using at least some of the left and right hemisphere at the same time. 1 It is also vital to understand what is meant by asymmetry, symmetry refers to identical or nearly identical forms on opposite sides of a dividing line or central axis, asymmetry is the opposite referring to the unevenness of two half's. 2

With exception to the mouth or vent, which are an opening to a cavity or passage of the body, we have two of nearly everything- one on the left and the other on the right. The brain also reflects this principle of joint duplication, even though it is viewed by most as the unitary and inseparable foundation of self. The brain comprises two structures, the left and right cerebral hemispheres, which are completely separate except for the cerebral commissures connecting them.

Although the left and right hemispheres are visually similar (see bellow), there are major differences in there function. This essay will focus on these differences by discussing the major aspects of cerebral asymmetry named above. In this essay the difference in the left and right hemispheres should become apparent and the capacity to which they function independently- different thoughts, memories, and emotions. 3

Cerebral asymmetry refers to anatomical, physiological or behavioural differences between the two cerebral hemispheres. The hemisphere that is larger, more active, or greater in performance is dominant. The scientific study of cerebral dominance is recent and dates back to Paul Broca’s discovery in 1865, based on observing acquired language deficit (aphasia) following left hemisphere stroke, that the left cerebral hemisphere of right-handed people is dominant for language. Until the mid 1940’s, the neurological agreement was that the left hemisphere of right-handers is dominant for all higher functions and the right hemisphere is dominant in left-handers. European neurologists and neuropsychologists, such as Hecaen, Piercy, McFie and Zangwill, then noted that the left hemisphere is dominant for language and planned movements, whereas the right hemisphere is dominant for visuo-spatial functions. This led to replacing the view of limited LH specialization by the theory of complementary hemispheric specialization (Denes ; Pizzamiglio 1999, Heilman ; Valenstein 1993). 4

In order to understand cerebral asymmetry in further detail it is important to look at the research methods in lateralization of function.

Popular psychology is a topic in lateralization of function, it tends to make broad and sometimes unscientific generalizations about certain functions (e.

g. logic, creativity) being lateral, that is, located in either the right or the left side of the brain. Researchers often criticise popular psychology for this, because the popular lateralizations are often distributed across both hemispheres, however, mental processing is divided between them. 5

Fundamental to brain process lateralization is that the lateral sulcus generally is longer in the left hemisphere than in the right hemisphere, reflecting asymmetry. The extent of specialised brain function by area remains under investigation. If a specific region of the brain is either injured or destroyed, its functions can sometimes be recovered by a neighboring region, even opposite hemisphere, depending on the area damaged and the patient’s age. While functions are lateralized, the lateralization’s and functional trends are not applicable in every case. Having undergone a hemispherectomy (removal of a cerebral hemisphere) there are no “ left-brain only” or “ right-brain only” people. 5

Brain function lateralization is evident in the phenomena of right or left-handedness, of right or left ear preference, but a person’s preferred hand is not a clear indication of the location of brain function. Although 95% of right-handed people have left-hemisphere language function, only 18. 8% of left-handed people have right-hemisphere language function. Additionally, 19. 8% of the left-handed have bilateral language functions. 5

Research conducted by Pierre Paul Broca, in 1861 showed one of the first signs of brain function lateralization. His research involved the male patient nicknamed “ Tan”, who suffered a speech deficit (aphasia). “ Tan” was one of the few words he could articulate, hence his nickname. In Tan’s autopsy, Broca determined he had a syphilitic lesion in the left cerebral hemisphere. This left frontal lobe brain area (Broca's Area) is an important speech production area. The motor aspects of speech production deficits caused by damage to Broca's Area are known as Broca's aphasia. It has been noted in the assessment of aphasia that the patient cannot clearly articulate the language being employed. 5

In 1900s Hugo-Karl Liepmann discovered another example of cerebral lateralization of function, apraxia. Similarly to aphasia, apraxia is almost always associated with left-hemisphere damage, apart from the fact that its symptoms are bilateral (involving both sides of the body). Patients with apraxia have difficulty performing movements when asked to perform them; however they have no difficulty performing the same movements when they are not thinking about them. 6

Having discovered that the left hemisphere plays a special role in both language and voluntary movement, a concept known as cerebral dominance was conducted. According to this, one hemisphere, usually left, takes the dominant role in controlling all complex behavioral and cognitive processes, the other playing a minor role. This then led to referring to the left hemisphere as the dominant hemisphere and the right as the minor hemisphere. 6

We will now look at the split-brain approach. Split-brain is a lay term to describe the result when the corpus callosum connecting the two hemispheres of the brain is severed to some degree. The surgical operation to produce this condition is called corpus callosotomy. Research done in the

1930s and 40s suggested that it did nothing at all. The corpus callosum had been cut in monkeys and several other laboratory species, but the animals seemed no different after the surgery then they had been before. Similarly human patients born without a corpus callosum seemed perfectly normal. 7

However, its function was later discovered by Roger Wolcott Sperry who carried out some of the earliest split-brain research, and was later joined by Michael Gazzaniga. Two astounding theoretical points were discovered, first, it showed that one function of the corpus callosum is to transfer learned information from one hemisphere to the other. Second, it showed that when the corpus callosum is cut, each hemisphere can function independently. 7 Research by Gazzaniga and Sperry in the 1960s on split-brain patients led to a greater understanding of functional laterality. Split-brain patients are patients who have undergone corpus callosotomy (usually as a treatment for severe epilepsy), a severing of a large part of the corpus callosum. The two hemispheres of the brain are connected by the corpus callosum allowing them to communicate. When these connections are cut, the two halves of the brain have a reduced capacity to communicate with each other. This led to many interesting behavioral phenomena that allowed Gazzaniga and Sperry to study the contributions of each hemisphere to various cognitive and perceptual processes. One of their main findings was that the right hemisphere was capable of rudimentary language processing, but often has no lexical or grammatical abilities. 8

When a person with a split-brain is shown an image in his or her left visual field (that is, the left half of what both eyes see), they will be unable to name what he or she has seen. This is because the speech-control center is in the left side of the brain in most people, and the image from the left visual field is sent only to the right side of the brain. Since the two sides of the brain cannot communicate, the patient cannot name what the right side of the brain is seeing. The person can, however, pick up and show recognition of an object (one within the left overall visual field) with their left hand, since that hand is controlled by the right side of the brain. 9

We must now discuss some of the differences between the left and right hemispheres. It is important to understand that for many functions, there are no differences between the hemispheres, and when functional differences occur, these tend to be slight biases in favour of one hemisphere or the other- not absolute differences (Brown & Kosslyn 1993). It is widely believed that different abilities exist entirely in one hemisphere or the other. For instance it is believed the left hemisphere has complete control over language and the right hemisphere complete control over emotion and creativity, however this is not the case. 10

Generally the left and right hemispheres of our brain process information in different ways. We tend to process information using our dominant side. No one is totally left-brained or totally right-brained. Just as we have a dominant hand, eye, and even foot, we probably have a dominant side of the brain. It is vital to develop both sides of our brain. 11

The differences between the two hemisphere's are, the left hemisphere is important for all forms of communication. We know this because when it is damaged; perhaps as a result of an accident or a stroke, there can be serious problems in speaking (aphasia). After left-hemisphere damage there can also be difficulties with other complicated movements of the mouth, or of the hands and arms — demonstrating a pout, or miming how to salute or to hammer a nail, for example. It seems that the left hemisphere specializes in controlling certain movements, including the movements we use to communicate. In people who are born deaf and who communicate using hand movements (manual sign language), damage to the left hemisphere can badly affect there signing ability. 12

The right hemisphere, by comparison, doesn't appear to be involved much in communication, although it can help us understand words to some extent. Instead, it specializes in receiving and analysing information from the outside world. Therefore, damage to the right hemisphere may result in our being unable to tell the difference between melodies, or having difficulty in identifying a face or in locating an object accurately in space. Some parts of the right hemisphere are mainly concerned with helping us understand what we hear (auditory), while other parts help us make sense of things that we see. The temporal lobe (in the lower part of the hemisphere, see below) analyses much of the auditory input, while the occipital and parietal lobes (in the rear and upper regions, see below) provide information about where objects are. The frontal lobes in each hemisphere seem to be important in planning our actions. 12

We will now discuss the three prominent theories of cerebral asymmetry, these are, Analytic-Synthetic Theory, Motor Theory, and Linguistic Theory.

The analytic-synthetic theory suggests that there are two fundamentally different modes of thinking, an analytic mode (Left Hemisphere) and synthetic mode (Right Hemisphere), and that the neural circuitry for each is fundamentally different. This theory suggests the left hemisphere (pieces of the whole) operates in a logical, sequential, analytic fashion. The right hemisphere (the whole) makes immediate, overall synthetic judgments; it organizes and processes information in terms of wholes. 13

The motor theory (Kimura, 1979) suggests that the left hemisphere is specialized for fine motor movement of which speech is but one example. Evidence for this theory comes from reports that lesions of the left hemisphere disrupt facial movements more than do right hemisphere lesions, even when they are not related to speech. The degree of disruption of nonverbal facial movements is positively correlated with the degree of aphasia. 13

The linguistic theory is based on the view that the primary function of the left hemisphere is language, this is based on studies of deaf people who communicate using American Sign Language, this capability is lost if these people experience damage to the left hemisphere, even when they are able to make the movements necessary, although this may just show that ASL is a language, and that language is highly analytical. 13

So far in this essay we have focused on the functional asymmetry of the brain, emphasizing on the lateralization of language-related functions. We will now shift the emphasis to language localization, which refers to the location within the hemispheres of the circuits that participate in language-related activities. We will now focus on the Wernicke-Geschwind model, which is the predominant theory of language localization.

Broca claimed that a small area in the inferior left prefrontal lobe (Broca's area) in the left hemisphere is the center for speech production. Damage to this area leads to deficits primarily speech production (problems with expression) and also grammatical understanding. In 1874 Carl Wernicke conducted the next major study of the cerebral localization of language, concluding on the source of 10 clinical cases that there is a language area in the left temporal lobe, following the main auditory cortex. Wernicke argued this second language area was the cortical area of language comprehension, as a consequence it became known as Wernicke's area. It was suggested by Wernicke that specific lesions of Broca's area create a condition of aphasia whose symptoms are primarily expressive, characterized by normal comprehension of both written and spoken language and by speech that retains its meaningfulness despite slow, labored, disjoint, and poorly articulated. This became known as Broca's aphasia. In contrast, damage Wernicke's area leads to deficits to semantic language understanding (problems with response) and speech is perplexing, despite having correct grammar, rhythm and accent (word salad). This became known as Wenicke's aphasia. 14

Damage to the pathway connecting Broca's and Wernicke's areas is called the arcuate fasciculus; this produced a third type of aphasia, conduction aphasia. Wernicke concluded understanding and spontaneous speech is intact but patients with damage to the arcuate fasciculus would not be able to repeat words they have just heard. 14

Damage to the left angular gyrus, which is the area of left temporal and parietal cortex just posterior to Wernicke's area, another cortical area that has been implicated in language, will create the inability to read despite intact language comprehension and production, known as alexia, and the inability to write, known as agraphia. Dejerine 1892, done an examination with a patient that suffered from both alexia and agraphia, and although he was incapable of reading and writing he had no difficulty speaking or understanding speech. Dejerine’s postmortem examination exposed damage in the pathways connecting the visual cortex with the left angular gyrus. In conclusion he found the left angular gyrus is liable for comprehending language-related visual input, which is received directly from the adjacent left visual cortex and indirectly from the right visual cortex via the corpus callosum. 15

Following on from the work of Broca, Wenicke, and Dejerine, Norman Geschwind revived the localization of language ideas and added some new interpretation creating a powerful theory known as the Wernicke-Geschwind model. There are seven components of this model, all in the left hemisphere: primary visual cortex, angular gyrus, primary auditory cortex, Wernicke’s area, arucate fasciculus, Broca’s area, and primary motor cortex. The way the Wernicke-Geschwind model is thought to work is, when having a conversation with someone, the speech of the other person is received by the primary auditory cortex and carried to Wernicke’s area where it’s acknowledged.

To respond, the thought generated in Wernicke’s area goes via arcuate fasciculus to Broca’s area, then to the primary motor cortex and articulatory areas (face, lip, and tongue muscles, voice box, and muscles associated with lungs). When reading aloud your primary visual cortex is transmitted to your left angular gyrus, translating the visual form of the word into its auditory code and transmitting it to Wernicke’s area for comprehension. Wernicke’s area then activates the suitable responses in your arcuate fasciculus, Broca’s area, and motor cortex, extracting the appropriate speech sound. 16

In evaluating the Wernicke-Geschwind model it is important to assess its ability to predict the language-related deficit produced by damage to various parts of the cortex. A study conducted on the surgical removal of cortical tissue showed that by removing all of Broca’s area typically has no lasting effects on speech. Some speech problems were observed after the removal of Broca’s area, however these were said to be the course of swelling. Patients that undergone the removal of Broca’s area suffered from damage that had little lasting effect on language.

Wernicke-Geschwind’s model has been supported by experimental evidence in two general respects. First, evidence has established that Broca’s and Wernicke’s area play’s important roles in language. Second, there is a tendency for aphasis linked with anterior damage to involve deficits that are more expressive and those linked with posterior damage to involve deficits that are more receptive.

However, evidence has not been supportive of specific predictions of the Wernicke-Geschwind model. First, damage restricted to the boundaries of the cortical areas often has little lasting effect on the use of language. Second, damage to other brain areas can produce aphasia. Third, Broca’s and Wernicke’s aphasia are rarely pure, aphasia is both receptive and expressive. Fourth, there seems to be major individual differences for cortical localization of language. 17

Despite these issues, the Wernicke-Geschwind model has been an extremely important theory, still guiding the study of clinical diagnosis of aphasia. Nevertheless, due to the lack of experiential support for its predictions, researchers have largely abandoned the Wernicke-Geschwind model

We will now look at functional brain imaging and the localization of language, which is a cognitive neuroscience approach, alternate to the Wernicke-Geschwind model perspective. Functional brain-imaging techniques have developed the study of the localization of language. Numerous PET and fMRI studies of subjects engaging in various language-related activities have been developed.

In the 19th Century, there were bits of evidence that other brain areas play some role in language, though these have remained uncertified, as scientists could not use animal models to investigate language networks in the same way they could visual or movement networks in the brain. Advanced brain imaging techniques such as PET, and MRI have allowed scientists to begin studying these areas in living humans. Standard MRI shows the major tissue structures of the brain. An alternative called " functional" MRI allows researchers to identify which areas are being used during different tasks, including producing and understanding language. 18

The fMRI study of silent reading by Bavelier and colleagues (1997) measured the brain activity of healthy subjects while they read silently. The general purpose of the research was to get a sense of the extent of cortical involvement in reading. The subjects in Bavelier and colleagues study viewed sentences displayed on a screen. Between periods of silent reading was control periods, during these subjects were presented with strings of consonants. The differences in activity during the reading and control periods served as the basis for calculating the areas of cortical activity associated with reading. Three important points emerged from this analysis, first, the areas of activity were patchy; that is, they were tiny areas of activity separated by areas of inactivity. Second, the patches of activity were variable; that is, the areas of activity differed from subject to subject and even from trial to trial in the same subject. Third, although some activity was observed in the classic Wernicke-Geschwind areas, it was extensive over the lateral surfaces of the brain. The results show two clear points: First, even though there was important activity in the right hemisphere, there was far more activity in the left hemisphere; second, the activity extended far beyond those areas predicted by the Wernicke-Geschwind model to be involved in silent reading (e. g. activity in Broca's area and motor cortex would not have been predicted). 19

The objective of Damasio's PET study (1996) in contrast to the purpose of the study by Bavelier and colleagues, which was to assess the extent of activity associated with silent reading, was to look selectively at the temporal-lobe activity involved in naming objects within particular categories.

Damasio and colleagues recorded the PET movement in the left temporal lobes of healthy subjects while they named images presented on a screen. The images were of three different types: famous faces, animals, and tools.

Naming objects set off the left temporal lobe outside the classic Wernicke's language area. Extraordinarily, the exact area that was activated by the naming depended on the category: Famous faces, animals, and tools each activated a slightly different area. Study of aphasic patients with damage in the specific area has supported the existence of category-specific lexical areas in the left temporal lobes. 20

In conclusion to this essay on cerebral asymmetry I have learnt that the body consists of two of nearly everything, including the brain. There are two structures of the brain, the left and right cerebral hemispheres. As we have discussed throughout the essay, this does not mean we have two brains, it means that each side of our brain has the capacity to function independently, but the brain is whole. The two hemispheres have different functions, e. g. the intake of thoughts, memories and emotions. Each hemisphere functions the opposite side of the body, the corpus callosum connects both hemispheres. The reason it is referred to as cerebral asymmetry is because scientific research has recently shown that not only do both sides of the brain have different functions, but there are also minor visual differences in the two sides to reflect this.

It has also become apparent that the cortical localisation of language theory suggests that language is generated and understood in the cortex, the outermost covering of the brain. Paul Broca and Carl Wernicke, 19th Century neurologists, noted that damage to specific cortical areas, which came to bear their names (Broca's area and Wernicke's area), produced primarily language production or language processing disorders, but not both. A large bundle of nerve fibers were found to connect Broca's and Wernicke's areas, and damage to this pathway also produced language disorders, or aphasias.

Having discussed the cognitive neuroscience approach to language which is opposite to the Wernicke-Geschwind model perspective, we can see that there has been much enthusiasm for the use of new functional brain-imaging technology to study language and the tendency for knowledge gained from the study of brain lesions to be ignored. However, for science to work at its best it is important to add new data to past data. E. g. significant right-hemisphere activity is almost always recorded by functional brain imaging during language-related activities, suggesting that the right hemisphere plays a significant role in language. Yet lesions of the right hemisphere rarely disrupt the same activities, suggesting that its role is not critical.