Localizationists vs. Connectionists :
Approaches to Language Processing and Production

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Introduction

Dating from about the mid-19th century, the history of aphasia research has experienced a tenuous and multifaceted relationship between anatomic localizationist and anti-localizationist approaches to language organization in the brain. In lay terms, some scientists thought that the language region in the brain works more or less as a unit. However, other researchers were of the opinion that individual language operators are localized in specific parts of such a region (Caplan, 1995).

Patients with speech problems gave early researchers the first clues about how the brain deals with language. As such, aphasia research was destined to offer an incredible insight to the organization of the brain in relation to various language processes. Lee (1997) indicates that the occurrence of specific language disorders caused by lesions to certain parts of the brain illustrates localization of functions in the brain. The two most famous types of aphasia are caused by injury to two specific areas of the brain, with varying results. These areas and their aphasias are called Broca's and Wernicke's. While Broca's aphasia limits speech, Wernicke's limits comprehension. The two areas are connected by a subcortical bundle of nerves called the arcuate fasciculus. Damage to this connector causes conduction aphasia, which impairs speech spontaneity and the ability to repeat what one hears. Caramazza (1991) maintains that research on aphasia will undoubtedly serve to provide an important source on a functional neuroanatomy for language processing.

Proponents and opponents of the localizationist or phrenological approach, regardless of their extreme or moderate views, do agree that the center for speech is in the left hemisphere of the cerebral cortex. Known as Broca's area and Wernicke's area, the two are thought to store information related to speech. Though the function of Broca’s area is not exclusively limited, this part of the frontal lobe, in the dominant hemisphere of an individual, is primarily related to speech production. It is usually associated with maintaining a list of words and parts of words used in producing speech and their associated meanings. The area is also linked to articulation of speech, and to semantic processing or assigning meanings to words we use. Semantic processing has been linked to the upper portion of the area, while articulation falls within the central part. Broca’s area is also believed to control not only spoken, but also written and signed language production. M1, the mouth area, is located nearby. It is the area of the brain responsible for controlling the physical movements of the mouth as well as other articulators used in producing speech (Crank et. al, 2000).

Though mainly concerned with semantic processing, Wernicke's area is also associated with some memory functions, especially short-term memory involved in speech recognition and production, as well as some hearing function and object identification. In addition, this area is sometimes associated with language comprehension, or processing of incoming language, whether it be written or spoken. Working in unison, Wernicke's area and Broca's area compliment each other; Wernicke's handling incoming speech while Broca's handling outgoing speech. Equally essential to facilitating language processing is the auditory cortex which is responsible for recognizing and receiving sound. From the primary auditory cortex, information is transmitted to the posterior speech area, including Wernicke's area. When speaking or reading, information travels From Wernicke's area to Broca's area, then to the Primary Motor Cortex to produce utterances (Crank et. al, 2000).

The Localizationist Approach to Language Processing and Production

According to Lecours et. al (1984, p. 223) and Landreth & Richardson (2004), Gall was one of the first scientists to suggest the existence of anatomo-functional relationship between precise cortical areas and various modes of human behavior. A student of Gall, Bouillaud claimed that anatomo-clinical research corroborated Gall's view about the cerebral seat of verbal memory. On the other hand, Broca, who was exclusively interested in "the seat of the Faculty of articulated language," believed that such a seat was a few centimeters away from Gall's area; i.e. in the third left-side frontal convolution. In time, this part came to be known as Broca's area. These and like-minded scientists were the pioneers of the localizationist approach. According to Bates (1999, p. 9), localization in its narrowest sense, commonly known as the phrenological approach, can be characterized as the belief that the brain is organized into "spatially and functionally distinct faculties or regions, each dedicated to specific functions by a "pre-packaged" genetic program."

During the last few decades, the phrenological approach to brain organization has found new blood and an increasing number of enthusiastic adherents. This fact has taken an added momentum in various proposals that language is an "instinct" (Pinker, 1994), or an "innate module" (Fodor, 1983), with its own neural architecture and specific genetic base. Indeed, Fodor's 1983 book celebrates the contributions of Gall, the father of the phrenologist movement. A classical drawing of Gall's subdivided and numbered brain adorns the cover of that book (as cited in Bates, 1999, p. 9).

To be sure, the phrenological approach has had its share of criticism. Bates & Dick (2000, p. 1) observe that although the left perisylvian region does show up in language activation studies designed to uncover discrete and dedicated "language areas," the literature is full of positive results for "right-hemisphere homologues of these zones, as well as prefrontal regions, parietal regions, temporal areas of various kinds, and cerebellar and subcortical findings." Other discouraging findings come from Molfese et. al (1983) who conducted a study using electrophysiological responses. The outcome suggests that a number of discrete mechanisms located over different regions of both brain hemispheres are involved in the processing of different vowel sounds. Such data, therefore, does not support a single localized region as responsible for vowel detection.

Another piece of criticism comes from an article by Dick & Bates (2000). The authors refute Grodzinsky's 1984 view that the neural tissues around Broca's area are specialized for and dedicated to syntactic operations. According to them, the very opposite is true. Not only do functional imaging studies show language-related activation is widely distributed, but many studies show that various brain regions in and around Broca's area are activated during non-linguistic tasks, such as object manipulation. In all, there is a growing body of evidence challenging the old assumption that the left hemisphere is "the" language hemisphere, even in adults. Citing (Elman, 1996), Myers (2004) asserts the right hemisphere does make an important contribution to language processing, but its contribution is qualitatively different from that of the left hemisphere, involving a number of functions including emotionality, intonation contours and figurative or metaphorical speech. According to Elman:

> "…the number of so-called language-specific areas are multiplying on almost a daily basis. Every new functional imaging study seems to bring another language area to our attention….This all leads to the conclusion that domains like language do not live within well-defined borders, at birth or at any other point in development." (Myers, 2004, p. 17)

With the development of new tools for brain imaging and functional localization of brain activity, researchers hope for a better understanding of brain functions in general, and linguistic processing in particular. Caramazza (1991) explains that electroencephalography (EEG) is a procedure in which electrical sensors are placed on the skull in specific patterns to measure the electrical activity of neurons. It has been found that such electrical stimulation of the cortex leads to temporary linguistic impairment when the perisylvian region of the left hemisphere is involved. Obler, L., & Gjerlow, K. (1999) report that scans done through Computerized Axial Tomography (CAT or CT) are useful for showing the location of brain lesions, whereas Positron Emission Tomography (PET) traces blood flow showing which parts of the brain are most active. Functional MRI (fMRI) scans areas where blood has lost oxygen, indicating a feeding activity of hungry brain cells. In brief, application of these and similar imaging techniques promises a true revolution in brain-related language research never seen before.

Taking this issue a step further, Geschwind (1984) states that if there is truly to be a neurolinguistics and a neuropsychology, then these fields must live with knowledge of the brain, just as research in the brain must continue to be influenced by the great discoveries in these disciplines. He sadly states, “The idea that somehow they are in opposition to each other is an unfortunate one.” This was then, exactly twenty years ago. Today, however, one can observe new interdisciplinary approaches which are making great strides towards the discovery of various relationships that exist between language and brain activity. Indeed, Geschwind can relax at last! His call for integrating raw anatomic brain knowledge with new neurolinguistics discoveries is finally at hand. One such interdisciplinary approach is currently live and kicking and is known as the connectionist approach to language.

The Connectionist Approach to Language Processing and Production

According to Elman (1998), connectionism focuses on learning from experiences gained in relation to one’s environment and, then, storing what is learned in a form of weighted connections between neurons. The prevailing form of connectionist models today is known as Parallel Distributed Processing (PDP). PDP took off about the middle of the 1980s with the release of an exhaustive two-volume collection edited, in 1986, by Rumelhart and McClelland, and the PDP Research Group, called *Parallel Distributed Processing: Explorations in the Microstructure of Cognition*, which served as a landmark in explaining, consolidating, and elaborating upon the various issues and intricacies of the fledgling new approach.

Proponents of connectionism adopt the view that the basic building block of the brain is the neuron. The neuron has six basic functional properties. Jagota quotes Dudai’s explaination of each one: “It is an input device receiving signals from the environment or other neurons. It is an integrative device integrating and manipulating the input. It is a conductive device conducting the integrated information over distances. It is an output device sending information to other neurons or cells. It is a computational device mapping one type of information into another. And, it is a representational device sub-serving the formation of internal representations” (Jagota, 1998, p. 1).

Anderson (1984) observes that according to connectionists, language processing is carried out by a large number of usually very simple processing elements. Called nodes or units, these elements have a dynamics that is roughly analogous to neurons. Capable of responding to stimuli, brain neurons are densely interconnected into a complex network. Large numbers of such neurons operate simultaneously and co-operatively to tackle various information processing problems. Christiansen (1999) further explains that neuron-related activity patterns are called ‘*vectors*’.

Information-processing vectors are known as ‘state vectors’. It is believed that understanding the behavior of “state vectors’ is essential to developing a theory which is both physiologically reasonable and cognitively interesting. Some predict that when a satisfactory brain theory comes along, it will be in a calculus form of such ‘state vectors’.

As for neural networks, Christiansen (1999) suggests that each node receives input, excitatory or inhibitory, from other nodes. The node responds to that input according to an activation mechanism and, in turn, excites or inhibits other nodes to which it is connected. Though details vary from one model to another, the majority of them, however, tend to adhere to this general scheme. Writing on the subject, Caramazza (1991) provides a clear and simple example of how neural network models can help researchers to better understand and appreciate the mechanism involved in language processing.

According to Caramazza, the functional architecture of the “lexical system” consists of a distributed but interconnected set of “lexical” components. Activation models are based on the assumption that a stimulus activates in parallel all stored representations. The degree of activation is proportional to the overall similarity between the input and the stored representation. As such, the stimulus word “car” activates the representations 'cat', 'tar', 'cart', 'cord', etc. Here, 'car', is activated most strongly while 'cat' is activated more than 'cord', and so forth. In brief, when the level of activation of a representation reaches a threshold value, the representation becomes available for further processing to other components of the system. The assumption is that only the representation that reaches a threshold value can serve to activate subsequent processing stages (Caramazza, 1991, p. 32).

Elaborating on the voluminous work of Rumelhart and McClelland, Elman (1998) suggests that the authors have pioneered a connectionist – parallel distributed processing – model of the acquisition of the past tense in English. The model successfully maps many stems onto their past tense forms, both regular, for example, (walk/walked) and irregular (go/went), and mimics some of the errors committed by children. It also demonstrates a U-shaped pattern of behavior in which positive initial performance is followed by a negative one, and then positive again. To be sure, this network model seems to follow the pattern on which the English past tense is formed through an inductive process, using analogy based on many examples. According to Pinker & Prince, “Networks that are trained on similar tasks exhibit the same patterns of behavior, yet the model contains no explicit rules, only a set of neuron-style units which stand for trigrams of phonetic features of the stem, a set of units which stand for trigrams of phonetic features of the past form, and an array of connections between the two sets of units whose strengths are modified during learning” Pinker & Prince (1988, p. 1).

Another landmark view of Rumelhart and McClelland was their conclusion that the notion of “rule” could “describe” the behavior of children as well as networks, but has no important role in generating that behavior. This opinion generated a storm of controversy and gave rise to hundreds of experiments with children and simulations with neural networks. The two authors claimed: “'We have, we believe, provided a distinct alternative to the view that children learn the rules of English past-tense formation in any explicit sense. We have shown that a reasonable account of the acquisition of past tense can be provided without recourse to the notion of a ‘rule’ as anything more than a description of the language.'” (as cited in Elman, 1998, p. 6). Some researchers maintain that this alternative view does not prove anything about what real children do. Nevertheless, it does give a very different account of what, until then, was thought to be the paradigm example of rule-learning by children. Thus, it is no wonder that such a model generated so much controversy.

Connectionists also try to explain how children learn words by experimenting on neural networks. Elman (1998, p. 9) explains that, **“**Clearly, knowledge of vocabulary cannot be innate: A child born in Singapore must be able to learn a different word for “milk” than a child born in Tibet. But how do infants even know that there are such things as words in the first place?” In fluent speech, for example, words are not separated by pauses or silence, and all the infant hears is a continuous stream of unsegmented noise. Thus, one is faced with the fundamental and complex question of how even a simple word is learned, let alone the whole vocabulary of a language.

One connectionist model which investigated this question began by considering what a person would do if confronted with the first two letters of a word, for example, “Ma_”, and asked to predict what came next. Such a person may correctly guess that there is a limited range of possibilities. Given the basic tenets of English vocabulary, the next letter is almost certainly a consonant, and “n”, “t”, “s” are far more likely than “v”. Surprisingly, this turns out to be exactly what the network learns. The network’s ability to predict letters depends on where in the word the letter is. Word-initial letters are difficult to predict because virtually any letter might occur, whereas after a few letters, the constraints limit the possible letters and the network’s predictions improve.

This simulation suggests a strategy that infants might use to learn words; i.e., the basic building units of their native languages. During the last ten years many new experiments have been carried out with mounting empirical evidence which suggests that infants do indeed apply this and similar strategies when learning a new language, be it their native tongue or otherwise. Equally interesting and thought- provoking, a number of researchers have come to the conclusion that, through statistical induction, many young infants are able to learn language regularities in artificially generated sequences that are both varied and complex (Elman, 1998).

“Recursion” is another PDP model of language processing and production. According to Elman, this model provides unequivocal evidence for innate knowledge of linguistic structure. For example, the fact that a neural network is able to learn complex grammar shows that these kinds of structures can be learned by example. Equally significant is the fact that networks do demonstrate “the importance of starting small.” This, in turn, suggests that what is special about children’s ability to learn languages may not be due to any special mechanism that they possess such as a “Language Acquisition Device” of the sort hypothesized by Chomsky. On the contrary, it is children’s processing limitations that make language learning possible. By having a restricted working memory, children are able to process simple patterns which, in turn, provide a crucial foundation for learning further generalities. Writing on the subject, Elman (1998, p. 17) observes: “What makes human language possible may turn out not to be the evolution of a separate Language Organ, as envisaged by Chomsky, but rather a number of fairly small tweaks and twiddles in the cognitive capacities. It is from the complex interaction of these many small changes that language emerges.”

Like the localizationist approach, the connectionist approach to language processing has also had its share of criticism. A rather stinging one came from Pinker & Prince (1988) who wrote an exhaustive rebuttal questioning many of the methodological assumptions made by Rumelhart and McClelland in their “past tense” simulations, as well as challenging their conclusions. Although the authors admitted that Rumelhart & McClelland’s model was a successful representation of what PDP models can do, they were skeptical of its validity as an accurate model of language processing and production. According to them, the claim that parallel distributed processing networks can eliminate the need for rules and rule-induction mechanisms in explaining human language is unwarranted and, thus, must be rejected.

Pinker & Prince (1988) also accused Rumelhart and McClelland of modeling ‘performance’ or ‘implementations’, while saying little or nothing about ‘competence’ or ‘algorithms’. Such an issue was destined to come up again several years later. Describing the connectionists’ view of learning algorithms vis-à-vis psychological status, Skoyles (1991, p. 2) wrote: “Apart from the fact that the algorithm itself is biologically implausible, the level of specificity required of the teacher is just not found in most psychological learning contexts…The randomized nature of the training regime and the catastrophic interference that occurs when a network is trained on new associations does not correspond to many realistic learning situations, if any.” Skoyles also expresses his concern with regards to Reilly’s (1983) suggestion: “What is important about connectionist leaning is not the learning as such, but what gets learned.” This seems an abdication of responsibility; connectionist models are described as learning models, not representation models (as cited in Skoyles, 1991, p. 2).

Connectionist researchers are fully aware of the doubts and worries facing their movement as well as the many pitfalls that lie before them. Despite such ups and downs, the new approach has stimulated a radical re-evaluation of many of the basic assumptions that were previously made about language processing and production. As research within this framework progresses, one looks forward to a more detailed and accurate understanding of the true relationship that exists between the brain and the mysterious phenomenon we call ‘language’.

References

Anderson, J. (1984). Neural Models and a Little About Language. In D. Caplan, A. Lecours & A. Smith (Eds.), *Biological Perspectives on Language Description* (pp. 361-395). Cambridge: MIT Press.

Bates, E. (1999). Plasticity, localization and language development [Electronic version]. *The changing nervous system: Neurobehavioral consequences of early brain disorders,* 214-253.

Bates, E. & Dick, F. (2000). Beyond Phrenology: Brain and Language in the Next Millennium [Electronic version]. *Brain and Language, 71,* 18-21.

Caplan, D. (1995). The Harvard Mahoney Neuroscience Institute Letter: On the Brain. *Language and the Brain*. Retrieved on October 26, 2004, from http://www.med.harvard.edu/ publications/ On_The_Brain/Volume4/Number4/

Caramazza, A. (1991). *Issues in Reading, Writing and Speaking: A Neuropsychological Perspective*. The Netherlands: Kluwer Academic Press.

Christiansen, M. (1999). Connectionist Natural Language Processing: The State of the Art [Electronic version]. *Cognitive Science, 23,* 417-437.

Crank, M., Lee, D., Kallinis, S., & Friedman, A. (2000). *Biotechnology and Its Social Impact.* Retrieved on October 27, 2004, from http://www.molbio.princeton.edu/courses/mb427/ 2000/ projects/0008/ existentialdilemma.html

Dick, F. & Bates, E. (2000). Grodzinsky's Latest Stand - or, just how specific are "lesion-specific" deficits? [Electronic version]. *The Behavioral and Brain Sciences, 23,* 29-29.

Elman, J. (1998). Connectionism and Language Acquisition [Electronic version]. *Essential readings in language acquisition*. Retrieved on October 26, 2004, from http://www.ecs.soton.ac.uk/~harnad/Papers/Py104/pinker.conn.html

Geschwind, N. (1984). Neural Mechanisms, Aphasia, and Theories of Language. In D. Caplan, A. Lecours & A. Smith (Eds.), *Biological Perspectives on Language Description* (pp. 220-247). Cambridge: MIT Press.

Jagota, A. (1998). *Connectionism Defined*. Retrieved on October 27, 2004, from http://neuron-ai.tuke.sk/NCS/VOL1/P3_html/node4.html

Landreth, A. & Richardson, R. (2004). Localization and the new phrenology: a review essay on William Uttal's: The new phrenology [Electronic Version]. *Philosophical Psychology, 17,* 1.

Lecours, A., Basso, A., Moraschini, S. & Nespoulous, J. (1984). Where is the speech area, and who has seen it? In D. Caplan, A. Lecours & A. Smith (Eds.), *Biological Perspectives on Language Description* (pp. 220-247). Cambridge: MIT Press.

Lee, Bora. (1997). *Does Empirical Evidence Support Innateness of Language?* Retrieved on October 26, 2004, from http://www.duke.edu/~pk10/language/language.htm

Molfese, V., Molfese, D. & Parsons, C. (1983). Hemispheric processing of phonological perception. In S. Segalowitz (Ed.), *Language Functions and Brain Organization*. New York: Academic Press.

Myers, J. (2004). *Brain and Language*. Retrieved on October 27, 2004, from http://www.ccunix.ccu.edu.tw/~lngmyers/PL_Neuro.txt

Obler, L., & Gjerlow, K. (1999). *Language and the Brain*. Cambridge: Cambridge University Press.

Pinker, S. and Prince, A. (1988). On Language and Connectionism: Analysis of a Parallel Distributed Processing Model of Language Acquisition [Electronic version]. *Cognition, 28,* 73-193.

Skoyles, J. (1991). The Limits of Connectionism and Cognition Revisited: All Reading Networks Need to be Trained [Electronic version]. *Psycoloquy, 9,* 2.