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Contribution of neuroimaging to research in neurolinguistics

What is Cognitive Neurolinguistics?

Cognitive Neurolinguistics studies the relation of language and communication to different aspects of brain function, i.e. it tries to explore how the brain understands and produces language and communication. This involves attempting to combine theory from neurology/neurophysiology (how the brain is structured and how it functions) with linguistic theory (how language is structured and how it functions). Structure (Hardware) and function (Software) are intricately interdependent and of equal theoretical and practical importance.

Cognitive Neurolinguistics is an example of interdisciplinary enterprise par excellence in which humanities as well as medical, natural and social sciences along with technology are represented.

Cognitive neurolinguistics is a part of spectrum of fields including neurology, speech pathology, psychology, linguistics, imaging, neurobiology and physiology and genetics. The boundaries are fuzzy and there is significant overlap and interaction.

The central questions of neurolinguistics are many, including: What happens to language and communication after brain damage of different types? How did the ability to communicate and the ability to use language develop in the evolution of the species? How can we relate this development to the evolution of the brain? How do children learn to communicate and use language? How can we relate their acquisition of language to the development of their brains? How can we measure and visualize processes in the brain that are involved in language and communication? How can we make good models of language and communication processes that will help us to explain the linguistic phenomena that we study? How can we make computer simulations of language processing, language development and language loss? How can we make experiments that will allow us to test our models and hypotheses about language processing? How can neurolinguistics data and theory guide us in planning speech therapy and other rehabilitative measures in a given patient with aphasia?

When neurolinguistics is approached as part of psycholinguistics, localization matters less. Neural activity is used like behavioral reaction time so as to determine the ‘when’ aspect (time course) of processes. Neurolinguistics can also be approached as part of neurobiology. Then the goal becomes to articulate a theory of language in terms of structure of brain. Herein comes role for Neuro-imaging. ‘Where’ and ‘how’ questions are just as important as ‘when’ questions. The scope of neurolinguistics is much more specifically defined than that of general cognitive sciences because it is based on linguistic theory.

As a result of advances in cognitive neurologistics the traditional model of language organization in brain is being refined to include new areas and new roles. Many box and arrow models have evolved to explain word processing and sentence construction and are being correlated with imaging data in health and disease.·

Focal neurodegenerative disease like Primary Progressive Aphasia lead to different constellation of language deficits than those encountered in stroke because left anterior and inferior temporal cortex is not typically damaged in CVA. Semantic dementia is characterized by progressive dissolution of modality independent semantics or meaning of words and objects. Quantitative Digital tools of neuroimaging help investigating the location and interaction of many co-terminus neural networks.

New tools of Study :

Two types of neurophysiological techniques are applied to language assessment: hemodynamic and electromagnetic. As shown in Table, the hemodynamic techniques – PET (positron emission tomography) and fMRI (functional magnetic resonance imaging) – have excellent spatial resolution (~1-2mm). Contrastingly, they offer a poor temporal resolution (~1sec), which does not conform to the temporal window of language cognition. Both PET and fMRI are efficient methods in localizing specific brain functions. The electromagnetic techniques – EEG (electroencephalography), evoked potentials and MEG (magnetoencephalography) – provide excellent temporal resolution, which lies on the order of milliseconds. This is an accountable strength when assessing the brain in the execution of linguistic tasks whose time window is also on the order of milliseconds. However, the EEG does not offer good spatial resolution (~1cm). Even the MEG, which offers improved localization in relation to the EEG, sometimes reaching the resolution of a few millimeters, cannot match the spatial precision of PET and fMRI.

One of the common methods in neurolinguistics is to surprise the brain in various ways, so as to get some sort of robust response. What the brain is surprised by can be useful way to find out what the brain knows. There is a surprise response called the 'mismatch negativity'. That is elicited when you habituate the listener to one sound category and then suddenly cross a perceptual boundary. The brain responds to implausibility (the shirt was ironed, the thunderstorm was ironed) and ungrammatically (the shirt was ironed, the bow was on ironed) in a robust manner.

Mid-fusiform gyrus shows activation on fMRI during reading tasks. To validate the observation one now can inhibit this region with cortical stimulation in patients undergoing surgery during awake craniotomy or through implanted electrode grid. Transient hypoperfusion of the region can be document during TIAs. Inhibitory repetitive transcranial magnetic stimulation in normal subjects during a task worsens the performance.

Table: Non Invasive research techniques