Does language lateralization depend on the hippocampus?

Children acquire language even in the presence of extensive damage to classical left-hemisphere language areas. Moreover, following acute brain lesions, children recover lost language functions much better than adults (Vargha-Khadem et al., 1994).

One reason for the superior recovery in children is a greater capability for functional reorganization, the most striking example being the shifting of language from the damaged to the intact hemisphere. Transhemispheric reorganization is an intriguing mechanism because it seems to allow the reinstatement of language by the recruitment of a homologous neural circuitry in the unaffected hemisphere.

Considerable reorganization, including transhemispheric shifting of language in response to brain lesions, can also occur in adults (Weiller et al., 1995). The degree of recovery in adults is highly variable. One reason may be that humans differ in the extent of hemispheric specialization and, as a consequence, in their capability to transhemispherically compensate for unilateral disturbances (Knecht et al., 2002). While in adults transhemispheric compensation seems to be rare, in children it is more common.

In this issue of Brain, Liégeois and her colleagues report on the neural reorganization of the language system in brain-damaged children. The researchers used functional magnetic resonance imaging during covert word generation, a task known to activate Broca’s area in healthy subjects, to identify the localization and lateralization of brain activation in children who had sustained early lesions or abnormalities of the left hemisphere. Interestingly, lesions in or near Broca’s area were not associated with a right hemispheric language-related brain activation, whereas patients with pathology of the left hippocampus, parahippocampus or inferior temporal pole showed right-lateralized or bilateral language-related brain activation during covert word generation. None of the children displayed dysphasia.

These results are remarkable for two reasons. They show how well language can be processed by cortical areas adjacent to the classical language regions. They also suggest a critical role of the left medial temporal lobe, probably the hippocampal formation, in determining the hemispheric lateralization of language. This begs the question of whether language lateralization depends on the hippocampus. The sample investigated in this study was small and the pathologies were heterogeneous. Given what we know about the variability of language lateralization, no firm conclusions can be drawn at this point. But I still raise the question.

The infant brain has greater synaptic density rendering it more interconnected than the adult brain. This is the basis for the concept of progressive localization of function during development. The gradual constriction of neural nets involved in sustaining a function such as language is thought to allow more efficient processing (Woods, 1991). This theoretical model agrees with quantitative studies showing a sharp decline in the number of synapses at about the time in development that a region becomes fully functional (Huttenlocher and Dabholkar, 1997). The concept parallels the idea of progressive functional commitment, which posits that after a pathological insult a brain region can substitute for the damaged one only so long as it is not committed to its own proper function. These concepts provide a theoretical framework for a superior perilesional reorganization of function in children. However, they do not provide ready explanations for a transhemispheric shift of function.

Children are still learning language and continue to increase their vocabulary and grammatical sophistication. The often fiercely held notion that language is innate and therefore not comparable to other cognitive domains has long distracted researchers from looking at the role of brain regions, like the hippocampus, that are involved in domain general functions. However, growing evidence indicates that the hippocampal formation plays a critical role in the memorization of words in the mental lexicon (Gabrieli et al., 1988) and also in the learning of rule-governed combinations of words by mental grammar (Opitz and Friederici, 2003).

The convergence of sensory information and the back-projections from the hippocampus to the frontal, temporal and temporoparietal cortex place the hippocampus in a unique position for binding information and consolidating new memories. These memories eventually become independent of the medial temporal lobe and then rely solely on neocortical regions—in the case of language on Broca’s and Wernicke’s area. Liégeois and colleagues found that, in children, lesions encroaching on these regions were associated with an intrahemispheric relocalization of language to neighbouring brain tissue only if the ipsilateral hippocampus was intact. Therefore, the hippocampus rather than the classical language regions may be the bottleneck for language development.
Based on work in rodents, Tang has proposed that asymmetry of the hippocampi may be the driving force for the development of cortical asymmetries (Tang, 2004). There are no data yet to support such a bottom-up hippocampal induction of cerebral lateralization in humans. But after left-sided damage, the right hippocampus might drive the recruitment of right hemisphere language-homologue cortical regions. Consistent with this idea, intracranial microelectrode recordings have shown that medial temporal lobe neurons in both hemispheres—not just the language-dominant one—are activated during verbal paired associative learning (Cameron et al., 2001). Furthermore, in patients with left hippocampal pathology, functional magnetic resonance imaging suggests that verbal memory engages the right medial temporal lobe (Richardson et al., 2003).

Unlike children, adults have fully acquired language. After aphasia from middle cerebral artery infarction, cortical reorganization allows variable degrees of language recovery. The most powerful mechanism capable of inducing reorganization is learning. Language learning, as we have seen, involves the hippocampus. The role of the hippocampus in language reorganization may have escaped our attention because occlusions of the middle cerebral artery usually leave hippocampal functions intact. The present finding by Liégeois and colleagues is an incentive to investigate more closely the role of the hippocampus in language reorganization in both children and adults.

Stefan Knecht
Department of Neurology,
University of Münster,
Germany

E-mail: knecht@uni-muenster.de

References