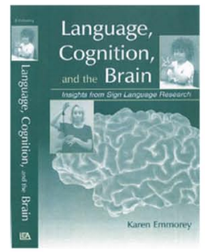
Brain Organization: Clues from Sign Aphasia

Ursula Bellugi[1], Gregory Hickok [2,1], Karen Emmorey[1], Edward S. Klima[1], Herbert Pickell[1], Marla Hatrak[1]

[1] The SalkInstitute for Biological Studies, La Jolla, CA, www.salk.edu [2] University of California, Irvine



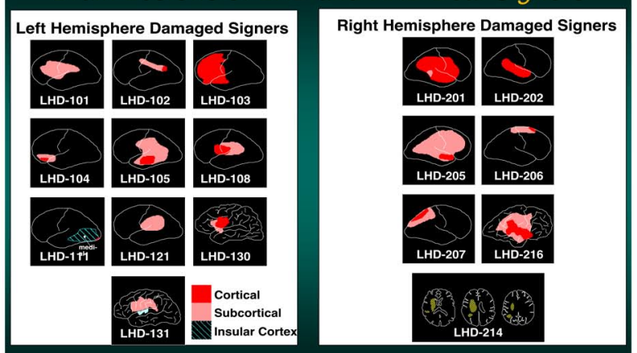
Introduction

The general objective of our research is to study the neurobiology of language. American Sign Language (ASL) displays complex linguistic structure, but unlike spoken language, conveys much of its structure by manipulating spatial relations. Space is used in ASL in multifunctional ways: (1) to encode grammatical relations (phonology, morphology, syntax); (2) to encode discourse relations via relations among spatial loci across sentences; and (3) to encode spatial relations directly to describe the layout of objects in real world space. We explore the properties of each of these uses of space, their interaction, and their neurobiological substrates, using new methods of brain imaging, and language and cognitive probes specially developed for these studies.

Program

These studies involve deaf life_long signers who have focal lesions to the left or right hemisphere. Signers inducted into the studies undergo neurological examinations, MRI, The Salk Sign Aphasia Examination (modelled after the BDAE and adapted for sign language), a series of linguistic probes for levels of ASL language structure, an apraxia battery, elicited narratives, spatial cognitive nonlinguistic tasks, and experimental tasks which probe spatial mapping and the differential uses of facial expression in ASL.

Brain Lesions of LHD and RHD Deaf Signers

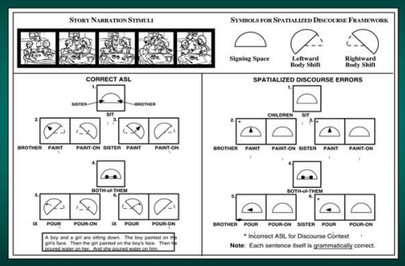


Findings

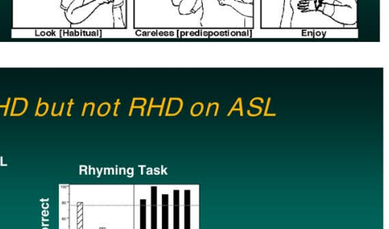
Brain Organization for Grammatical Aspects of Sign Language. In this overview, we show examples of the multifunctional use of space in ASL, and results of the effects of linguistic probes we have developed for sign language. We find that left hemisphere damage can lead to sign language aphasias including production of paraphasias, as it does for hearing people, but that right hemisphere damage in general does not. At the same time, we find that there is a principled dissociation between spatial cognitive functions and spatial language functions: there are gross visual spatial deficits in RHD signers but not LHD signers. Importantly, although right hemisphere damaged signers may show evidence of left hemispatial neglect in drawing and line cancellation; this did not interfere with sign language communication, either in production or comprehension. We find and have reported separately on different aspects of within hemisphere organization: a signer with damage in Broca's area who had paraphasias including those of bimanual coordination; a case of sign blindness, a signer with LHD who showed a principled separation between sign and mime, and so forth.

Brain Organization for Extragrammatical Aspects of Sign Language. We investigate other aspects of ASL that crucially involve complex spatial manipulations. (i) Spatialized Discourse. ASL discourse representations are encoded in space; many discourse functions (e.g., tracking referents across extended discourse) are achieved by manipulations of spatially expressed frames of reference. Right-hemisphere damaged signers do not in general show signs of aphasia but often show differential deficits at the spatialized discourse level. The complex spatial referential framework underlying ASL discourse can be disrupted by right hemisphere damage, but independently of impairment in spatial cognition and/or tangential signing. (ii) The Use of Space for Spatial Mapping. In addition to referential functions of signing space, ASL uses space to encode spatial relations directly. Through ASL classifier constructions, which convey the layout of objects in space. We find that right hemisphere damage can disrupt the use of space to represent space directly, although the use of space in the service of grammar may be unimpaired. These two functions of space (referential discourse and spatial mapping) may be differently represented in right hemisphere neural systems. (iii) Linguistic versus Affective Facial Expression. There is another layer of structure in the nonmanuual component of signing which is conveyed by distinct facial expressions (linguistic versus affective) in ASL which can break down differently with RHD and LHD (see Reilly et al, this session).

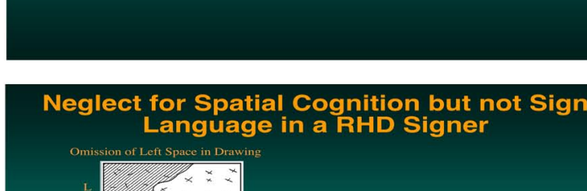
Spatial Discourse Deficits in RHD Signers



LHD Deaf Signer's Errors



Spatial Cognition Impairment in RHD



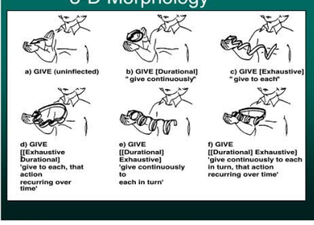
Discourse deficits in RHD signers

Different Deficit Patterns in 4 RHD Signers

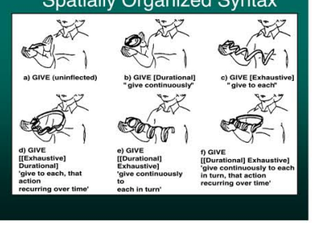
	Grammar	Discourse	
		Cohesion	Coherence
RHD-205 RHD-206	Spared	Spared	*Impaired*
RHD-207 RHD-216	Spared	*Impaired*	*Spared*

Spatial Structure of ASL Grammar

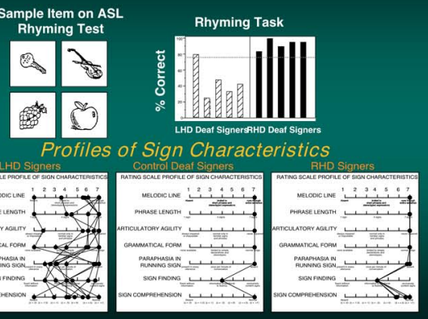
3-D Morphology



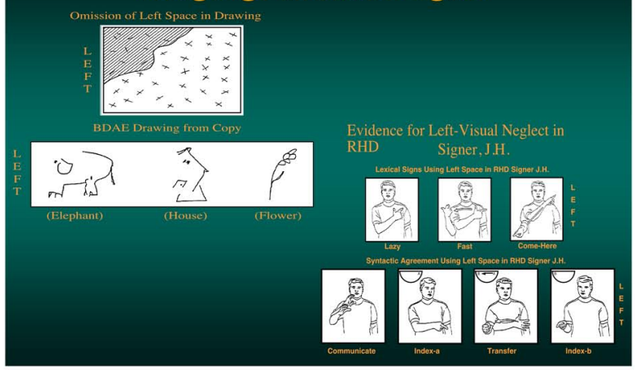
Spatially Organized Syntax



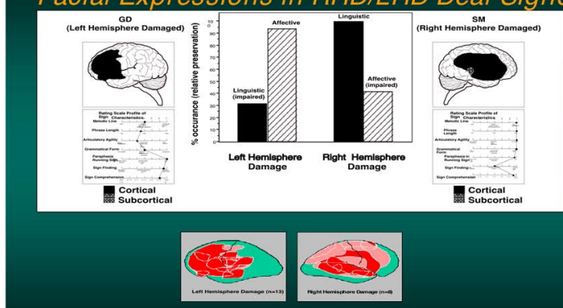
Deficits in LHD but not RHD on ASL



Neglect for Spatial Cognition but not Sign Language in a RHD Signer



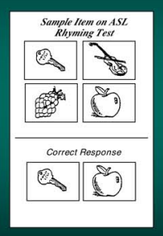
Dissociation between Affective and Linguistic Facial Expressions in RHD/LHD Deaf Signers

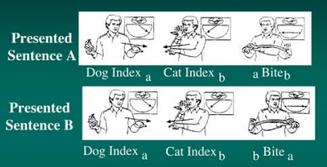


Superimposed lesions of LHD & RHD

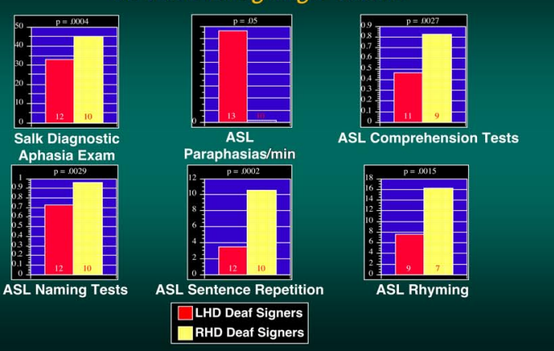
ASL Linguistic Probes

Sample Item on ASL Rhyming Test

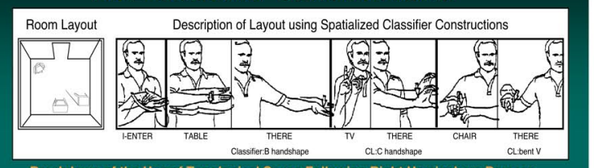




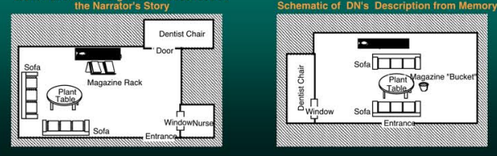
Differences between LHD/RHD Deaf Signers on ASL Language Tasks



Role of the Right Hemisphere in Spatial Mapping: ASL Classifier Constructions



Breakdown of the Use of Topological Space Following Right Hemisphere Damage



Conclusions

The over-arching goal of this program of studies is to elucidate the neurobiological foundations of human language. We approach this issue through the study of the neural organization ASL, a language that displays the complex linguistic structure of spoken languages, but encodes most of its linguistic information spatially. The study of the differential effects of focal lesions to the left or the right hemisphere in deaf life-long signers is allowing us to separate out modality-dependent from modality-independent contributions, providing a direct window on brain organization for language itself. Our studies have established that sign aphasias occur following damage to the left but not the right hemisphere for deaf signers as for hearing speakers (with the exception of one right lesioned individual with reversed asymmetry who is left handed). Our studies are geared toward examining similarities and differences within the left hemisphere for the neural basis of sign versus spoken language, considering the very different input and output systems of the two language modalities. These directions are helping to tease apart central and peripheral aspects of the neural organization of language. The effects of brain damage on sign comprehension involving visual rather than auditory perception, provides a fertile testing ground for a modality-tempered hypothesis of brain organization for language. We are beginning to map the neural basis of extra-grammatical functions afforded by ASL, leading to an understanding of right hemisphere functional and neuroanatomical organization. Our studies focus on the special properties of language in a different modality: spatially-organized discourse and the special realm where sign space is used to represent real world space. Because the discourse system of ASL encodes referential information overtly in space, direct study of the breakdown of discourse is possible. Experimental studies of the spatialized nature of the discourse referential system and the direct use of space to convey spatial relations in ASL may lead to new understanding of neural systems within the right hemisphere. We aim to provide converging evidence with studies using functional brain imaging to illuminate the neurobiology of language. This research helps to explore the extent and limits of neural plasticity in the brain. (Overvuew reference: Hickok & Bellugi, Handbook of Neuropsychology, 2001). This research is supported in part by NIDCD00201.