

## **The impact of deafness on cognition and visual language processing: Challenges from a neuroscience point of view**

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The paper consists of four parts: one on signed language as a tool for understanding brain function, the other part addresses some cognitive and communicative consequences of being a deaf sign language user, the third addresses the concept of working memory in the deaf from a visual language perspective, and finally, the fourth part lists the conclusions made.

### **Part 1: Signed language: a tool for understanding brain function**

#### *Sign language aphasia and neuropsychological dissociations*

As evidenced by sign language aphasia studies in the deaf, classical auditory language areas are also recruited by signed language (see Neville & Bavelier, 1998). The basis for this similarity is under current debate but the similarity seems to be independent of temporal processing skills and rather more dependent on grammatical processing necessary for both spoken and signed languages (Poizner et al., 1990).

What we also can see on the basis of patient data is that there are actually several general visuospatial functions which can be dissociated from (i.e., selectively impaired) visuospatial sign language functions: performance in standard neuropsychological tasks (Hickok et al., 1996), emotional facial expressions (Corina, 1989), and extra-grammatical spatial functions (Hickok et al., 1999).

Analogous to the issue of visuospatial dissociations, several studies have also addressed the issue of motor linguistic dissociations from general motor functions. In many deaf sign aphasic patients the motor processes specifically tied to producing sign language are dissociated from general motor performance indicated by apraxia tests (Hickok et al., 1996), and from the specific disorders of sign expression exhibited by PD patients (Kegl, Cohen & Poizner, 1999).

#### *The role of the right hemisphere in sign language*

The basic neural network for sign language specific activation has been established by Neville et al. in their fMRI studies of both deaf and hearing native signers (Neville et al. 1997, 1998): bilateral activation of Broca's and Wernicke's areas, the dorsolateral prefrontal cortex, the precentral sulcus, and the superior temporal sulcus. Interestingly, even imagined signs produce activation of similar networks (McGuire et al., 1997). Right hemisphere effects

can be documented for the lexical (Nishimura et al, 1999), sentence (Neville et al., 1997, 1998), discourse comprehension levels of sign language (Söderfeldt et al., 1994, 1997). This effect can be generalized across type of imaging techniques. The right hemisphere involvement does not seem to be due to modality of presentation (Söderfeldt et al. 1997). However, more analytical

studies need to be carried out. There are several competing hypotheses that need to be tested in the same experiment: (a) *extra-grammatical*, prosodic and topic coherence functions have been suggested, (b) sign language triggers *visuospatial modality-specific functions*, and (c) sign language activates sign specific, meaningful but nonmodality-specific functions.

## **Part II: Cognitive and communicative consequences of being a deaf native sign language user**

Recent work on the cognitive consequences of early sign language use has started to paint an exciting picture. Enhanced visual attention of peripheral events, is systematically observed in the deaf native signers (Neville & Lawson, 1987a,b,c), as is improved visuospatial cognition (Emmorey, Kosslyn, & Bellugi, 1993; Parasnis, Samar, Bettger, & Sathe, 1996), and better mental rotation of non-linguistic objects (Emmorey, Klima, & Hickok, 1998). The expertise of deaf ASL-signers to extract and remember facial features (McCullough & Emmorey, 1997), – in combination with the above improvements – all suggest that early use of sign language – typically combined with congenital deafness – may impact and cortically reorganize some brain functions (Neville, 1990, see also Wolf & Thatcher, 1990).

Multiple perspective taking in the deaf sign language user has recently been shown by Courtin and colleagues (Courtin, in press) to have significant effects on what is fashionably called "theories of mind" (e.g., Peterson & Siegal, 1995). Courtin has been able to show that deaf native signers outperform non-native signers and deaf non-signers on so called false belief attribution tasks.

Thus, there exist several visual-spatial, memory and attentional cognitive consequences of having sign language as a first language in the deaf native signer, representing compelling examples of cognitive compensation. There are potentially also communicative and social consequences of using sign language, rooted in the cognitive capacity of having "theories" of others' minds.

## **Part III: Working memory in the deaf**

Working memory is central to both perception and production of language (Baddeley, 1990). In a discussion of the functions played by working memory – bridging the gap between signal analysis and dialogue – Rönnberg et al. (1998) proposed a general working memory system for poorly specified linguistic input, applicable to various speech-based forms of communication in the profoundly hearing-impaired or deaf.

In our view (Rönnberg et al., 1998), the brain has the capacity for a variety of "phonological" codes – coding schemes that capitalize on a rapid combinatorial capacity for sublexical units. This apparent flexibility in coding strategy also implies that working memory can be conceptualized as either having a variety of loops for linguistic or other materials, or that there is at least some more amodal, basic sublexical processor which is common to all linguistic "loop effects"; for visual speechreading, cued speech, tactilely mediated speech perception, and for signed events (cf. Leybaert, 2000; Rönnberg et al., 1998).

There are reasons to believe that working memory for sign and speech share behavioral and functional similarities. Direct experimental evidence of "phonological loop" effects have been observed in sign (Wilson and Emmorey, 1997). Thus, phonological similarity was

manipulated by means of sign similarity, articulatory suppression was manipulated by irrelevant hand movements, and word length effects can be manipulated by means of sign length. In addition, Marschark and Meyer (1998) have been able to show that the sign loop has the same capacity as that for the hearing subjects, when adjusted for (manual) articulation rate. General working memory capacity also seems to support both speechreading skill and sign fluency in the same bilingual subject (Rönnberg et al. 1999), tactilely mediated speechreading (Rönnberg, 1993), as well as the use of digital hearing aids.

Again, perhaps the time is ripe to let neuroimaging studies decide whether there are several loops or amodal phonology, whether there is one general working memory capacity, or several? The answer to these questions drives new theory and application.

#### **Part IV: Conclusions**

- ❖ Classical anatomical structures in the left hemisphere are responsible for spoken as well as for sign language aphasias.
- ❖ Systematic dissociations exist: non-linguistic motor functions vs. linguistic motor functions, and visuospatial nonlinguistic functions vs. linguistically important functions.
- ❖ Recent imaging studies suggest that:
  - classical left hemisphere structures remain important
  - recent imaging studies also suggest that the right hemisphere plays a role in sign language. Several competing hypotheses exist.
- ❖ Several positive cognitive and communicative effects have been demonstrated: e.g. enhanced imagery/spatial cognition, memory for faces, peripheral attentional mechanisms, speechreading, and better "theories of mind".
- ❖ Recent studies have replicated "phonological loop" effects in working memory data with signed materials. Imaging studies are needed to decide the truth value of different loop and working memory hypotheses.

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### Note pour la traduction :

ASL American Sign Language : Langue des Signes Américaine

speechreading : lecture labiale

fMRI : IRM (imagerie par résonance magnétique)