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The neural correlates of highly iconic structures and topographic discourse in French Sign Language as observed in six hearing native signers

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ABSTRACT

"Highly iconic" structures in Sign Language enable a narrator to act, switch characters, describe objects, or report actions in four-dimensions. This group of linguistic structures has no real spoken-language equivalent. Topographical descriptions are also achieved in a sign-language specific manner via the use of signing-space and spatial-classifier signs. We used functional magnetic resonance imaging (fMRI) to compare the neural correlates of topographic discourse and highly iconic structures in French Sign Language (LSF) in six hearing native signers, children of deaf adults (CODAs), and six LSF-naïve monolinguals. LSF materials consisted of videos of a lecture excerpt signed without spatially organized discourse or highly iconic structures (Lect LSF), a tale signed using highly iconic structures (Tale LSF), and a topographical description using a diagrammatic format and spatial-classifier signs (Topo LSF). We also presented texts in spoken French (Lect French, Tale French, Topo French) to all participants. With both languages, the Topo texts activated several different regions that are involved in mental navigation and spatial working memory. No specific correlate of LSF spatial discourse was evidenced. The same regions were more activated during Tale LSF than Lect LSF in CODAs, but not in monolinguals, in line with the presence of signing-space structure in both conditions. Motion processing areas and parts of the fusiform gyrus and precuneus were more active during Tale LSF in CODAs; no such effect was observed with French or in LSF-naïve monolinguals. These effects may be associated with perspective-taking and acting during personal transfers.

1. Introduction

The neural bases of the signed languages used by deaf communities around the world have been studied for several years, probing many different aspects, such as the similarities and differences between spoken and signed languages during comprehension and generation (Bavelier et al., 1998; Braun, Guillemin, Hosey, & Varga, 2001; Emmorey, Mehta, & Grabowski, 2007; MacSweeney et al., 2002a), the effect of the syntactic use of space and other specific features of signed languages (Campbell, 2003; Emmorey et al., 2002, 2004; MacSweeney et al., 2002b), the relationships with the neural networks involved in action observation or non-linguistic gesture comprehension (Corina & Knapp, 2008; Husain, Patkin, Thai-Van, Braun, & Horwitz, 2009; MacSweeney et al., 2004), or the plastic changes associated with deafness and sign-language expertise (Newman, Bavelier, Corina, Jezzard, & Neville, 2002; Sadato et al., 2004). The present functional magnetic resonance imaging (fMRI) study explores the neural bases of two particular aspects of Sign Language discourse that are unavailable to spoken languages: (1) the use of signing-space and spatial-classifier signs to show the topographical relationships between objects and (2) highly iconic structures, such as situational and personal transfers, that mainly occur during narratives and allow the narrator to represent a previously experienced or fictional event in the signing-space via a "transfer" process. These transfers are "the visible traces of cognitive operations, which consist of transferring the signer's conceptualization of the real world into the four-dimensional world of signed discourse (the three-dimensions of space plus the dimension of time)" (translated from Sallandre, 2007 p. 108).

The first developmental linguistics studies that took iconicity into account did not find an effect on the acquisition of vocabulary (Orlansky & Bonvillian, 1984), pronouns (Petitto, 1987) or grammar (Bellugi & Klima, 1982). However, more recent research (and

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theories, e.g. Taub, 2001) led to a reappraisal of this question. Vinson and collaborators (2008) found that the age of acquisition of vocabulary correlated with iconicity. Several different groups reported an effect of vocabulary iconicity on cognitive processes (Courtin, 1997; Ormel, Hermans, Knoors, & Verhoeven, 2009; Thompson, Vinson, & Vigliocco, 2009; Vigliocco, Vinson, Woolfe, Dye, & Woll, 2005). Furthermore, the effect of iconicity would not be restricted to vocabulary (Schick, 2006). An effect of iconicity was reported on the emergence of classifier constructions (Slobin et al., 2003 – classifiers involve a kind of iconicity, see below) and of verb agreement (Casey, 2003).

Some authors also have looked for the neural bases of iconicity as present in vocabulary, classifier signs, topographic representations of space, and at the level of the sentence (Emmorey et al., 2002, 2004; MacSweeney et al., 2002b; for a case-study of Sign Language aphasia but normal pantomime production in a left-lesioned deaf signer, see Corina et al., 1992). Thus, iconicity is now quite largely described and addressed in the linguistic, cognitive and neuroscience literature.

In the present paper, we focus on the neuroanatomy of iconicity at the discourse level which, to the best of our knowledge, has not been addressed yet. We first describe a linguistic theory that accounts for iconicity at the sentence and discourse levels, as described by Cuxac (2000).

The highly iconic structures, initially described by French linguist Christian Cuxac, show similarities across different Sign Languages and are employed when people using different Sign Languages happen to interact (Cuxac, 1997). They are also frequently used during the course of daily conversation. More precisely, Cuxac and his colleagues, working on French Sign Language (LSF, Langue des Signes Française) have distinguished up to 20 different linguistic structures (Cuxac, 1993; Sallandre, 2003), which they gathered under the generic label of "highly iconic structures", (English for "structures de grande iconicité") with different components such as personal transfers, situational transfers, or double transfers (Sallandre, 2003).

Within the highly iconic structures framework, personal transfers occur during discourse, after the construction of the signing-space and spatial mapping processes, to focus on parts of the telling that the signer wants to stress or to present in action. Spatial mapping, which is "the cohesive use of signing-space at a discourse level rather than (...) the topographic use of space to describe a spatial scene" (Emmorey 2002, p. 69), is often a prerequisite for personal transfers.

A personal transfer in Cuxac's theory corresponds to a "*referential shift*", "*role taking*" or "*role shift*" in other linguistic frameworks (Sallandre, 2006). Referential shift is described as a narrative technique used to express direct quotation or to convey action, from a particular point of view (Bahan & Petitto, 1980; Emmorey, 2002; Padden, 1986). A related process can occur in spoken languages when quoting a character, with vocal and facial/body imitation. In Sign Languages, however, as Poulin and Miller (1995, p. 121) state, "the use of referential shift is not limited to reported speech. In effect, with referential shifting, the signer can also report actions (...), states (...), or thoughts." For example, Liddell and Metzger (1998) have written in terms of *reported actions* to refer to actions that are described during referential shits, that is: from the characters' point of view. Different authors have utilized several examples to illustrate the various uses of referential shift in their texts (Engberg-Pedersen, 1995; Lillo-Martin, 1995; Mather & Winston, 1998; Quer, 2005; Roy, 1989; Sallandre, 2003, 2007). However, a main difference between Cuxac's theory and other ones lies in the status of real linguistic devices attributed to the highly iconic structures by Cuxac as soon as 1983, while many other authors refer to these devices as gestures, of which the "significance (...) as part of discourse has been minimized in linguistic theory" (Liddell & Metzger, 1998, p. 658).

During personal transfers, the signer expresses the "state of mind" of the character (living entities such as a human or an animal – as already exemplified in Roy, 1989 – or personified inanimate objects such as a planet or a golf ball, cf. Cuxac, 2000). Adopting the perspective of the character during a personal transfer involves a shift of the signing-space. The narrator indicates this shift by adopting a slightly different orientation or by a quick change in gaze direction and a different facial expression (Emmorey & Reilly, 1998; Engberg-Pedersen, 1995; Roy, 1989). The "signing style" is modified accordingly. In particular an amplification of different elements that participate to Sign Language prosody can be observed, including modifications of the rhythmic patterns of sign production (Braem, 1999), body movements (van der Kooij, Crasborn, & Emmerik, 2006), linguistic and emotional or attitudinal facial expressions (Nespor & Sandler, 1999).

A "situational transfer" could be used to express, in Sign Language, a sentence like "the horse leaps over the fence". The situational transfer is achieved by first pointing to a given place in sign space ("here, a fence") and then moving the forearm to this place: the fence is symbolized by, transferred to the forearm of the narrator. Then, the horse would be represented by the other hand using a classifier shape. The hand would proceed to "jump" over the other arm (the fence): the action is reported in a "highly iconic" way (for thorough details on highly iconic structure theory, see Cuxac, 2000). Historically, highly iconic structures for depicting constructed dialogs and actions have received more attention in the linguistic analyses of LSF than in other Sign Languages. The difference between ASL or BSL versus LSF linguistic analyses (Sallandre, 2003) surely explains why, to the best of our knowledge, the neural correlates of highly iconic structures, as detailed by Cuxac et al., have not yet been studied with neuroimaging.

Another important, although more familiar, aspect of Sign Languages is that environments are seldom described with spatial prepositions such as "in front of", "close to", or "on the right of". Instead, the signer structures the signing-space topographically so as to directly represent the location of the different objects. The latter objects can be represented using classifiers. Classifiers are linguistic structures whose hand shapes specify object category (e.g., a flat surface, such as a book). The position of the classifier in the signing-space represents the spatial relation between objects and, for this reason, classifiers are also iconic though in a different way than the highly iconic structures presented above (e.g., a book is lying at the right of an overturned glass; for more details on classifiers, see Emmorey, 2003). Taylor and Tversky (1992, 1996) reported that English speakers tended to use a survey perspective when describing a large-scale environment (the plan of a town, in their experiment) while they used a route perspective for small-scale environments (a convention center). Emmorey and Falgier (1999), using the same experimental setup, reported that when signers adopt a survey perspective, the signing-space becomes a diagrammatic spatial format (also labeled *token space* in (also labeled *token space* in S Liddell, 1995; *model space* in Schick, 1990). Spatial formats are "the topographic structure of signing-space used to express locations and spatial relations between objects" (Emmorey 2002, p. 92).

Although signed languages share their essential linguistic aspects with spoken languages, they also possess discourse-level linguistic structures (e.g. personal transfers, situational transfers) that are essentially alien to spoken languages and whose neural correlates remain largely unknown. For instance, it is not yet known whether the neural bases of the understanding of a topographical description are any different in spoken and signed languages. So far, the neuroimaging literature on the neural bases of signed language comprehension and generation has shown that signed languages mainly rely on the same set of left-hemispheric supramodal areas as spoken languages (e.g. Broca's and Wernicke's