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Comprehensibility and neural substrate of communicative gestures in severe aphasia

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ABSTRACT

Communicative gestures can compensate incomprehensibility of oral speech in severe aphasia, but the brain damage that causes aphasia may also have an impact on the production of gestures.

We compared the comprehensibility of gestural communication of persons with severe aphasia and non-aphasic persons and used voxel based lesion symptom mapping (VLSM) to determine lesion sites that are responsible for poor gestural expression in aphasia.

On group level, persons with aphasia conveyed more information via gestures than controls indicating a compensatory use of gestures in persons with severe aphasia. However, individual analysis showed a broad range of gestural comprehensibility. VLSM suggested that poor gestural expression was associated with lesions in anterior temporal and inferior frontal regions. We hypothesize that likely functional correlates of these localizations are selection of and flexible changes between communication channels as well as between different types of gestures and between features of actions and objects that are expressed by gestures.

1. Introduction

Manual gestures are ubiquitous companions of speech. They emphasize, modify, and complement spoken messages (McNeill, 1992) and may take over pragmatic functions in discourse like regulating turn-taking (Bavelas, Chovil, Coates, & Roe, 1995).

Typical speakers' gestures usually display information that is similar or redundant with their verbal utterance, but sometimes gestures add information that is complementary or additional to the spoken expression (e.g. Beattie & Shovelton, 1999). Occasionally gestures may even transmit information independent of speech, but typical speakers use gestures definitely less frequently in isolation than in combination with speech. Various theoretical models of gesture production propose that gesture and speech arise from shared a communicative intention (e.g. De Ruiter, 2000; Kita & Özyürek, 2003). According to the Sketch Model (De Ruiter, 2000) that has been built upon Levelt's model of speech production (Levelt, 1989), speech and gesture both have a communicative function. They origin from a shared communicative intention but are proceeded to production via separate channels. This view suggests a flexible trade-off relationship with one communication channel compensating for the other in certain communicative contexts.

1.1. Gestural support of speech in exceptional communicative contexts

It is mostly in exceptional communicative contexts as, for example, in very noisy surrounding or in communication with speakers of foreign languages that gestures take over the full transmission of meaning. Typical speakers can adapt their gestures to situations in which they have to be used as sole means of communication. Indeed, changes of the range and quality of gestures have been demonstrated in individuals who were instructed to express messages without speaking (e.g. Goldin-Meadow, McNeill, & Singleton, 1996; Helmich, Skomroch, & Lausberg, 2014; Hogrefe, Ziegler, & Goldenberg, 2011).

Impaired verbal expression in aphasia could potentially provide such an exceptional situation when gestures are needed for compensating the insufficiency of verbal expression (Borod, Fitzpatrick, Helm-Estabrooks, & Goodglass, 1989; Goodwin, 2000; Herrmann, Reichle, Lucius-Hoene, Wallesch, & Johannsen-Horbach, 1988). However, the compensation of aphasia by gestural expression is less straightforward than it might appear on first sight. Persons with aphasia have been typical speakers until the cerebral accident, with a life – long habit of producing gestures

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alongside undisturbed speech. The use of gestures as an autonomous or at least strongly supporting communication channel demands expansion of the gestural repertoire and adaptations of habitual gestures for securing their comprehensibility without disambiguation by speech.

Adaptations of gestures for use as main communication channel are difficult for typical speakers, but the difficulty is even higher for persons with aphasia: They have to produce their gestures in the presence of brain damage and brain damage can interfere with production of communicative gesture in addition to its impact on verbal expression.

1.2. Use of communicative gestures in severe aphasia

Several studies investigated the use of spontaneous gesture in persons with severe aphasia (PWSA). Most of these studies suggest that PWSA benefit from gestures for transmitting information in communication (Feyereisen, Barter, Goossens, & Clerebaut, 1988; Goodwin, 2000; Herrmann, Koch, Johannsen-Horbach, & Wallesch, 1989; Herrmann et al., 1988; Hogrefe, Ziegler, Weidinger, & Goldenberg, 2012; Hogrefe, Ziegler, Wiesmayer, Weidinger, & Goldenberg, 2013; van Nispen, van de Sandt-Koenderman, Mol, & Krahmer, 2014). PWSA use more conceptual gestures than typical speakers (Hogrefe, Rein, Skomroch, & Lausberg, 2016). With respect to the communicative gain, it has been shown that gestural communication can convey relevant information alongside an extremely reduced verbal output (Herrmann et al., 1989; Hogrefe et al., 2012). Indeed, in some cases spontaneous gestures convey more information than speech (Hogrefe et al., 2013).

However, some studies suggest that efficient gesture use does not increase in accordance with the severity of aphasia (Glosser, Wiener, & Kaplan, 1986; Mol, Krahmer, & van de Sandt-Koenderman, 2013). This failure is probably due to the influence of accompanying neuropsychological disorders like limb apraxia on gesture production (Borod et al., 1989; Feyereisen, Barter, et al., 1988; Hogrefe et al., 2012).

Studies comparing gestural behaviour of typical speakers to gestural behaviour of PWSA show that the latter use gesture differently from typical speakers. They employ a wider range of different hand gestures with respect to formal diversity (e.g. different movement types, different local positions of the hand). This effect holds also when exclusively participants with limb apraxia are regarded (Hogrefe, 2011). However, another study (Mol et al., 2013) indicates that PWSA use primarily specific iconic gestural representation techniques like outlining the form of a referent or producing a deictic gesture. The authors of this study conclude that representation techniques that require undisturbed access to conceptual knowledge like performing pantomimes with or without object appear seldom in PWSA.

Two our knowledge, there are only two group studies investigating the communicative gain of gestures in PWSA in comparison to speakers without aphasia (Herrmann et al., 1988; Mol et al., 2013). One study showed that in dyads PWSA produced more meaning-laden gestures than their significant others and that these gestures were adequately used in the communicative context (Herrmann et al., 1988). A closer look on the types of gestures revealed that PWSA mainly produced codified emblems like head shaking or nodding that appeared as reactions to utterances of the significant others – this gesture type is probably retrieved as single a representation from a mental lexicon (De Ruiter, 2000), and as such its production may be less demanding for the speaker. Indeed, when produced to command, emblems are less prone to failures than pantomimes which do not have a codified form-meaning relationship. This observation holds for persons with brain damage as well as for persons without brain damage (e.g., Goodglass & Kaplan, 1963; Hanna-Pladdy et al., 2001).

Mol et al. (2013) videotaped persons with and without aphasia who performed two short communication tasks, in which two brief messages had to be conveyed. Their gestures were videotaped and judges were asked to assign the silent video records to one of the two messages. The judges recognized messages produced by PWSA less frequently than those of persons without aphasia, indicating that more information could be derived from the messages of the typical speakers. In conclusion, studies investigating gestural behaviour in PWSA suggest an enhanced use of communicative gestures in these persons. However, research so far leads to diverging results concerning the communicative gain of these gestures.

1.3. Neural substrates of gesture production

To date, most of the research concerning specific neural correlates of gesture production has been dedicated to the production of isolated gestures to command. Especially the production of pantomimes of tool use to command has attracted interest as an inability to produce these gestures has been regarded as a core manifestation of apraxia (Finkelnburg, 1870; Geschwind, 1975; Goldenberg, 2013; Steinthal, 1871). Pantomimes of tool use are communicative in the basic sense that they depict objects and actions in a way that other subjects can understand but they do not themselves alter the material state of the indicated objects.

Several voxel based lesion symptom mapping (vlsm) studies have explored the neural substrates of defective pantomime to command in patients with left brain damage. They found responsible lesions in inferior frontal lobe (Buxbaum, Shapiro, & Coslett, 2014; Goldenberg, Hermsdörfer, Glindemann, Rorden, & Karnath, 2007; Mengotti et al., 2013; Weiss et al., 2016), middle and anterior temporal lobe (Buxbaum et al., 2014; Goldenberg & Randerath, 2015; Hoeren et al., 2014; Mengotti et al., 2013; Price et al., 2010), and in supramarginal and angular gyrus (Buxbaum et al., 2014; Goldenberg & Randerath, 2015; Hoeren et al., 2014; Mengotti et al., 2013; Price et al., 2010) of the left hemisphere. None of these localizations was constant across all studies, but no other localizations were invoked. It is noteworthy that they are all located in the ventral part of the brain where they form a continuous territory of heteromodal cortex.

To our knowledge, there are only two studies that explored the specific neural correlates of co-speech gesture production during spoken descriptions of short movie clips (Göksun, Lehet, Malykhina, & Chatterjee, 2013, 2015). These two studies focused on spatial aspects of gesture production. In the first study (Göksun et al., 2013), the authors found for a group of 32 persons with brain damage (16 with damage to left and 16 with damage to the right hemisphere) that the production of spatial gestures correlated negatively with the accuracy of naming spatial relations. Under the assumption of a linear relationship, five out of seven persons with aphasia and preposition naming deficits produced fewer gestures than expected. For these five persons, lesions maximally overlapped in the left posterior middle frontal gyrus and the left inferior frontal gyrus as shown by a lesion overlap map. In the second study (Göksun et al., 2015), the same participants were included. They had to describe short motion events in order to elicit verb-preposition combinations. As gestural counterparts to the verb-preposition combinations gestures expressing manner and path information were analysed. Whereas path gestures depict the path of a motion, e.g. moving the flat hand from one side to the other to indicate the direction of a movement, manner gestures depict the way the movement was performed, i.e. moving the hand in circles to depict the way an object rolled down a hill.

The authors found deficits in naming of paths, i.e. using prepositions in patients with lesions in the left superior temporal gyrus