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10. Neuropsychology of gesture production

Abstract

This chapter focuses on where in the brain – in terms of the right and left hemispheres – co-speech gestures are generated. This question is not only of neurobiological relevance but its investigation also provides an empirical basis to explore with what kind of cognitive and emotional processes in the two hemispheres gesture generation may be associated. First addressed are the methodological difficulties and the approaches currently used to empirically investigate the question of hemispheric specialization in the production of gestures. Second, an empirically grounded theory proposing a left hemispheric generation of co-speech gestures is presented and critically discussed. The left hemisphere proposition is contrasted by empirical data providing evidence for a right hemispheric generation of gestures. The chapter concludes with a proposition on the distinct roles of the right and left hemispheres in gesture production.

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1. The methodological challenge to investigate the neuropsychology of the production of spontaneous gestures

Little is known about the neuropsychology of the production of communicative gestures, which are spontaneously displayed in communicative situations or when talking to oneself. In these situations, many different types of communicative gestures in this example, as classified by occur, such as deictics, batons, ideographics, iconographics, kinetographics, or emblems (Efron [1941] 1972).

The neurobiological correlates of the production of these spontaneous hand gestures are difficult to investigate, as most of these gestures are generated implicitly, i.e., beyond the gesturer's awareness. In contrast, explicit gestures, which are generated within the gesturer's awareness, can be more readily subject to empirical investigations, because they can be executed on command. The investigation of the neurobiological correlates of explicit gestures now profits from the great progress in the development of neuroimaging methods. However, these methods are not suited for the investigation of the production of spontaneous, implicitly generated gestures, because neuroimaging investigations require that gestures are generated on command in time and repetitively and, in order to prevent movement artifacts, that the gesturer is immobile except for movements of the lower arms. The examination of gestures, which are executed on command, is only of limited value for understanding the production of spontaneous gestures, because the neurobiological correlates of explicit gesture production differ from those of implicit gesture production (Bogen 2000; Buxbaum et al. 1995; Geschwind et al. 1995; Lausberg et al. 1999; Lausberg et al. 2003; Liepmann and Maas 1907; Marangolo et al. 1998; Rapcsak et al. 1993; Tanaka et al. 1996; Watson and Heilman 1983). While implicit gestures can be generated in the right hemisphere or in both hemispheres, there is a left hemispheric specialization for many components of the explicit gesture production. Therefore, despite the current progress in neuroimaging techniques, the state of the art to examine the contribution of the right and left hemispheres to the production of spontaneously displayed gesture types is to examine hand preferences in healthy subjects or in split-brain patients.

The anatomical basis to infer hemispheric specialization from hand preferences is that the left hemisphere controls the (contralateral) right hand, and vice versa, the right hemisphere the (contralateral) left hand. In subjects with normal neural connection, the corpus callosum, which is the biggest neural fiber connection between the right and left hemispheres, enables to exert control also over the ipsilateral hand. As an example, if a right-handed person with left hemisphere language dominance intends to write with the left hand, the command is send from the language-competent left hemisphere via corpus callosum to the right hemisphere, which controls the left hand.

Split-brain patients offer a unique opportunity to examine hemispheric specialization in the production of spontaneous gestures, because in these patients the corpus callosum is sectioned (in this chapter, the term "split-brain patients" will be used for patients with complete callosal disconnection independently of the cause, i.e., operation or stroke). In most cases, the operation is conducted in patients with intractable epilepsy in order to prevent that epileptic seizures spread from one hemisphere to the other. It is noteworthy, that this operation is rarely indicated, therefore only a few split-brain subjects are available for studies. After callosal disconnection, each hand can distinctly be controlled only by the contralateral hemisphere (Gazzaniga, Bogen, and Sperry 1967; Lausberg et al. 2003; Sperry 1968; Trope et al. 1987; Volpe et al. 1982). As a result, the actions of the right and left hands reflect competence or incompetence of the contralateral hemisphere. As an example, as the left hemisphere is language dominant, these patients cannot execute verbal commands with the left hand, which is controlled by right hemisphere (left hand apraxia). In contrast, the split-brain patient's right hand performs worse than the left hand in copying figures (right hand constructional apraxia), because the right hand is disconnected from the right hemispheric visuo-spatial competence (e.g. Bogen 1993; Lausberg et al. 2003). Therefore, studies on spontaneous hand preferences in split-brain patients provide valuable information about the neurobiological correlates of the production of different gesture types.

Likewise, in healthy subjects spontaneous hand preferences reflect the activation of the contralateral hemisphere (Hampson and Kimura 1984; Verfaellie, Bowers, and Heilman 1988). Hampson and Kimura (1984) observed in right-handed healthy subjects a shift from right hand use in verbal tasks toward greater left hand use in spatial tasks. They suggested that the problem-solving hemisphere preferentially uses the motor pathways, which originate intrahemispherically. Consequently, the right hemisphere that primarily solves the spatial task employs the contralateral left hand. Indeed, in behavioral laterality experiments, when resources are sufficient for both decision and response programming, there is an advantage to responding with the hand controlled by the same hemisphere that performs the task (Zaidel et al. 1988). In the same line, right-handers prefer the left hand for self-touch gestures (Lausberg, Sassenberg, and Holle submitted). Self-touch gestures are displayed when individuals are stressed or emotionally engaged (Freedman and Bucci 1981; Freedman et al. 1972; Freedman and Hoffmann 1967; Freedman 1972; Lausberg 1995; Lausberg and Kryger 2011; Sainsbury 1955; Sousa-Poza and Rohrberg 1977; Ulrich 1977; Ulrich and Harms 1985). Further, the right hemisphere is activated more than the left during emotionally loaded or stressful situations (Ahern and Schwartz 1979; Berridge et al. 1999; Borod et al. 1998; Grunwald and Weiss 2007; Killgore and Yurgelun-Todd 2007; Stalnaker, Espana, and Berridge 2009). Thus, the left hand preference for self-touch reflects the right hemispheric activation during emotional engagement. It is noteworthy that if the body-focused activity includes the manipulation of body-attached objects, such as playing with a necklace, there is a significant right-hand preference (Lausberg, Sassenberg, and Holle submitted). This concurs well with the left hemispheric dominance for tool use (see 5. for detailed discussion).

However, in healthy subjects, if required the intact corpus callosum enables each hemisphere to exert control over the ipsilateral hand. Therefore, in studies on healthy subjects other factors have to be ruled out, which might require the use of a specific hand. These are as follows:

(i) handedness; recently, handedness is considered to be a multidimensional trait (Brown et al. 2006; Corey, Hurley, and Foundas 2001; Healey, Liedermann, and Geschwind 1986; Wang and Sainburg 2007). Right-handers typically show a left hand preference for movements, which rely on the axial musculature and involve strength and secure the accurate final position, while they prefer the right hand for movements, which require dexterity and fine motor coordination and control of trajectory speed and direction;

(ii) a semantic purpose, such as when talking about the left or right of two objects (Lausberg and Kita 2003);
(iii) cultural conventions, such as when Arrente speakers in Central Australia use the left hand to refer to targets that are on the left and vice versa (Wilkins and de Ruiter 1999). Likewise, in explicit gesture production, right-handers make 68% of reaches to left hemispace with the left hand (Bryden, Pryde, and Roy 2000);
(iv) an occupation of the right hand with some other physical activity, such as holding a cup of coffee.

If these factors are controlled for, in empirical studies on healthy subjects spontaneous hand preferences are a good indicator of hemispheric specialization.

2. Kimura's neuropsychological theory on the left hemispheric specialization for communicative gesture production

An important suggestion in the literature is Kimura's hypothesis (1973a, 1973b) that hand preference for free movements, i.e., communicative gestures, is determined by language lateralization in the two hemispheres. Kimura (1973a) noted that right-handers preferred the right hand in free movements that accompany speech (left : right ratio 10:31). Among left-handers, those with right ear advantage and inferred left hemisphere language used both hands for speech-accompanying gestures with a slight left hand preference (left : right ratio 48:42), and those with left ear advantage clearly preferred the left hand (left : right ratio 83:29) (Kimura 1973b). Thus, Kimura proposed that hand preference for communicative gestures was determined by speech lateralization in the cerebral hemispheres. More explicitly, right-handers prefer the right hand for communicative gestures because their left hemisphere controls certain oral (i.e., speech) as well as brachial movements (i.e., communicative gestures) (Lomas and Kimura 1976). However, in her theory, Kimura did not clearly distinguish between language comprehension, language production, and motor control of oral movements. She infers a lateralization of the control of "certain oral movements" in right-handers from dichotic examination. However, this provides indirect evidence at best, since dichotic listening tasks usually measure phonetic perception, which, in turn, may be associated with auditory language comprehension more than with other language functions (Zaidel, Clarke, and Suyenobu 1990). Kimura did not consider handedness as a factor that could influence hand preference for communicative gestures. She rejected the interpretation that language lateralization and handedness as independent additive factors would explain the patterns in the three groups. In her opinion, this assumption would not sufficiently explain the high number of right hand gestures in left-handers with left ear advantage. Instead, she suggested that in left-handers, both hands are used for gesticulation because of bilateral language representation, "where speech is not unilaterally organized, gesturing should also be manifested less unilaterally" (Kimura 1973b: 54). Since Kimura further suggested that gestures and speech were controlled by a common system, her hypothesis concerning left-handers would, strictly speaking, imply that if a left-hander gestured with his left hand he would rely on right hemisphere language and if he "spoke" with his left hemisphere he would use his right hand for gestures that accompany speech. This proposition would require further investigation. In addition, in Kimura's interpretation of the data, the exclusion of handedness as an independent additive factor is not well-founded.

A further limitation of Kimura's theory is the lack of an explanation for left hand gestures in right-handers. Even in those studies, which report a statistically significant right hand preference for right-handers, the percentage of left hand gestures in unimanual gestures ranges between 25 and 39% (Dalby et al. 1980; Kimura 1973a; Lavergne and Kimura 1987; Souza-Poza, Rohrberg, and Mercure 1979; Stephens 1983). In addition, in several studies on hand use in communicative gestures, either right hand preference was not significant (Lausberg and Kita 2003; Lavergne and Kimura 1987), or an equally frequent use of the right and left hands was reported (Blonder et al. 1995; Ulrich and Harms 1979).

To summarize, there is ample evidence to question Kimura's theory that speech and gestures are controlled by a common motor system that in right-handers is located in the left hemisphere.

3. Evidence for a right hemispheric generation of gestures

Since David McNeill's original idea to examine communicative gestures in split-brain patients up to now, communicative gestures have been analyzed in five subjects: N.G. (Lausberg et al. 2007; McNeill 1992; McNeill and Pedelty 1995), L.B. (McNeill 1992; McNeill and Pedelty 1995), A.A. and G.C. (Lausberg et al. 2007), and U.H. (Lausberg, Davis, and Rothenhäusler 2000; Lausberg et al. 2007). The right-handed patients A.A., N.G. (and presumably L.B.) had exclusively left hemispheric language production and left hemisphere praxis dominance. The same applies to U.H., but he was left-handed. G.C. had bihemispheric language production and he suffered from intermanual conflict. Therefore, he sometimes even sat on his left hand and exclusively used the right hand to prevent an intermanual conflict. This, in turn, influenced his overall pattern of hand preference for communicative gestures.

As stated above, in split-brain patients the right hand can only be controlled distinctly by the left hemisphere and vice versa, the left hand by the right hemisphere. According to Kimura's theory, namely that speech and gestures are controlled by a common motor system that in right handers is located in the left hemisphere, split-brain patients with left hemispheric language production should exclusively use the right hand for communicative gestures. However, the split-brain studies reveal that this is not the case. In McNeill's transcript on N.G. and L.B. (1992) it is documented that they gestured with both hands. A systematic investigation of hand preferences in split-brain patients (Lausberg et al. 2007) evidenced a retest-reliable left-hand preference for communicative gestures in the three patients A.A., N.G., and U.H., who had left hemisphere language dominance and left hemispheric specialization for praxis. The left-hand preference for communicative gestures cannot be interpreted as an unusual pattern of hand preferences resulting from callosal disconnection because similar patterns of hand preferences were observed in the two study control groups. The patients with complete callosal disconnection did not differ from patients with partial callosotomy and from healthy subjects with respect to number of total communicative gestures per minute, number of right hand gestures per minute, number of left hand gestures per minute, number of bimanual gestures per minute, and asymmetry ratio scores (Kimura 1973a) as a measure of hand preference. Thus, despite the fact that the split-brain patients were unable to use the left hand on verbal command (left verbal apraxia), they spontaneously preferred the left hand for communicative gestures. This data evidences that spontaneous communicative gestures can be generated in the right hemisphere independently from left hemispheric speech production.

Hence, the question arises what determines the hand choice for spontaneous communicative gestures. Thus far, factors other than speech dominance or handedness have rarely been investigated systematically. In the following sections, I will argue that the hand choice for different gesture types reflects the hemispheric lateralization of different cognitive and emotional functions, which the generation of the specific gesture types is associated with. The following review of empirical studies reveals distinct patterns of hand preferences for the different gesture types.

4. Specific hand preferences for different gesture types

The review of studies on hand preferences for gesture types is complicated by the fact that different researchers apply different gesture coding systems, the types of which show only partial conceptual overlap. Therefore, in the following review I will use Efron's seminal coding system (1972) as a frame of reference. It comprises the following categories: baton (emphasizing the beat pattern of the speech), deictic (pointing to a real or imagined object or indicating a direction), emblematic gestures (conventional signs having specific linguistic translation), physiographic with the subtypes iconograph (depicting a form) and kinetograph (depicting a movement), and ideographic (sketching a thought pattern). Please note that there is only a partial overlap between McNeill's concept of metaphorics and Efron's concept of ideographics. As there is no match for Efron's category of ideographics in other coding systems, if necessary in the following review this gesture type is summed up with physiographics under the term pictorial gestures.

McNeill's gesture type analysis of the split-brain patients N.G. and L.B. showed that beats emphasizing prosody (in Efron's terminology: batons) were performed mainly (N.G.) or exclusively (L.B.) with the left hand, whereas iconic gestures that pictured the verbal content (Efron's physiographics) were performed exclusively (N.G.) and mainly (L.B.) with the right hand (McNeill 1992; McNeill and Pedelty 1995). In the study by Lausberg et al. (2007), the four split-brain patients A.A., N.G., G.C., and U.H. produced batons and tosses (definition: Short up-down or circular movement of hand with upward or outward accent) more often with the left hand than with the right hand. Likewise, unilateral shoulder shrugs were displayed more often with the left shoulder than with the right. In contrast, pantomime gestures (definition: The speaker-gesturer him/herself pretends to perform a motor action, often referring to the use of a tool, e.g. tooth brushing, or the direct manipulation of an object or in adaptation to an imaginary surroundings) were displayed more often with the right hand in all four patients. In G.C. und U.H, deictics/directional gestures were produced more often with the right hand, whereas N.G. produced them more often with the left hand. Further analysis revealed that N.G consistently used the right hand when pointing to the right and the left hand when pointing to the left. A similar trend as in N.G. was found in U.H.. A.A. produced deictics/directional gestures infrequently with no hand preference. For physiographics, there was a right hand preference in G.C., N.G., and U.H., whereas for ideographics, there was a clear left hand preference in N.G. and U.H.. A context analysis was conducted only on U.H. (Lausberg, Davis, and Rothenhäusler 2000). U.H.'s left hand pictorial gestures occurred in speech pauses and reflected the ideational process (ideographics). In contrast, the right hand was used exclusively for pictorial gestures, which matched the verbal utterance semantically (physiographics) and temporally. U.H.'s unilateral shrugs of the left shoulder occurred frequently and in a context of lack of knowledge and resignation, whereas the rare unilateral shrugs of the right shoulder were performed when talking about the "right side". Furthermore, his right hand deictics only referred to the external space, whereas the left hand deictics occurred when the patient referred to himself.

Analogous hand preferences for the specific gesture types are observed in healthy subjects. Souza-Poza, Rohrberg and Mercure (1979) reported that in right-handers a right hand preference was only significant for the representational gestures (includes all of Efron's types except for batons), but not for the nonrepresentational gestures (Efron's baton). Stephens (1983) found a significant right hand preference for iconics, a non-significant right hand preference for metaphorics, as well as a non-significant left hand preference for beats (Efron's baton). In a study by Blonder et al. (1995), a right-handed control group showed a trend towards more right hand use for symbolic gestures (Efron's emblematic), whereas the left hand was used more often for expressive gestures (Efron's baton). In Foundas et al. (1995) study, a right-handed control group showed a significant right hand preference for content gestures (includes all of Efron's types except for batons and partly ideographic) and for emphasis gestures (Efron's baton) as well as a right hand trend for fillers (overlap with Efron's ideographic). Kita, de Condappa and Mohr (2007) reported a significant right hand preference for deictics (idem to Efron) and for depictive gestures (includes Efron's ideographic and physiographic), except for those depictive gestures that had a character viewpoint in a metaphor condition. For deictics, a right hand preference has been reported in healthy adults (Kita, de Condappa, and Mohr 2007; Wilkins and de Ruiter 1999) and in infants and toddlers (Bates et al. 1986; Vauclair and Imbault 2009). In a recent study by Lausberg, Sassenberg and Holle (submitted), a distinct pattern of hand preferences for different gesture types was found in 37 right-handed participants. In order to collect a broad spectrum of data, the participants were examined in two different communicative settings, i.e., during narrations of everyday activities and during semi-standardized interviews with personal topics. No hand preferences were found for self-deictics, body-deictics, directions, iconographics, batons, back-tosses, palm-outs, shrugs, and emblems. While there was a significant left hand preference for self-touch (see 1.), a significant right-hand preference was found for pantomimes, positions (Definition: The hand positions an imaginary object/subject at a specific location in an imaginary scene, which is projected into the gesture space.), traces (definition: The hand traces an imaginary line or contour), deictics to external loci, kinetographs, and body-attached object manipulation.

5. Hemispheric specialization for the production of different gesture types

The pattern of hand preferences as reported above for the different gesture types cannot be explained by handedness, because in all cited studies right-handers were investigated (only the split-brain patient U.H. was a left-hander, but his left-handedness did not substantially alter his pattern of hand preference for the different gesture types as compared to the right-handed patients A.A. and N.G.). The current theoretical models of handedness as a multidimensional trait serve to explain the complementary functions of the right and left hands during tool use and object manipulation, but they provide only little explanation for the hand choice in spontaneous gestures in communicative situations. The exception is that right-handers might prefer the right hand for those gesture types, which require a high degree of fine motor coordination and modulation of speed or direction. However, the execution of the right hand preference gesture types, such as deictics, pantomimes, positions, traces, kinetographs, or iconographs (see 4.) does not require more fine motor coordination than the execution of the gesture types with no hand preference, such as self-deictics, body-deictics, directions, ideographics, metaphorics, batons, back-tosses, palm-outs, shrugs, and emblems. In other words, the fact that the right and left hands are used to execute the latter gesture types is not due to kinesi simplicity. Thus, handedness cannot sufficiently explain the hand preferences for the different types of hand gestures, which are spontaneously displayed in communicative situations. With this viewpoint, I partly agree with Kimura (1973a), who rejected handedness as an independent additive factor that could influence the hand choice for free movements and self-touch. However, I suggest that especially in the case of kinesically complex gestures handedness is a co-factor that influences the hand choice.

The following paragraphs focus on the relation between hand preferences for the different gesture types and hemispheric lateralization for different cognitive and emotional functions, such as emotional processes, prosody, metaphorical thinking, and the tool use competence. It is noteworthy that there is a group of gesture types, i.e., batons, tosses, self-deictics, and shrugs, for which split-brain patients show a clear left hand preference and for which the right-handed healthy subjects show either a trend towards more left hand use or no hand preference. This suggests that in right-handed healthy subjects the effect of the right hemisphere generation of these gesture types, which is strongly suggested by the split-brain data, is attenuated because the intact corpus callosum potentially enables the right-handers to use the more dexterous right hand.

For *batons*, no hand preference or a trend towards more left hand use was found (Blonder et al. 1995; Lausberg et al. 2007; Lausberg, Sassenberg, and Holle submitted; McNeill 1992; Souza-Poza, Rohrberg, and Mercure 1979; Stephens 1983). The same applies to *back-tosses*, which set rhythmical accents just like batons (Lausberg et al. 2007; Lausberg, Sassenberg, and Holle submitted). The exception was Foundas et al. (1995), who reported a right-hand preference for emphasis gestures in 12 healthy subjects. Thus, two assumptions concerning the neuropsychology of batons and tosses are forwarded here:

(i) both hemispheres are equally competent to execute batons and tosses; or
(ii) the influence of right-handedness was attenuated by the right-hemispheric prosodic contribution to generation of these gesture types.

Indeed, as batons and tosses emphasize prosody, it can be hypothesized that their production is associated with the right hemispheric specialization for the production of emotional prosody and a contribution to prosodic fundamental frequency (e.g. Schirmer et al. 2001). Furthermore, in a functional magnetic resonance imaging (fMRI) study the right hemisphere planum temporale was identified as a region of beat/speech integration during perception (Hubbard et al. 2009). This interpretation of a major right hemispheric contribution to the production of batons contrasts McNeill's position that "non-imagistic beats" are generated in the "image-poor, language-rich left cerebral hemisphere" (1992: 345–7). McNeill's conclusion is surprising, because his investigation of N.G. and L.B. demonstrated that they mainly or even exclusively used the left hand for beats.

Deictics are displayed more often with the right hand than with the left hand (Bates et al. 1986; Kita, de Condappa, and Mohr 2007; Lausberg et al. 2007; Vauclair and Imbault 2009; Wilkins and de Ruiter 1999). Unfortunately, most of the studies do not report the target of the deictic (left space, right space, body part, the self), which makes it difficult to link the grove category of deictics to a specific cognitive function. In explicit gesture production, right-handers make 68% of reaches to left hemispace with the left hand (Bryden, Pryde, and Roy 2000) and Arrente speakers in Central Australia conventionally use the left hand to refer to targets that are on the left (Wilkins and de Ruiter 1999). In contrast to the right hand preference for deictics to external loci, no hand preference was found for body-deictics (definition: Pointing to a body part, often accompanied by gaze at the respective body part) and self-deictics (definition: Pointing to the sternum or chest, not accompanied by gaze) (Lausberg, Sassenberg, and Holle submitted). In a previous study on a split-brain patient, it was reported that the patient used his right hand for deictics, which referred to the external space, whereas the left hand deictics occurred when the patient pointed to himself (self-deictic) (Lausberg et al. 1999). Thus, it could be assumed that the right-handers' tendency to use the right hand for deictics is attenuated, when he/she refers to him-/herself. It is plausible that the generation of self-deictics is associated with more emotional engagement than the generation of most of the deictics, which refer to the external space. There is ample evidence that the right hemisphere plays the dominant role in emotional processing (Ahern and Schwartz 1979; Borod et al. 1998; Killgore and Yurgelun-Todd 2007), and it is well established that emotional expression is stronger on the left side of the face than on the right (Borod, Koff, and White 1983; Borod et al. 1998; Moscovitch and Olds 1982). Likewise, Moscovitch and Olds (1982) documented a shift towards more left hand use for communicative gestures, which were accompanied by an emotional facial expression, as compared to communicative gestures with no concurrent facial expression. In the same vein, Sousa-Poza, Rohrberg, and Mercure (1979) reported a shift towards more left hand use for communicative representational gestures when talking about personal topics versus unpersonal topics. Thus, the right hemispheric emotional engagement, which seems to be associated with the generation of these gesture types, induces a shift toward more left hand use.

Despite the fact that *shoulder shrugs* can be controlled by ipsilateral motor pathways, in a previous study on split-brain patients a left side preference for unilateral shrugs was documented (Lausberg et al. 2007). In healthy subjects, no side preference was found for unilateral shrugs. Shrugs are interactive signs with an emotional connotation, which often occur in the context of helplessness and resignation (Darwin [1890] 2009; Johnson, Ekman, and Friesen 1975). Thus, it is plausible that their generation is related to the right hemispheric specialization for emotional expression. Likewise, the split-brain patients U.H.'s unilateral shrugs of the left shoulder occurred frequently and in a context of lack of knowledge and resignation, whereas the rare unilateral shrugs of the right shoulder were performed when talking about the "right side" (Lausberg, Davis, and Rothenhäusler 2000).

The significant right hand preference for *pantomime* gestures (Lausberg et al. 2007; Lausberg, Sassenberg, and Holle submitted) is in line with lesion studies and functional neuroimaging studies, which demonstrate that the left hemisphere plays a central role in the generation of pantomime gestures on command in right-handers and left-handers. Split-brain patients demonstrated a left hand callosal apraxia when pantomiming on command to visual presentation of tools (Lausberg et al. 2003). Furthermore, patients with left hemisphere damage were more impaired in pantomiming tool use on command than right hemisphere damaged patients (De Renzi, Faglioni, and Sorgato 1982; Hartmann et al. 2005; Liepmann and Maas 1907). Neuroimaging studies demonstrated that independently of whether the right or left hand is used, pantomime is accompanied by left hemisphere activation (Choi et al. 2001; Hermsdörfer et al. 2007; Johnson-Frey, Newman-Norlund, and Grafton 2005; Moll et al. 2000; Ohgami et al. 2004; Rumiati et al. 2004). Lausberg et al. (2003) suggested that the generation of pantomime gestures relies on the specifically left hemispheric competence to link the movement concept for tool use with the mental representation of the tool.

There would be some reasons to assume a left hand preference for *trace* gestures, because visuo-constructive abilities are localized in the right hemisphere. Split-brain patients spontaneously choose the left hand for visuo-motor tasks (Graff-Radford, Welsh, and Godersky 1987; Lausberg et al. 2007; Sperry 1968;) and they show better performances with the left hand than with the right in these kind of tasks, e.g. when drawing the Taylor figure. Furthermore, in right-handed healthy subjects Hampson and Kimura (1984) observed a shift from right hand use in verbal tasks toward greater left hand use in spatial tasks. Likewise, for *position* gestures a right hemisphere advantage could be assumed because the right hemisphere is specialized for the conceptualization of imaginary scenes in the whole gesture space, while the left hemisphere neglects the gesture space left of the subject's body midline (Lausberg et al. 2003). However, for both gesture types, trace and position, a significant right hand preference was evidenced in the recent study by Lausberg, Sassenberg, and Holle (submitted). With regard to gesture type phenomenology, it could be hypothesized that trace and position gestures are derived from pantomime gestures. Trace gestures can be regarded as body-part-as-object pantomimes, i.e., as pantomiming "drawing" with the index used as if it were a pen (Alternatively, in an evolutionary scenario it could hypothesized that first the finger was used and then it was replaced by a pen [C. Müller, personal communication]). In the same vein, the position gesture could be the pantomime of placing something. Thus, trace and position gestures might originate from pantomimes or even further from tool use or direct object manipulation. However, in contrast to the actual pantomime gestures, in which the gesturer pretends to act, e.g. "I am drawing" or "I am positioning", the gestural message of trace and position gestures focuses on the contour, which is created, e.g. "a square", or on the position, which is marked in an imaginary scene, e.g. "here is [the church], and behind it, there is [the super market]". The present data indicate that despite the fact that the gestural information is primarily of spatial nature, the origin of the gesture type, which is here the left hemispheric function pantomiming, or in other words, the "gestural mode of representation" (Müller 2001) overruns the impact of the right hemispheric spatial contribution.

The data comparison for *pictorial gestures* is complicated by the fact that researchers here use quite different concepts (Efron: iconographics, kinetographics, ideographics; McNeill: iconic, metaphoric). In general, for pictorial gestures, there is a significant right hand preference (Foundas et al. 1995; McNeill 1992; Lausberg et al. 2007; Souza-Poza, Rohrberg, and Mercure 1979; Stephens 1983). However, metaphoric use (Kita, de Condappa, and Mohr 2007; Stephens 1983) and ideographic use (Lausberg et al. 2000; Lausberg et al. 2007) induce a shift toward more left hand use. This observation concurs with the dominant role of the right hemisphere for the processing of conventionalized metaphors (e.g. Ferstl et al. 2008; Mashal and Faust 2009).

6. Conclusion

The split-brain data provide evidence that spontaneous communicative gestures can be generated in the right hemisphere independently from left hemispheric speech production. Furthermore, split-brain patients as well as healthy subjects show distinct hand preferences for specific gesture types. While right-handers prefer the right hand for deictics, pantomimes, traces, positions, and for concrete pictorial gestures, they prefer the left hand or no hand for self-deictics, batons, tosses, shrugs, and ideographics/metaphorics. Neither handedness nor speech-lateralization can explain the distinct pattern of hand preferences. Instead, I argue that the hand preferences for the different gesture types reflect the lateralization of cognitive and emotional functions in the left and right hemispheres, which are associated with the production of these gesture types. Some of the right hand preference gesture types are characterized by a close relation to tool use, which is a primarily left hemisphere competence. In contrast, the left hand preference gesture types are related to the right hemispheric competences for prosody, emotional processes, and metaphorical thinking. The substantial right hemispheric contribution to the generation of these gesture types attenuates the right-handers' right hand preference or even induces a left preference. Thus, I suggest that some gestures, which are spontaneously displayed in communicative situations, directly emerge from right hemispheric emotional processes, processes underlying prosody, and metaphorical thinking.

7. References

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11. Cognitive Linguistics: Spoken language and gesture as expressions of conceptualization

Abstract

Speakers of oral languages use not only speech but also other kinds of bodily movements when they communicate. From the perspective of cognitive linguistics, all of these behaviors can provide insight into speakers' ongoing conceptualizations of the physical world and of abstract ideas. Increasing attention is being paid in Cognitive Linguistic (CL)

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