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Social cues, mentalizing and the neural processing of speech accompanied by gestures

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ABSTRACT

Body orientation and eye gaze influence how information is conveyed during face-to-face communication. However, the neural pathways underpinning the comprehension of social cues in everyday interaction are not known. In this study we investigated the influence of addressing vs. non-addressing body orientation on the neural processing of speech accompanied by gestures.

While in an fMRI scanner, participants viewed short video clips of an actor speaking sentences with object- (O; e.g., shape) or person-related content (P; e.g., saying goodbye) accompanied by iconic (e.g., circle) or emblematic gestures (e.g., waving), respectively. The actor's body was oriented either toward the participant (frontal, F) or toward a third person (lateral, L) not visible.

For frontal vs. lateral actor orientation (F > L), we observed activation of bilateral occipital, inferior frontal, medial frontal, right anterior temporal and left parietal brain regions. Additionally, we observed activity in the occipital and anterior temporal lobes due to an interaction effect between actor orientation and content of the communication (PF > PL) > (OF > OL).

Our findings indicate that social cues influence the neural processing of speech–gesture utterances. Mentalizing (the process of inferring the mental state of another individual) could be responsible for these effects. In particular, socially relevant cues seem to activate regions of the anterior temporal lobes if abstract person-related content is communicated by speech and gesture. These new findings illustrate the complexity of interpersonal communication, as our data demonstrate that multisensory information pathways interact at both perceptual and semantic levels.

1. Introduction

Human communication is composed of both linguistic information (words and sentences) and pragmatic information (non-verbal actions such as gestures, facial expressions, body orientation and eye gaze; e.g., Holler & Beattie, 2003). Of such pragmatic information, the direction in which a speaker's body is oriented is particularly important during face-to-face interaction. For instance, in a group setting a speaker may position his or her body towards a particular person and compose his or her gestures expressly for that listener (see Özyürek, 2002). In this way, the speaker uses his or her body to guide communication.

The impact of these non-verbal signals on the listener is poorly understood. In particular, little research has been done on the neural substrates responsible for processing body orientation and gestures during verbal communication. Kilner, Marchant, and Frith (2006) used magnetic encephalography (MEG) techniques to investigate the effect of body orientation (forward vs. backward actor position) on the processing of arm and hand movements. They found that the observation of arm and hand movements interact with the social relevance of the body orientations (forward > backward presented actor) in parietal brain regions. This study showed that the brain processes underlying the observation of simple arm and hand movements are affected by social relevance (as operationalized by the speaker's body's orientation). However, the influence of social relevance at more complex levels of speech and gesture processing is unknown.

Previous studies on the perception of social cues have focused on mentalizing (the process of inferring the mental state of another person) triggered, for example, by gaze direction (e.g., Kampe, Frith, & Frith, 2003). Mentalizing is thought to rely on a neural system comprised of the paracingulate cortex, the temporal poles, and the superior temporal sulcus at the temporo-parietal junction (Baron-Cohen et al., 1999; Brunet, Sarfati, Hardy-Bayle, & Decety, 2000;

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Castelli, Happeỉ, Frith, & Frith, 2000; Fletcher et al., 1995; Frith, 2001; Vogeley et al., 2001). Kampe et al. (2003) showed that signals indicating an intention to communicate (such as calling a person's name or making eye contact) activate the paracingulate cortex and bilateral temporal poles. Furthermore, Bristow, Rees, and Frith (2007) demonstrated that social context affects an individual's neural response to gaze shifts. In their study, social context was manipulated by the gaze of a face presented to participants immediately before target (point on the periphery of the screen) onset. This face was either focused on (social) or averted from (non-social) the participant before the target appeared. They found greater activation in the medial prefrontal cortex and precuneus when participants correctly shifted their gaze toward the target in the social context, but found no activation when participants shifted their gaze in the non-social context. These neural responses to non-verbal cues such as eye gaze (e.g., Kampe et al., 2003), body orientation, or gesture (Özyürek, 2002) may aid an individual in recognizing others' intentions to communicate. This research suggests that non-verbal social cues may play an important role in language comprehension during face-to-face interactions.

Gestures that communicate information often accompany verbal dialogue (e.g., Goldin-Meadow, 1999; Kendon, 2004) and widely differ in their content (e.g., Efron, 1972; Kendon, 1997; McNeill, 1992, 2005). One important type of gesture, emblems (Ekman & Friesen, 1969; "emblematic gesture" Efron, 1972) (such as the hand signal for "OK" or the "thumbs-up" motion) do not bear any physical similarity to what they signify. Even though emblems are meaningful in and of themselves, they often accompany speech. In everyday conversation, emblematic gestures are often used to express information about social life or interpersonal situations. They refer to relatively abstract concepts, such as feelings (e.g., the strike gesture), evaluations (e.g., thumbs down) or orders (e.g., beckoning somebody over) and contain information regarding people. Another type of communicative gesture, iconic gestures (terminology of McNeill, 1992) resemble what they convey, such as when someone stretches his hands apart to indicate width, to illustrate a shape (e.g., circle) or to demonstrate a movement (e.g., a rotation). Iconic gestures generally refer to concrete and descriptive properties of objects rather than abstract interpersonal information.

The neural processes that underlie the perception and comprehension of gestures that accompany speech (co-verbal gestures) have received increasing interest in the field of neuroscience (e.g., Dick, Goldin-Meadow, Hasson, Skipper, & Small, 2009; Green et al., 2009; Holle, Gunter, Rüschemeyer, Hennenlotter, & Iacoboni, 2008; Hubbard, Wilson, Callan, & Dapretto, 2009; Kelly, Creigh, & Bartolotti, 2009; Kircher et al., 2009a; Skipper, Goldin-Meadow, Nusbaum, & Small, 2009; Straube, Green, Weis, Chatterjee, & Kircher, 2009; Willems, Ozyurek, & Hagoort, 2007, 2009). While the first studies in this area investigated iconic co-verbal gestures (Green et al., 2009; Holle et al., 2008; Willems et al., 2007), newer investigations have focused on gestures paired with abstract sentences (metaphoric co-verbal gestures; Kircher et al., 2009a; Straube et al., 2009). The findings from these studies suggest that the left posterior temporal lobe is involved in integrating iconic gestures with associated concrete verbal content (Green et al., 2009; Holle et al., 2008) as well as integrating metaphoric gestures with related abstract verbal information (Kircher et al., 2009a). Additionally, activation of the left IFG appears to be especially important for processing gestures that accompany abstract verbal information (Kircher et al., 2009a; Straube et al., 2009) or when the integration load is high, as it is for mismatch manipulations (Green et al., 2009; Willems et al., 2007). Though research has been done on the processing of iconic and metaphoric co-verbal gestures, past studies have not investigated the processing of speech accompanied by emblematic gestures or the influence of social cues on the processing of speech and gestures.

Iconic gestures relay concrete object-related information, whereas emblematic gestures convey abstract person-related information. These types of gesture may therefore be processed in relatively distinct brain areas. Past research suggests that the processing of person-related information calls upon bihemispheric neural pathways, while the processing of object-related knowledge is less affected by right hemispheric lesions (Lambert, Swain, Miller, & Caine, 2006). Additionally, past research on the semantic processing of living and non-living concepts suggests that the right hemisphere is slightly better at processing living concepts than it is at processing object-related content (e.g., Pilgrim, Moss, & Tyler, 2005). Furthermore, medial frontal regions were found to be more involved in making judgments about people than in making judgments about objects (Yoon, Gutchess, Feinberg, & Polk, 2006) or animals (e.g., Mason, Banfield, & Macrae, 2004). Finally, due to their abstractness, emblematic gestures are more likely to be processed in anterior brain regions than are iconic gestures, as suggested by results from past research on metaphoric gestures (Kircher et al., 2009a). In addition to differences in content, iconic and emblematic gestures may also differ in their form and physical features. This may be because emblematic gestures are rather symbolic (e.g., the okay, thumbs-up, or victory gestures) in comparison to iconic gestures, which describe physical characteristics of an object (e.g., drawing a circle in the air to represent a ball or stretching the hands apart to illustrate width). Therefore, emblematic gestures are often comprised of less extended movements than iconic gestures, which could lead to different mechanisms of perceptual neural processing.

Several issues regarding this area of research are still unresolved. It has yet to be shown if social cues affect the processing of speech–gesture communications, if brain regions implicated in mentalizing are involved in these processes, and if these processes are independent of the content of the communication. By a factorial manipulation of actor orientation (frontal vs. lateral) and speech–gesture content (person- vs. object-related content) we hope to shed light on the effects of social cues on the neural processing of speech–gesture utterances. We tested the following alternative hypotheses: first, if mentalizing processes elicited through social cues in natural communication situations are universal, then we predict consistent neural signatures across different types of communication content. However, if mentalizing processes are dependent on the context of communication, we predict distinct effects on the neural processing of natural speech–gesture utterances with either object- or person-related content.

Specifically, we hypothesized that the neural processing of social cues (when the actor is addressing the participant; frontal [F] > lateral [L]) is predominantly performed by regions that are involved in mentalizing processes (e.g., Kampe et al., 2003). With regards to the communication content, we predicted that left posterior temporal and occipital regions would be involved in the processing of iconic gestures with object-related content (O > P; e.g., Green et al., 2009; Holle et al., 2008). In contrast, we predicted that the processing of emblematic gestures with person-related content (P > O) would yield activity in the temporal poles due to social and emotional processing (e.g., Olson, Plotzker, & Ezzyat, 2007; Zahn et al., 2007, for a review), in medial frontal structures due to the processing of person-related information (e.g., Mason et al., 2004; Mitchell, Heatherton, & Macrae, 2002; Yoon et al., 2006) and in the left inferior frontal gyrus due to the processing of abstract speech and gestures (e.g., Kircher et al., 2009a).

Mentalizing processes should be relatively unaffected by the content of the communication if they reflect universal processes in response to social cues. However, if they are in fact dependent on the communication content, this would lead to an interaction effect between both factors (actor-orientation and communication content) and unique patterns of activation for actor orientation in person- and object-related content conditions.