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On predicting others' words: Electrophysiological evidence of prediction in speech production

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ABSTRACT

The present study investigated whether lexical processes that occur when we name objects can also be observed when an interaction partner is naming objects. We compared the behavioral and electrophysiological responses of participants performing a conditional go/no-go picture naming task in two different conditions: individually and jointly with a confederate participant. To obtain an index of lexical processing, we manipulated lexical frequency, so that half of the pictures had corresponding names of high-frequency and the remaining half had names of low-frequency. Color cues determined whether participants should respond, whether their task-partner should respond, or whether nobody should respond. Behavioral and ERP results showed that participants engaged in lexical processing when it was their turn to respond. Crucially, ERP results on no-go trials revealed that participants also engaged in lexical processing when it was their partner's turn to act. In addition, ERP results showed increased response inhibition selectively when it was the partner's turn to act. These findings provide evidence for the claim that listeners generate predictions about speakers' utterances by relying on their own action production system.

1. Introduction

Many joint actions require that we anticipate others' actions: Think of playing a piano duet, dancing a tango or walking through a narrow doorframe together. It is quite easy to imagine the consequences of not predicting in advance whether our partner will take the first turn crossing the doorframe or whether he/she will leave the first turn to us. The same is true for a conversation, which constitutes a paradigm case of joint action (Clark, 1996; Garrod & Pickering, 2004). When having a conversation, predicting others' verbal actions and integrating them in our own action plan is key. In the present article we explore the involvement of the production system in predicting another's verbal actions.

It has been suggested that predicting others' actions involves processes that are also engaged in the planning and performance of one's own actions (e.g., Knoblich, Butterfill, & Sebanz, 2011). There is considerable evidence for the engagement of motor representations not only during action perception (e.g., Rizzolatti & Craighero, 2004)

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but also during anticipation of others' actions (Aglioti, Cesari, Romani, & Urgesi, 2008; Kourtis, Sebanz, & Knoblich, 2013; Ramnani & Miall, 2003; van Schie, Mars, Coles, & Bekkering, 2004). This evidence supports the assumption that interaction partners predict each other's actions through motor simulation (Wilson & Knoblich, 2005). Forward models in the motor system allowing one to predict one's own actions may also enable the prediction of others' actions at multiple levels (Wolpert, Doya, & Kawato, 2003; see also, Brown & Brüne, 2012, for a review).

This interweaving of action and action perception has recently been spelled out for the role of language production in conversational contexts. According to Pickering and Garrod (2007) (see also, Gambi & Pickering, 2011; Pickering & Garrod, 2013, for reviews) the language production system generates forward models (imitative plans) at specific levels of representation, including semantics, syntax, and phonology, to predict utterances during language comprehension. However, apart from studies revealing the involvement of motor processes during speech perception (e.g., Fadiga, Craighero, Buccino, & Rizzolatti, 2002; *motor theories of speech perception*, see Hickok, 2012), little is known about the exact role that our production system plays in predicting others' utterances, especially at more abstract levels of representation (e.g., lexical) where articulation is not present. The main objective of the present study was to investigate whether lexical processes in speech production are involved during the anticipation of a task-partner's utterance. To achieve this aim, a task sharing paradigm (see below) was adapted to a picture naming task (hereafter *joint picture naming task*) in which pictures had to be named either by a participant, by a task-partner, or by no one (depending on the color in which the pictures were presented).

Task sharing paradigms have been used to study a particular process of joint action, namely action planning (Knoblich et al., 2010). Very briefly, this experimental approach consists in two individuals performing independent tasks in a shared setting. Importantly, since participants are not explicitly required to coordinate their actions, the task sharing paradigm provides a conservative estimate of the extent to which people engage in planning not only their own actions, but also their task-partner's actions.

The main observation from task sharing studies has been that two individuals performing one part of a task each show a similar pattern of performance as one individual performing both parts on her own (e.g., Sebanz, Knoblich, & Prinz, 2003; Welsh, 2009). This was first demonstrated using a spatial compatibility task (Simon, 1990) where participants are instructed to respond to stimulus color (e.g., left key press for red and right key press for green stimuli) and to ignore stimulus location. When participants perform this task alone, they show faster responses when the irrelevant stimulus location and the spatial location of the response to be given to stimulus color overlap. Sebanz et al. (2003) developed a social version of the compatibility task and compared participants' performance in two conditions: an individual go/no-go condition in which the participant was alone in the room and was instructed to respond only to one of the colors (e.g. respond to red) and to do nothing for the other color (e.g. do not respond to green) and a joint go/no-go condition in which participants performed the task with a partner. Importantly, the task for the participant was the same as in the individual go/no-go condition (e.g. respond only to red). The only difference was that the partner was instructed to perform the complementary task (e.g. respond to green). Sebanz et al. (2003) showed a spatial compatibility effect in the joint condition (similar to the standard individual condition in which the participant was instructed to perform both tasks), but not when the participant was performing the task alone. This has been taken to indicate that our own actions and others' actions are planned in a functionally similar manner (Welsh, 2009).

Electrophysiological studies have also employed the task sharing paradigm to investigate what happens during no-go trials that do not require a response from the participant, but from his or her task-partner. The relevant comparison here is between these no-go trials the task-partner needs to respond to and a second set of no-go trials that neither the participant nor the task-partner needs to respond to. Larger amplitudes of the so-called No-Go P300 (actually peaking around 450–550 ms after stimulus onset; Sebanz, Knoblich, Prinz, & Wascher, 2006; Tsai, Kuo, Hung, & Tzeng, 2008; Tsai, Kuo, Jing, Hung, & Tzeng, 2006) have been reported for no-go trials that require the task-partner to respond compared to those that nobody responds to. This No-Go P300 modulation has been taken as an index that the other's action is planned, and that, consequently, inhibitory action control processes are required to ensure that participants do not act when it is the other's turn.

Although several different versions of the task sharing paradigm have been developed and yielded a rich set of behavioral and electrophysiological findings (for an overview, see Obhi & Sebanz, 2011; Wenke et al., 2011), it still remains unclear which aspects of the other's task are included in our own planning. The crucial question is to what extent people mentally perform the other's task when it is not their own turn, but their task-partner's turn to act. According to the *actor co-representation* account (Dolk et al., 2011; Philipp & Prinz, 2010; Vlainic, Liepelt, Colzato, Prinz, & Hommel, 2010; Wenke et al., 2011), task-partners form a representation that specifies which events they are responsible for and which events require their partner to act (e.g., red: me; green: you). The *task co-representation* account (Atmaca, Sebanz, & Knoblich, 2011; Sebanz, Knoblich, & Prinz, 2005) claims that representations of another's task specify not only *when* the other needs to act, but also *what* she needs to be doing (e.g., green: task-partner needs to press right key). Despite several attempts, previous studies have largely failed to find conclusive evidence for task co-representation since the joint compatibility effect described above can be explained as a result of representing when it is the co-actor's turn (Philipp & Prinz, 2010; Wenke et al., 2011) or even just being sensitive to her spatial location (Dittrich, Dolk, Rothe-Wulf, Klauer, & Prinz, 2013; Dolk et al., 2011).

The fact that unlike other forms of action, language is inherently social and has been very well characterized in