Neuropsychologia 84 (2016) e2–e12

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

Neural correlates of second-language communication and the effect of language anxiety

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ARTICLE INFO

Keywords:
Speech production
Verbal communication
Second language
Social skill
Anxiety

ABSTRACT

Communicative speech is a type of language use that involves goal-directed action targeted at another person based on social interactive knowledge. Previous studies regarding one's first language (L1) have treated the theory of mind system, which is associated with understanding others, and the sensorimotor system, which is associated with action simulation, as important contributors to communication. However, little is known about the neural basis of communication in a second language (L2), which is limited in terms of its use as a communication tool. In this fMRI study, we manipulated the type of speech (i.e., communication vs. description) and the type of language (L1 vs. L2) to identify the specific brain areas involved in L2 communication. We also attempted to examine how the cortical mechanisms underlying L2 speech production are influenced by oral proficiency and anxiety regarding L2. Thirty native Japanese speakers who had learned English as an L2, performed communicative and descriptive speech-production tasks in both L1 and L2 while undergoing fMRI scanning. We found that the only the L2 communication task recruited the left posterior supramarginal gyrus (pSMG), which may be associated with the action simulation or prediction involved in generating goal-directed actions. Furthermore, the neural mechanisms underlying L2 communication, but not L2 description, were sensitive to both oral proficiency and anxiety levels; a) activation in the left middle temporal gyrus (MTG) increased as oral proficiency levels increased, and b) activation in the orbitofrontal cortex (OFC), including the left insula, decreased as L2 anxiety levels increased. These results reflect the successful retrieval of lexical information in a pragmatic context and an inability to monitor social behaviors due to anxiety. Taken together, the present results suggest that L2 communication relies on social skills and is mediated by anxiety and oral proficiency.

1. Introduction

Communicative speech is a type of goal-directed language use that is understood as contextualized action (Holtgraves, 2002). The ability to communicate relies on social learning, which involves participation in communication through observation, imitation, and execution (Lieven and Tomasello, 2008). Because one's first language (L1) has been acquired through social interactions with others since early infancy, L1 communication is believed to be an effortless, spontaneous, and automatic process. This contrasts with most second languages (L2), because L2 use is affected by various external and internal factors, including the means by which L2 was learned (e.g., social interaction or grammatical translation), limited L2 proficiency, lack of exposure to communicative contexts, and learners' anxiety about L2 use. For example, L2 linguistic knowledge learned through traditional grammar instruction is not sufficiently available for use in actual communication (Ellis et al., 2009; Segalowitz, 2010). Anxiety is also an important contributor the quality and quantity of communication in L2 (Dewaele, 2013; Horwitz, 2010). Although many L2 researchers have emphasized that L2 communication should be acquired through intensive practice in social interactive contexts (Bardovi-Harlig and Bastos, 2011; Dekeyser, 2007; Segalowitz, 2010), little is known about the neural basis of L2 communication.

DOI of original article: http://dx.doi.org/10.1016/j.neuropsychologia.2014.11.013
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http://dx.doi.org/10.1016/j.neuropsychologia.2016.02.012
0028-3932/

Most previous L2 neuroimaging studies have focused exclusively on the linguistic aspects (e.g., syntactic construction, lexical selection) of word- and sentence-level production (Abutalebi, 2008; Golestani et al., 2006; Indefrey, 2007) and have not devoted sufficient attention to language use as a social action. These studies have reported greater involvement of the left inferior prefrontal and left parietal areas, which are assumed to be language-related regions, in L2 than in L1 production. The present study aimed at investigating the cortical mechanisms involved in the production of communicative speech in L2, comparing the production of descriptive speech in L2 with that in L1 production. It is true that both communicative and descriptive utterances are produced using linguistic rules, such as those related to vocabulary and grammar, but people generate communicative utterances based on internal goals in certain contexts. Thus, communicative speech involves knowledge and skill related to social interactions, such as the ability to "read" others' intentions and predict the consequences of speech acts (Noordzij et al., 2010; Pulvermüller et al., 2014). To consider possible candidate neural circuits for L2 communication, the following sections briefly review previous L1 communication studies focused on two key neural systems: the theory-of-mind system that underpins the ability to "read" the minds of others and the sensorimotor area involved in action simulation.

Previous neuroimaging studies on L1 communication have provided evidence that the theory-of-mind system, including the medial prefrontal cortex (mPFC), the posterior superior temporal sulcus (pSTS), the temporal pole (TP), and the precuneus, plays an important role in understanding or generating communicative messages by inferring and monitoring the intentions or beliefs of others based on the social context (Noordzij et al., 2010; Sassa et al., 2007; Willems et al., 2010). According to Sassa et al. (2007), these theory-of-mind-related areas showed greater activation when subjects communicated with others (i.e., during a communication task) than when they simply described to others what was happening (i.e., during a description task). In their study, both tasks involved speech production, but only the communicative task involved an intentional communicative component in the speech produced. Willems et al. (2010) also found that generating communicative messages directed toward someone else was more strongly associated with the mPFC than was the performance of linguistically modulated tasks (i.e., semantic difficulty), and these areas seemed to be less sensitive to linguistic difficulty and more related to general social interactive knowledge (Noordzij et al., 2010; Willems et al., 2010). Therefore, it is important to investigate whether and how communication in L2 also relies on the theory-of-mind system to generate appropriate communicative messages.

Recent neuroimaging studies have reported that the fronto–parietal motor areas are important for processing communicative speech because communicative speech is a goal-directed activity targeted at another person and thus includes embodied action sequences (Egorova et al., 2014; Pulvermüller et al., 2014; van Ackeren et al., 2012). For example, Egorova et al. (2014) examined how brain responses differed when the same message was uttered in two different contexts (i.e., requesting vs. naming), which induced different action sequences. They showed that the requesting but not the naming condition activated the fronto–parietal sensorimotor area after the onset of the speech act. van Ackeren et al. (2012) also found that motor areas (including the inferior parietal lobule) were involved in comprehending an indirect request (e.g., "It is hot in here," conveying an indirect request that the hearer open a window) compared with when the same message was uttered as a descriptive sentence (e.g., "It is hot in here," literally meaning that the temperature is high). Although interpretations of these findings differed slightly among these researchers, it is clear that action simulation or predictions about efferent copies generated by prior experience are activated in the sensorimotor areas during communicative speech processing and thus facilitate understanding and production of communicative utterances (Glenberg and Gallese, 2012; Pickering and Garrod, 2013; Pulvermüller et al., 2014). Processing simulations or predictions may be important for the acquisition of pragmatic knowledge related to typical action sequences, dialog schemas, or discourse conventions in language development (Pickering and Garrod, 2013; Pulvermüller et al., 2014). It has been suggested from a developmental perspective that motor skills are important for acquiring communication skills (McCleery et al., 2013; Oberman and Ramachandran, 2007). In a similar vein, behavioral L2 studies have supported the notion that improved communicative ability in L2 requires that learners engage in interpersonal activities with others using the target language (Bardovi-Harlig and Bastos, 2011). Consistent with this reasoning, we hypothesized that the fronto–parietal motor areas would be essential to the acquisition of L2 communicative skills and that these areas would exert greater demands while individuals communicated in L2 than when they did so in L1 due to differences in interactive experiences with these two languages.

According to psycholinguistic models of speech production, a speaker needs to pass through a number of processing stages, including conceptual preparation and preverbal message generation, followed by linguistic formulation and morpho–phonological and phonetic encoding (De Bot, 1992; Levelt, 1999). L1 communication requires controlled attention to planning preverbal messages based on a speaker's factual knowledge about the external world and his/her knowledge about the interlocutor's internal state of mind (theory of mind). However, the rest of speech processing, such as the formulation of linguistic information and actual articulation, can operate automatically, in the absence of the speaker′s conscious monitoring (Levelt, 1999). In contrast, L2 speech production generally requires controlled processing during conceptualization, formulation, and articulation due to limited L2 proficiency (De Bot, 1992; Segalowitz, 2010). De Bot (1992) also argued that even L2 speakers who seem to engage in conceptual preparation with ease may not know how to convey their intended messages due to their lack of L2 proficiency and relatively infrequent experiences using that language in social contexts. Thus, L2 speakers need to strategically formulate a preverbal message in a way that compensates for their limited abilities and experiences using L2 for communicative purposes. Retrieving appropriate pragmatic knowledge and expressions from one's mental lexicon involves greater cognitive demands in L2 than in L1.

By manipulating the type of speech (communication vs. description) and the type of language (L1 vs. L2) in an experimental setting, we attempted to investigate the brain areas sensitive to communicative speech production irrespective of language type and to identify those sensitive to language type irrespective of speech type. We also aimed to determine the specific brain areas associated with L2 communication by examining the interaction between language type and speech type. These areas may serve as an important neural circuit in the acquisition of communicative skills (i.e., knowing how to use language as a social tool). We recruited 30 Japanese native speakers who learned English as L2 and had limited opportunities to use English outside the classroom. They were asked to casually talk to an actor in a video (i.e., a communication task) or describe an actor's situation (i.e., a description task) in both L1 and L2 while undergoing functional magnetic resonance imaging (fMRI). We also examined how the neural correlates of L2 speech production are influenced by L2 oral proficiency and anxiety levels. We evaluated L2 communicative ability by administering a validated oral proficiency test outside the fMRI and measured the level of anxiety associated with daily