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Do we embody second language? Evidence for 'partial' simulation during processing of a second language

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A B S T R A C T

The present paper investigates whether the processing of emotion language in the context of a second language (L2) entails motor simulations and whether simulation models extend to negation also for L2. Participants were exposed to sentences in L2 describing emotional expressions while facial muscle activity was continuously measured. Sentences mapped either directly upon the *zygomatic* muscle (e.g., "I am smiling") or did not (e.g., "I am frowning"), and were presented in the affirmative and negative form. Similarly to studies involving first language (L1), the zygomatic muscle was activated when reading affirmative sentences relevant to the muscle. In contrast, and differently from what previously observed in L1, reading sentences in the negative form ("I am not smiling") did not lead to relaxation/inhibition of the zygomatic muscle. These results extend the simulation models to the comprehension of L2 but they also provide important constraints and contribute to the debate about grounding of the abstract and concrete concepts.

1. Introduction

The ability to share, to communicate, and to understand emotions is fundamental for our social life (Dewaele, 2008; Fussell, 2002; Rimé, 2007). Language is a powerful emotion elicitor (Velten, 1968), it can affect judgments (Johnson & Tversky, 1983) and, therefore, have important implications for face-to-face communication (Kawakami, Phills, Steele, & Dovidio, 2007). However, research on emotion language (i.e., emotion words, emotion-loaded words, descriptions of emotion-related events and emotion discourse) has characteristically focused on native language (L1). According to different theories, second language (L2) either uses the same or different mechanisms and neural substrates as L1. In order to advance our understanding of L2 processing and, as a result, also of L1 processing, the present paper investigates motor simulations during the comprehension of emotion language in the context of L2 (see Zwaan & Taylor, 2006).

1.1. Simulation during language comprehension

A fundamental question in cognitive neuroscience concerns the role of sensory and motor information in representing conceptual knowledge in the brain and in understanding objects, actions and words (see Tomasino & Rumiati, 2013).

The investigation of the neural system underpinning language processing has identified a network of brain areas including frontal and temporal left-hemisphere regions that, together with subcortical structures, are differentially involved in specific aspects of linguistic computation, from word level to sentence processing (Friederici, 2002; Ojemann, 1991; Poeppel & Hickok, 2004). The neurobiological models suggesting that these areas operate autonomously from other brain areas (e.g., modality-specific ones; Pylyshyn, 1980) largely fall into the traditional linguistic notions that language operates on abstract representations via formal rules (cf. Vukovic & Shtyrov, 2014) and does not benefit from the functional contributions of the sensorimotor system (e.g., Fodor, 1983).

However, recent theoretical arguments and an increasingly rich set of converging research findings together suggest that the processing of language may entail also the automatic recruitment of sensorimotor systems (Baumeister, Rumiati, & Foroni, 2015; Boulenger et al., 2006; Buccino, Riggio, Melli, Gallese, & Rizzolatti, 2005; De Grauwe, Willems, Rueschemeyer, Lemhöfer, & Schriefers, 2014; Filimon, Nelson, Hagler, & Sereno, 2007; Fischer & Zwaan, 2008; Foroni & Semin, 2009; Gentilucci & Gangitano, 1998; Glenberg & Kaschak, 2002; Glover & Dixon, 2002; Hauk, Shtyrov, & Pulvermüller, 2008; Quené, Semin, & Foroni, 2012; Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012; Moseley, Carota, Hauk, Mohr, & Pulvermüller, 2011; Pulvermuller, 2005;

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Winkielman, Niedenthal, & Oberman, 2008; Zwaan & Taylor, 2006). In general, neuroimaging research shows the involvement of the primary motor cortex (BA 4) in the processing of action verbs (e.g. Hauk, Johnsrude, & Pulvermuller, 2004; Kemmerer, Castillo, Talavage, Patterson, & Wiley, 2008; Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005; Pulvermüller, Shtyrov, & Ilmoniemi, 2005). Studies using transcranial magnetic stimulation (TMS) find that motor-evoked potentials (MEPs) recorded from hand muscles change when stimulation is applied on the hand motor area following action language presentation (e.g., Buccino et al., 2005). Additionally, several studies report involvement of the premotor cortex (BA 6) in action language comprehension (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Hauk et al., 2004; Tettamanti et al., 2005).

These findings are regarded as evidence in support of embodiment theories, which claim that conceptual knowledge is grounded in sensory–motor systems (Barsalou, 1999, 2008; Gallese & Lakoff, 2005; but see Mahon & Caramazza, 2008). Researchers holding this opinion claim that language processing is mediated by implicit motor simulations (Barsalou, 1999, 2008; Simmons, Hamann, Harenski, Hu, & Barsalou, 2008; Willems & Casasanto, 2011) and shares a common neural substrate with actual motor processing (Gallese & Lakoff, 2005). Namely, understanding a sentence like “I am smiling” entails in the comprehender the embodied sensorimotor simulations of the content described by linguistic utterances (e.g., de Zubicaray, Arciuli, & McMahon, 2013). That is, the re-enactment of a smile (i.e., simulation: activation of the zygomatic muscle; Foroni & Semin, 2009; Winkielman et al., 2008).

Related to the question whether language comprehension recruits motor simulations, an extension of this research investigates how negation is represented. Negation is of paramount importance for human reasoning because it refers to an abstract aspect of reality, namely the absence of a concept (e.g., Hasson & Glucksberg, 2006; Horn, 2001) and it allows us to reason by contradiction and to cope with false and contradictory statements. Thus, understanding how we comprehend negation can also contribute toward a more general understanding of how people construct and evaluate alternatives (cf. Hasson & Glucksberg, 2006). However, negation of action is a largely unexamined proposition so far (see Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007; Liuzza, Candidi, & Aglioti, 2011; Tettamanti et al., 2008; Tomasino, Weiss, & Fink, 2010) and presents a challenge for models suggesting that the motor system drives action processing.

The few studies that did investigate this topic using functional magnetic resonance imaging (fMRI) found a partial deactivation in action-related areas during comprehension of negative sentences (e.g., Tettamanti et al., 2008; Tomasino et al., 2010). However, the brain imaging literature on this topic so far does not reveal – due to fMRI’s poor temporal resolution, the large variability of experimental designs and procedures, and the presence of conflicting results (cf. Tomasino et al., 2010) – the actual causes of neural activation or deactivation in motor systems (Kemmerer & Gonzalez-Castillo, 2010). Therefore, it cannot be ruled out that such changes in brain activation are epiphenomenal and may only reflect secondary post-comprehension processes such as imagery or covert simulation (Lotto, Hickok, & Holt, 2009). Aravena et al. (2012), for instance, using ‘grip-force’ measurement to investigate negation found that action words in negative sentences had no significant effect on force-grip. However, this result it is open to multiple interpretations. In fact, even the lack of effect on force-grip by action words in negative sentences could be potentially compatible with evidence of reduced motor system activations in Tettamanti et al. (2008) and in Tomasino et al. (2010).

Recently, Foroni and Semin (2013) investigated the somatic correlates of negation in L1 and showed that reading sentences involving the affirmative form (“I am smiling”) leads, indeed, to the activation of the zygomatic muscle, while reading sentences involving the negation (“I am not smiling”) leads to the relaxation/inhibition of the same muscle. Importantly, because these effects occurred early (within 200 ms post-stimulus), they do suggest that motor simulation co-occurs with lexico-semantic processing. Furthermore, these results (but see also Bartoli et al., 2013) are in line with the simulation argument and recent fMRI studies (e.g., Tettamanti et al., 2008; Tomasino, Maieron, Guatto, Fabbro, & Rumiati, 2013; Tomasino et al., 2010).

In summary, while fMRI evidence mostly included action-related language (e.g., kick) suggesting the possible involvement of motor-area in the comprehension of negative sentences as they report a partial deactivation in action-related areas during comprehension of negative sentences (e.g., Tettamanti et al., 2008; Tomasino et al., 2010), Foroni and Semin (2013) went further and investigated the involvement of motor simulations during processing of L1 in the case of emotion language.

Thus, there is some empirical evidence suggesting that processing affirmative emotion language in L1 recruits the motor simulation of emotional states (e.g., activation of the corresponding facial muscles), while negative emotion language leads to relaxation/inhibition of motor simulation. Motor simulations, together with its subsequent bodily feedback, likely plays a major role during social interactions (e.g., Foroni & Semin, 2009, 2011a, 2011b; Hess & Bourgeois, 2010; Kawakami et al., 2007; Niedenthal, Mermillod, Maringer, & Hess, 2010; Oberman & Ramachandran, 2007; Winkielman et al., 2008). However, due to the scarcity of research on processing emotion language in L2, it is currently unknown whether L2 processing also requires motor simulations. In line with this possibility, Dudschig, de la Vega, and Kaup (2014) suggested that not only L1 but also L2 words “become automatically interconnected with sensory–motor processes” (p. 19). In the same vein, some authors have also argued that L2 comprehension requires motor simulations but in different degree (Vukovic & Shtyrov, 2014). These results suggest that the comprehension of emotion language in L2 should entail motor simulations (see Zwaan & Taylor, 2006) and they challenge the idea that L2 processing takes place in a fully amodal manner (cf. Dudschig et al., 2014).

Investigating motor simulation in L2 is of paramount importance because comprehension of L2 is a critical challenge for models suggesting that the motor system drives action-language processing. It has been argued that L2 is acquired and processed through the same neural structures responsible for L1 (Abutalebi, 2008) suggesting that simulations should be involved in L2 processing (Dudschig et al., 2014) as they are in L1 processing. Due to the overlapping between acquisition and processing of L1 and L2, if simulations are involved in L1 but not in L2, one could also question the suggestion that motor involvement is a necessary condition for language processing.

In the following, evidence about the neural mechanisms underlying the acquisition and processing of L1 and L2 will be reviewed. Subsequently, hypotheses underlying the present work will be described.

1.2. Neural mechanisms underlying acquisition and processing of L1 vs. L2

A basic issue in the study of L1 and L2 comprehension is whether a L2 learnt later in life can be processed through the same neural mechanisms underlying L1 acquisition and processing. Considering that L1 is acquired implicitly and is mediated by innate learning mechanisms triggered during a critical period, it remains unclear whether the same mechanisms underlie the acquisition of L2 (Perani & Abutalebi, 2005).

The socialization histories for L1 and late L2 are very different (Dewaele & Pavlenko, 2002; Harris & Ayçiçeĝi, 2009; Pavlenko,