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Research report

Lexical and gestural symbols in left-damaged patients

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ABSTRACT

Motor activations reported during action-word understanding have raised the question as to whether the system for motor production contains semantically-relevant information. Cognitive neuropsychologists have provided compelling evidence that damage to the system for production of object-directed (transitive) actions does not necessarily lead to detrimental changes in the individuals' ability to understand the corresponding action words, and *vice versa*. We addressed this question focusing on intransitive symbolic gestures (emblems; e.g., waving goodbye), which are known to engage different resources, or neural representations, than object-directed actions, and are thought to enjoy a special relationship with language, due to a lexicalized relation between form (the gesture) and its meaning. We tested 12 left-damaged patients (and 17 healthy controls) on praxis (imitation and gesturing-to-verbal-command) and lexical–semantic tasks (naming and word–picture matching) involving the same emblems. With the group-level analyses, we replicated correlations between praxis and language deficits typically observed in left-damaged patients. The analyses of patients' performance at the single-case level, however, revealed double dissociations between the ability to produce emblems and the ability to retrieve and recognize their lexical–semantic definition. Double dissociations, even in the event of positive group-level correlations across tasks, imply that the motor representation of a gesture and the lexical–semantic representation of the corresponding word rely on functionally independent system. This study is the first systematic neuropsychological investigation of the relationship between the lexical–semantic and the motor representation of emblems, the closest counterpart of words in the gestural domain.

1. Introduction

A number of empirical phenomena suggest that the neural systems for language understanding and action production are closely interactive: understanding action-related words correlates with activity in fronto-parietal motor regions (Hauk et al., 2004; Tettamanti et al., 2005; Tomasino et al., 2007), enhances corticospinal excitability (Oliveri et al., 2004; Papeo et al., 2009, 2011), and facilitates motor behavior (Glenberg and Kaschak, 2002; Scorolli and Borghi, 2006; Zwaan and Taylor, 2006).

A key question is whether the system for action production contains semantically-relevant information necessary for action-word understanding. A current popular view is that understanding words such as *grasping* relies on the basic ability to perform the corresponding physical action, which

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makes available the internal simulation of that action during conceptual processing: motor representations sustaining action performance would thus be a central part in the lexical–semantic representation of action-related words (Rizzolatti and Arbib, 1998; Rizzolatti and Craighero, 2004). This view predicts that damage to the system for action production should lead to detrimental changes in the patients' ability to understand action words.

However, cognitive neuropsychologists have shown that damage to the left mouth/hand/foot sensorimotor cortices could leave unaffected the patients' ability to recognize verbs and nouns related to mouth/hand/foot actions (Arévalo et al., 2012). Moreover, large-scale studies of patients' brain lesions revealed no single case with focal damage to motor/premotor cortices and impaired lexical–semantic processing of action-words (Kemmerer et al., 2012). Along this line, in a recent multiple-single case study, we found that left-damaged patients could have normal comprehension of action-verbs and tool-nouns, even though they had lost the ability to imitate the implied actions and use tools (Papeo et al., 2010; see Papeo and Hochmann, 2012, for a more extensive review). In that study (Papeo et al., 2010), we tested patients' ability to understand and produce meaningful object-directed actions. The focus on object-directed actions, in ours as well as in most studies in the field, is implicitly motivated by the proposal that the motor substrates recruited during conceptual tasks encode actions not just in terms of means (i.e., specific motor sequences), but primarily in terms of goals (Johnson Frey et al., 2003; Rizzolatti and Craighero, 2004).

Object-directed actions perhaps represent the most obvious category of goal-directed actions. *Emblems* such as "thumbs up" to mean "OK" too, fall in the category of meaningful goal-directed actions: these are symbolic, culturally-defined gestures that, while not related to a physical object, are nevertheless directed to a (communicative) goal, as they are intentionally used in social interaction to convey meanings and evoke behavioral responses in other individuals (Frey, 2008). In this perspective, emblems meet the criteria of the actions that are held to induce motor *resonance*, or activity, in the human brain.

On the other hand, considering their praxis features, object-directed actions and emblems fall into the different categories of transitive and intransitive (non-object-direct) gestures, respectively, which might differ in terms of representational properties (e.g., one is constrained by the object-features and the other by the socio-cultural context) and procedures for production (Bartolo et al., 2003; Cubelli et al., 2000; Mozaz et al., 2002; Ochipa et al., 1989), and/or in terms of the implicated cognitive resources (Carmo and Rumiati, 2009; Króliczak and Frey, 2009). This observation leaves open a possibility that neuropsychological results on object-directed actions might not be readily generalized to emblems.

Emblems also differ from other intransitive gestures, such as co-speech (i.e., gestures that spontaneously accompany speech production; Goldin-Meadow, 1999), as they have meaning independent of speech and can occur on their own (Ekman and Friesen, 1969); they are symbols, in that their meaning results from a conventional and arbitrary relation between form (the sign) and referent. These properties assign to emblems a *language-like* aspect, to the extent that they may be represented in a mental *lexicon* (McNeill, 1992), and encoded in a way analogous to word recognition. For instance, processing meaningful and meaningless emblems elicits a difference in the event-related potential component N400, analogous to the electrophysiological correlate of the distinction between words and pseudowords (Gunter and Bach, 2004; see also Wu and Coulson, 2005). A magneto-encephalography study showed that the processing of emblems involves two stages, at ~230 and 370 msec, reminiscent of the lexical-access and meaning-selection stages for word recognition (Nakamura et al., 2004). Further, activity in the *classic* perisylvian language network (inferior frontal and posterior temporal cortices) has been found during the observation of communicative symbolic gestures (Xu et al., 2009). These circumstances suggest that emblems could enjoy a special relationship with language (McNeill, 1992). This view is emphasized in some evolutionary accounts of language, whereby the brain system for manual communication is regarded as the direct precursor of the speech architecture (Gentilucci and Corballis, 2006; Rizzolatti and Arbib, 1998).

We reasoned that, if the system for action production is part of the system maintaining the lexical–semantic definition of gestures (i.e., action-words), the link between the two systems could be particularly strong in the case of emblems, as they share more properties with words, relative to other gestural categories. Using the cognitive neuropsychology approach, we tested whether damage to the mechanism for emblem production necessarily results in damage to the lexical–semantic representation of the corresponding words.

While a parallel between symbolic gesturing and language has been widely documented in infants' development (Bates and Dick, 2002; Hill, 2001), neuropsychology to date has not yet provided a clear contribution to this enterprise. Available studies involved groups of aphasics (individuals with language dysfunction) showing either weak association between the conceptual processing of symbolic gestures and the ability to reproduce them (Gainotti and Ibbia, 1972; Gainotti and Lemmo, 1976), or strongly correlated performances on verbal and gestural communication competence (e.g., auditory language comprehension and production of conventional gesture; Wang and Goodglass, 1992), attributed either to the severity of aphasia (Glosser et al., 1986) or to the general loss of intellectual efficiency (Goodglass and Kaplan, 1963).

In the current study, we tested 12 consecutive left-damaged patients (and 17 healthy controls) on praxis and language tasks, involving the very same emblems. Praxis was tested by presenting a set of emblems for imitation and verbal commands to trigger execution; the same emblems were used for a naming task and the corresponding words (i.e., verbs) were presented for word–picture matching. Different modalities of stimulus presentation and response (visual stimuli for naming and spoken words for recognition) allowed us to assess the semantic level of word representations (Caramazza and Shelton, 1998; Warrington and Shallice, 1984).

Patients' performance on praxis and language tasks was analyzed both at the group-level, to test whether it was possible to reproduce the correlations, commonly reported in groups of left-damaged patients, between aphasic and apraxic