Neuropsychologia 48 (2010) 3824–3833

Contents lists available at ScienceDirect

Neuropsychologia

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

Improving language without words: First evidence from aphasia

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ARTICLE INFO

Article history:
Received 21 March 2010
Received in revised form 10 July 2010
Accepted 23 September 2010
Available online 29 September 2010

Keywords:
Rehabilitation
Aphasia
Anomia
Stroke
Lexical deficit
Gesture
Embodied theory

ABSTRACT

The pervasiveness of word-finding difficulties in aphasia has motivated several theories regarding management of the deficit and its effectiveness. Recently, the hypothesis was advanced that instead of simply accompanying speech gestures participate in language production by increasing the semantic activation of words grounded in sensory-motor features, hence facilitating retrieval of the word form. Based on this assumption, several studies have developed rehabilitation therapies in which the use of gestures reinforces word recovery. Until now, however, no studies have investigated the beneficial effects of gesture observation in word retrieval.

Here, we report whether a different modality of accessing action-motor representation interacts with language by promoting long lasting recovery of verb retrieval deficits in aphasic patients.

Six aphasic participants with a selective deficit in verb retrieval participated in an intensive rehabilitation training that included three daily sessions over two consecutive weeks. Each session corresponded to a different rehabilitation procedure: (1) "action observation", (2) "action observation and execution", and (3) "action observation and meaningless movement". In the four participants with lexical phonologically based disturbances, significant improvement of verb retrieval was found only with "action observation" and "action observation and execution". No significant differences were present between the two procedures. Moreover, the follow-up testing revealed long-term verb recovery that was still present two months after the two treatments ended.

In support of a multimodal representation of action, these findings univocally demonstrate that gestures interact with the speech production system, inducing long-lasting modification at the lexical level in patients with cerebral damage.

1. Introduction

The hypothesis that gestures play an important role in lexical retrieval dates back to the beginning of the twentieth century (DeLaguna, 1927; Dobrogaev, 1929; Mead, 1934). In the earliest published study, Dobrogaev (1929) reported that speakers instructed to inhibit facial expressions and gestural movements of the extremities found it difficult to produce articulate speech. More recently, Rimé (1982) and Rauscher, Krauss, and Chen (1996) showed that preventing gestures affected speech fluency adversely; in fact, the effects were similar to those found when word retrieval was prevented by other means (i.e., when subjects were requested to use rare or unusual words).

More evidence supporting the interaction between gestures and lexical retrieval comes from studies of brain-damaged patients. Hadar, Wenkert-Olenik, Krauss, and Soroker (1998) reported that aphasics whose speech problems primarily concerned word retrieval tended to gesture more than both normal controls and other aphasics whose problems lay at a conceptual level. About 70% of the gestures of patients with word retrieval difficulties were associated with a hesitation or an erroneous production. Thus, viewed in relation to speech, it appears that aphasic patients have involved a compensatory strategy by increasing gesture production.

According to these data, gestures and speech are two separate communication systems and gestures function as an auxiliary support when verbal expression is temporally disrupted or word retrieval is difficult (Hadar, 1989; Hadar et al., 1998; Krauss & Hadar, 1999).

Based on this assumption, several studies have proposed rehabilitation therapies in which the use of simple gestures or

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0028-3932/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.neuropsychologia.2010.09.025

pantomime paired with verbal production improved word recovery (Code & Gaunt, 1986; Hanlon, Brown, & Gerstman, 1990; Raimer, Singletary, Rodriquez, Ciampitti, Heilman, & Rothi, 2006; Rodriquez, Raymer, & Rothi, 2006; Rose, Douglas, & Matyas, 2002). Code and Gaunt (1986) wanted to examine whether combining gesture and speech would improve or hindered the production of either or both systems in a patient with severe apraxia and aphasia. They found significant improvement in the patient's ability to produce a small range of useful hand signs, especially on those enhanced through word-cued gesture (i.e., where the word equivalent to the gesture was cued by the therapist and the gesture was required as response) and gesture-cued word (where the therapist gave the gesture and the patient was required to produce the word as response) facilitations. Additionally, there was some indication that access to single-word production was facilitated when the patient was cued with an appropriate hand sign, and access to hand signs was likewise facilitated when the patient was cued with an appropriate word. In the Hanlon et al.'s work (Hanlon et al., 1990) the effects of different unilateral gestural movements on naming to confrontation were examined. It was hypothesized that activating the hemiplegic right arm to execute a communicative but non-representational pointing gesture would have a facilitatory effect on aphasics' naming ability. Results showed that gestures produced through activation of the proximal (shoulder) muscolature of the right paralytic limb facilitated naming performance.

Gestures paired with verbal production have frequently been used to treat naming impairments in patients with aphasia (Pashek, 1998; Raimer & Thompson, 1991; Richards, Singletary, Koehler, Crosson, & Rothi, 2002; Rose et al., 2002). Rose and colleagues (Rose & Douglas, 2001; Rose et al., 2002) noted that gestural treatment using pantomimes was more effective in individuals with a phonologically based word retrieval impairment than in those with semantically based word failure. Raimer et al. (2006) examined the effect of pantomime paired with verbal training for noun and verb retrieval in a group of aphasic participants. Effects were evaluated in spoken naming to pictured objects and actions. Results showed that naming improvements were present for trained nouns and verbs but not for untrained words.

Contrary to the assumption of a functional separation between gestures and speech, another hypothesis suggests that the two systems are closely linked to the same conceptual representation (McNeill, 1992).

In line with Martin et al.'s proposal (Martin, Wiggs, Ungerleider, & Haxby, 2000), it is assumed that the semantic representation of a concept is composed not only of stored information about the features defining that concept, such as its typical form, color and motion but also of the motor movement associated with its use. Semantic representation of word concepts can be encoded in both propositional and non-propositional formats, and words whose retrieval is facilitated by gestures are more likely to be analogically encoded in sensory-motor features (Krauss, Chen, & Gottesman, 2000; Krauss & Hadar, 1999). In the embodied cognition view, there is "no language module" and the representation of a concept is crucially dependent upon sensory-motor processes related to that concept (Barsalou, 1999; Gallese & Lakoff, 2005; Rizzolatti & Craighero, 2004).

Several lines of evidence have already demonstrated a strong connection between language and action, particularly with regard to language comprehension. Words mediating actions performed with different motor districts (e.g. the feet 'kick', the hands 'pick' and the mouth 'licks') enhance the same neural substrates involved in executing those actions (Binkofski & Buccino, 2006; Fadiga, Craighero, Buccino, & Rizzolatti, 2002; Hauk & Pulvermuller, 2004; Pulvermuller, Hauk, Nikulin, & Ilmoniemi, 2005; Rizzolatti, Fogassi, & Gallese, 2001). Similarly, in a behavioural study Sato, Mengarelli, Riggio, Gallese, and Buccino (2008) found slower responses with the right hand when subjects had to categorize hand-action-related verbs semantically than when the task involved foot-action-related verbs.

Conversely, it has been showed that gesture execution influences word comprehension and production also when subjects are simply asked to observe the performed action (Bernardis & Gentilucci, 2006; Gentilucci & Dalla Volta, 2008; Gentilucci, Dalla Volta, & Gianelli 2008). These results are in accordance with the hypothesis of a shared motor representation for the execution and observation of actions (the so-called "mirror neuron" theory) (Rizzolatti & Arbib, 1998; Rizzolatti, Fadiga, Fogassi, & Gallese, 1999). This motor representation, by matching observation with execution, makes it possible for individuals to recognize and understand the meaning of actions performed by others (Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti et al., 1996). Accordingly, brain-imaging studies have indicated that Broadmann's area 44 (BA44) which is located in the pars opercularis of the inferior frontal gyrus, together with the superior temporal sulcus and the inferior parietal lobule, may serve as a core neural network for action understanding (Binkofsky et al., 1999; Buccino et al., 2001; Fadiga, Fogassi, Pavesi, & Rizzolatti,1995; Rizzolatti, Fogassi, & Gallese, 2000; Zadeh, Koshi, Zaidel, Mazziotta, & Iacoboni 2006). This fronto-parietal network has reciprocal connection in the underlying white matter located in the superior longitudinal fasciculus (SFL). The most inferior branch of SFL originates from the rostral portion of the inferior parietal lobule (Broadmann's area 40) and terminates in ventral area 6, area 44 and are 9/46 (Petrides & Pandia, 2002).

In Gentilucci et al.'s works (Bernardis & Gentilucci, 2006; Gentilucci & Dalla Volta, 2008; Gentilucci, Dalla Volta, & Gianelli 2008), the execution of meaningful gestures modified the voice spectra of words that had the same meaning, but not of meaningless words (i.e., pseudo-words). Moreover, observing a meaningful gesture affected verbal responses in the same way as executing the same gesture. The authors concluded that the spoken word and the symbolic gesture are coded as a single signal by a unique communication system.

Nevertheless, it is still an open question to what extent this interaction works and at which level of the language production system gestures might exert their influence.

The more traditional view has suggested that gestural information might contribute to the construction of the speaker's communicative intention and might affect lexical retrieval only indirectly (Hadar & Butterworth, 1997; Hadar et al., 1998; Hanlon et al., 1990); more recent works, however, have indicated that gestures and language production closely interact at least at a motor/articulatory level (Bernardis & Gentilucci, 2006; Gentilucci & Dalla Volta, 2008; Gentilucci, Dalla Volta, & Gianelli 2008).

In this study, we investigated whether observing gestures exert its influence in the language production system also at a lexical level by promoting long-lasting recovery of word retrieval deficits in aphasic patients.

As far as we know, no other studies have previously addressed this issue. In most of the previous treatments, gestures were combined with a verbal cue (Pashek, 1998; Raimer & Thompson, 1991; Richards et al., 2002; Rose et al., 2002) and when they were used as the only facilitation, they were not semantically related with the action (Hanlon et al., 1990). With regard to gesture observation, while the studies univocally addressed their crucial role for language comprehension, no studies have been reported on the relationship between gestures and lexical retrieval. Specifically, we were interested in exploring whether "the observation of semantically congruent actions" and/or "the observation and execution of semantically congruent actions" would improve verb-finding difficulties in a group of anomic patients.