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Research Report

Language and its interacting components: The right hemisphere hypothesis in derivational morphology

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ABSTRACT

Traditionally, it has been assumed that language is part of a distributed neural system largely lateralized to the left cerebral hemisphere. However, more recent studies have challenged the traditional hypothesis supporting a more interactive view of language processing. Instead of considering the language faculty as modular and independent from other cognitive functions, it is hypothesized that language makes use of other cognitive domains. This issue has also been specifically addressed in derivational morphology processing, a language task traditionally considered purely linguistic. Very recently, in a group of Italian non-aphasic right brain-damaged (RBD) subjects, a selective deficit in deriving nouns from verbs (e.g. osservare [to observe] → osservazione [observation]) was reported. It was attributed to damage to response selection and inhibition mechanisms required by the derivational task. The aim of the present study was to investigate this issue further. Twelve RBD subjects, six of whom were selectively impaired in deriving nouns from verbs, and six healthy controls were asked to perform a response selection task that required the activation of facilitatory and inhibitory components. Results showed that subjects with a derivational morphological deficit exhibited slower reaction times than the subjects in the other RBD group only when they had to inhibit the expected response to select the correct answer. Moreover, lesion analysis revealed the involvement of the right subcortical structures. The relationship between derivational morphology and response selection mechanisms in the right hemisphere is discussed within the view of inter-hemispheric cooperation between different cognitive domains in language tasks.

1. Introduction

Since the first half of the 20th century, a great deal of research has shown that damage to the left (LH) but not to the right hemisphere (RH) specifically affects language functions.

Later behavioural and neuroimaging studies on healthy volunteers, as well as on brain-damaged subjects, challenged the LH language dominance view and supported the idea of a more distributed language network in the two hemispheres. Although the LH is dominant in phonological and morpho-syntactic tasks, several studies have demonstrated that lexical–semantic processes require inter-hemispheric cooperation (Gazzaniga and Sperry, 1967; Joanette and Goulet, 1986; Zaidel et al., 1995). In fact, the hypothesis has been advanced that

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in word recognition tasks the two hemispheres have different access to different meanings of ambiguous words. In particular, it appears that the right hemisphere is more capable of maintaining the second meaning of an ambiguous word at a later stage of processing than the left hemisphere (Koivisto, 1997; Burgess and Simpson, 1988; Chiarello and Beeman, 1998; Chiarello, 1998). Several facets of comprehension can also be damaged as a consequence of right hemisphere lesions. These include non literal meanings such as metaphoric processing (Brownell et al., 1990), indirect speech acts (Hirst et al., 1984), and making or revising discourse inferences (Brownell et al., 1986; McDonald and Wales, 1986).

Recently, a more interactive view of language processing was proposed (Taylor and Regard, 2003). Instead of considering the language faculty as completely specialized or 'modular', behavioural and neuroimaging results suggest that cognitive tasks frequently share component functions with other tasks that make use of similar representations and that these component functions tend to be anatomically localizable. For example, it has been shown that perceiving rhythms and imaging the completion of a tune activate the left inferior frontal gyrus in an area close to that activated by sentences (Platel et al., 1997; Halpern and Zatorre, 1999) just as a very general cognitive component supported by the left inferior frontal gyrus is involved in the representation of various types of hierarchically organized (motor or auditory) sequences.

With regard to the right hemisphere contribution in comprehension tasks, the hypothesis has been advanced that it may be related to its use in manipulating information retrieved from episodic memory (Buckner, 1986). It has also been suggested that in RBD subjects semantic impairments may be linked to generally limited attentional capacity resources rather than to a specific deficit in semantic processing (Murray, 2000; Moneta et al., 2003).

In summary, the fact that specific areas of the brain are involved in language tasks does not always imply that the cognitive function of those areas is specifically linguistic *in nature*.

Recently, Marangolo and Piras (2008) proposed an interaction between the two hemispheres in language tasks. Although neuropsychological and neuroimaging studies have traditionally attributed a dominant role in morphological processing to the left hemisphere (Miceli and Caramazza, 1988; Badecker and Caramazza, 1989; Panzeri et al., 1990; Laine et al., 1999a,b; Miceli et al., 2002; Tyler et al., 2002, 2004), very recently these authors found that five out of nine RBD subjects presented a clear dissociation between impaired derivational morphology and preserved inflectional processing. Interestingly, no subject was aphasic and all selectively failed only when they were asked to derive a noun from a verb [e.g. *fall-ire* (*to fail*) → *fall-imento* (*failure*)]. Errors were mainly substitutions of the derived noun with the past participle of the verb (e.g. fall-imento (failure) → fallito (failed)) (Marangolo and Piras, 2008). These data provide an exact replication of two previous single case findings (Marangolo et al., 2003). As the patients' different performances were not due to more extensive right hemisphere damage in the pathological group, the authors looked for differences in the damaged anatomical substrates that were responsible for the observed deficit. Results showed that, unlike patients who did not have the morphological deficit, the pathological group exhibited lesions to the right basal ganglia (specifically the caudate nucleus and the corona radiata). These structures were also found to be active in healthy subjects performing a derivational task during fMRI (Marangolo et al., 2006). In interpreting the reported selective deficit, one possible explanation proposed by the authors was that in the selected group of patients damage to the right basal ganglia in some way interfered with the selection processes involved in deriving nouns from verbs (Marangolo and Piras, 2008).

Lexical processing in unimpaired adults shows that both inflected and derived forms are mentally represented as connected to the verb base form (Colombo and Burani, 2002; Burani et al., 1984; Marslen-Wilson, 2007; see also, for a similar view for languages such as Hebrew, Serbo-Croatian, and Finnish, Deutsch et al., 1998; Kostic and Katz, 1987; Laine et al., 1999a,b, respectively). Considering that Italian verbs include about 50 inflected forms and that usually more than one word is derived from a given verb, Italian verbs are organized in very large morphological families. Hence, deriving a noun from a verb implies selecting the required suffix from a set of semantically competing alternatives, some of which are plausible but incorrect [i.e. osserv-are (to observe) → osserv-azione (observation), osserv-atore (observer) but not osserv-ista]. In contrast, in the case of nouns derived from adjectives, these selection processes are easily performed because the number of alternatives is greatly reduced [i.e. only gentil-ezza (kindness) and gentil-mente (kindly) derive from gentil-e (kind)]. Indeed, subjects made very few errors in this task. The authors argued that damage to the right basal ganglia made it impossible for the patients to select the correct answer from the set of semantically related competitors and that it was mainly substituted by the past participle of the verb, which is the most competitive inflection of the Italian paradigm and in some cases can also be used as a derived noun (i.e., l'osservato (the observed)). Taken together these findings suggest that deriving nouns from verbs involves structures in the right hemisphere, such as the basal ganglia, which could reflect the activity of cognitive components that interact with the linguistic task even though they are not specifically linguistic.

In the present study, we wanted to investigate directly the hypothesis that the derivational morphology deficit is in some way related to a difficulty in inhibiting a dominant response in a set of possible competitors. To this aim, 12 right damaged patients, eight of whom had been previously studied (Marangolo and Piras, 2008), and six age and educational level matched healthy controls were asked to perform 4 derivational tasks. Six out of 12 patients confirmed the previous results, with a clear dissociation between their impaired production of nouns derived from verbs and preserved performance in all other derivational tasks.

All subjects were then asked to perform a response selection task requiring the establishment of an expectation about which word in a set of items held in working memory was most likely to be relevant to a subsequent response. At the outset of each trial, three words were presented serially (see Fig. 1) and subjects were asked to remember the words so as to be able to respond at the end of the trial. After presentation of the memory set, a bias cue (i.e. a number from 1 to 3) appeared. Subjects were informed that in most cases (valid