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Research paper

Neural correlates of verb and noun processing: An fMRI study of Persian

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ABSTRACT

The purpose of this fMRI study is to examine the neural substrata of verb and noun processing within a grammatical context in Persian, a language with a complex morphosyntactic structure. The main aim was to assess the possible impact of the morphosyntactic properties of Persian on the neural representations of different grammatical categories. To this end, 14 healthy native speakers of Persian were required to covertly complete sentences by generating verbs or nouns within a grammatical context, in response to each relevant drawing. Common regions were activated by both verbs and nouns in occipital cortex, temporal cortex, and cerebellum. In the direct comparisons, only verb processing revealed larger activation in middle temporal gyrus (bilaterally) and left fusiform gyrus. This study, as the first report on Persian, demonstrates that verbs and nouns are processed and represented to a great extent via common cortical regions with few activation differences, possibly reflecting the verb-specific morphosyntactic properties of the Persian language.

1. Introduction

Where and how lexical information is represented and processed in the brain is one of the burning questions in the neuroscience of language. Nouns[1] and verbs, as two of the pivotal grammatical classes of every language, have attracted the closest attention in the scientific community. The neuropsychological studies conducted on brain-damaged patients have so far spoken to a double dissociation between nouns and verbs (Cappa & Perani, 2003). Lesions in the temporal lobe are reported to cause an impairment in producing nouns (Damasio & Tranel, 1993; Glosser & Donofrio, 2001); while, verb

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[1] We are aware that a distinction is made between Noun/verb and object/action categories, the former referring to the grammatical class and the latter to the semantic class (see Vigliocco et al., 2011). Therefore, when we refer to the stimuli used in the study and their naming, we use object and action. When we talk about the integration of these stimuli into the sentence, we prefer to use nouns and verbs since their grammatical and morphosyntactic properties also play a role here.

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processing is mainly impaired by lesions in the left frontal lobe(Cappa & Perani, 2003; Daniele, Giustolisi, Silveri, Colosimo, & Gainotti, 1994; Shapiro & Caramazza, 2003). These findings are not always consistent. There are studies which reported patients with verb impairment whose lesion was not within the left frontal cortex (Aggujaro, Crepaldi, Pistarini, Taricco, & Luzzatti, 2006; Daniele et al., 1994; Maria Silveri & Di Betta, 1997; Silveri, Perri, & Cappa, 2003; Tranel, Adolphs, Damasio, & Damasio, 2001) and patients with lesions in the left prefrontal cortex but who were unimpaired in processing verbs (De Renzi & di Pellegrino, 1995).

Several explanations have been proposed for the differences in neural substrates observed in the majority of aphasic patients. Neural differences between nouns and verbs are generally attributed to either specific syntactic (Friedmann, Wenkert-Olenik, & Gil, 2000) or semantic level information (Bird, Howard, & Franklin, 2000; Pulvermüller, Lutzenberger, & Preissl, 1999; Vigliocco et al., 2006). In addition to semantic and syntactic properties, nouns and verbs differ in their morphological operations as well. In some languages, nouns are marked for number, and in some others even for gender and case. But verbs are more complex and may be inflected for number, tense, aspect and agent in some of the world languages. More recent studies demonstrate that different morphological operations underlying noun and verb processing might be the organizing parameter of lexical knowledge in the brain(Pulvermuller & Shtyrov, 2009; Shapiro, Moo, & Caramazza, 2006). Some researchers, on the other hand, question the attribution of the observed differences to a single level of linguistic information; they suggest, instead, that a combination of semantic, syntactic, morphological, and phonological factors might be the organizing factor in the brain (Black & Chiat, 2002; Kellenbach, Wijers, Hovius, Mulder, & Mulder, 2002).

The results of neuroimaging studies are not always consistent with lesion-based studies (Crepaldi et al., 2013; Crepaldi, Berlingeri, Paulesu, & Luzzatti, 2011; Mätzig, Druks, Masterson, & Vigliocco, 2009). There are studies which found, besides commonalities, greater activation for verbs in left temporal and premotor-prefrontal regions (Davis, Meunier, & Marslen-Wilson, 2004; Liljeström et al., 2008; Palti, Ben Shachar, Hendler, & Hadar, 2007; Perani et al., 1999), left middle temporal gyrus (LMTG) (Bedny, Caramazza, Grossman, Pascual-Leone, & Saxe, 2008; Longe, Randall, Stamatakis, & Tyler, 2007; Peelen, Romagno, & Caramazza, 2012; Tyler, Randall, & Stamatakis, 2008), left posterior temporal and parietal regions (Fiez, Raichle, Balota, Tallal, & Petersen, 1996; Liljeström et al., 2008; Martin, Haxby, Lalonde, Wiggs, & Ungerleider, 1995), and left frontal lobe regions (Damasio et al., 2001; Finocchiaro, Basso, Giovenzana, & Caramazza, 2010; Liljeström et al., 2008; Martin et al., 1995; Tranel, Martin, Damasio, Grabowski, & Hichwa, 2005; Tsigka, Papadelis, Braun, & Miceli, 2014), and for nouns in regions of temporal lobe (Shapiro et al., 2005; 2006), inferior parietal sulcus and precentral sulcus bilaterally (Fujimaki et al., 1999) and right superior frontal sulcus and anterior cingulate gyrus (Warburton et al., 1996). Several studies having directly compared noun and verb processing showed no activation differences between these classes (Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Khader, Scherag, Streb, & Rösler, 2003; Li, Jin, & Tan, 2004; Siri et al., 2008; Sörös, Cornelissen, Laine, & Salmelin, 2003; Tyler, Russell, Fadili, & Moss, 2001; Vigliocco et al., 2006); while others revealed selective activation for each of them in the brain (Hauk, Johnsrude, & Pulvermüller, 2004; Martin et al., 1995; Shapiro et al., 2006).

The possible contribution of typological properties to neural processing can be assessed by comparing results of brain imaging studies in different languages to one another. There have been 3 documented neuroimaging studies on language processing carried out in healthy Persian speakers using object stimuli (Mahdavi et al., 2008, 2010, 2011). The results of the first two studies (Mahdavi et al., 2008, 2010) revealed a strong activation in Broca's area using noun generation, word reading and reverse word reading tasks in Persian. The third study (Mahdavi et al., 2011) used 5 different linguistic tasks, to unravel the cortical representation of nouns in Persian. All these studies found activation in the several frontal and temporal regions known to subserve linguistic functions, and concluded that the cortical representation of Persian resembled that of other Indo-European languages such as English. These studies, however, only made use of object pictures which were named at the word level without engaging morphosyntactic information. It is therefore not surprising that they found convergence between resulting activation patterns and those observed in other studies with other languages, since in Persian, as in many other languages, nouns are only marked for number. On the other hand, given the unique morphosyntactic properties of the Persian verbal system as compared to those of some other Indo-European languages, it is possible that specifically examining these properties might reveal activation differences between Persian and other languages with simpler morphology suggesting underlying language-variant processes (Finocchiaro et al., 2010; Li et al., 2004).

The Persian language, a member of Indo-European family of languages, has a set of distinctive linguistic properties. The canonical word order in Persian is SOV. In Persian, verbs carry a more complex morphology to express tense, aspect, mood, number as well as person relative to several other European and Asian languages such as English and Chinese. One of the strikingly distinctive features of Persian is that it has less than two hundred simple verbs, the rest are light verb constructions (LVCs). In other words, verbs in Persian are a closed class(Family, 2014). In order to make LVCs, light verbs are joined with nouns, adjectives, adverbs, prepositions and prepositional phrases, and this changes the meaning to create a completely verbal meaning (e.g./zamin khordan/, literally translated as “earth eat”, meaning ”to fall down”). Regardless of the category of the nonverbal element attached to the light verb, the former always comes first (see example 1). The person-number inflections are attached to the verbal part of the LVCs, while pronominal clitics (PC) indicating the object of the verb can be attached to the verb or to the nonverbal part of the construction (see example 2) (Mahootian, 2010).