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Verb naming fluency in hypokinetic and hyperkinetic movement disorders

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ABSTRACT

Cortical motor regions are also considered to play a role in action related language. These regions are affected differently in different types of movement disorders. Parkinson's disease, a hypokinetic movement disorder, has been shown to cause action language disruptions alongside movement deficits. Action language, however has not been investigated in primary cervical dystonia, a hyperkinetic movement disorder. The aim of this study is to investigate whether action language is affected differently in hypokinetic and hyperkinetic movement disorders which have different effects on movements. Thirty patients with Parkinson's disease, thirty with primary cervical dystonia patients and thirty healthy controls were included in the study. Participants performed phonemic, semantic and action fluency tasks. Verbs produced during action fluency were grouped as action and non-action verbs and group differences were investigated. Our results showed that all participants performed similarly in all of the fluency tasks. Mean action content of the verbs produced in action fluency did not differ in between groups. During action fluency, however, whereas healthy controls produced more action verbs than non-action verbs, both patient groups did not have this difference between verb groups. Primary cervical dystonia patients produced less action verbs compared to healthy controls. The lack of action language deficits in Parkinson's disease and only an action verb deficit in primary cervical dystonia without any other action language deficits rejects strong embodiment.

1. Introduction

Embodiment theory suggests that mental representations are grounded in bodily actions and in modality-specific systems of the brain (Cardona et al., 2013; Gallese & Sinigaglia, 2011). In embodied semantics, sensorimotor brain regions involved in action execution are considered to also play a role in action related language (Arevalo, Baldo, & Dronkers, 2010). However, the degree of sensorimotor system contribution to semantic processes is still under debate. The views range from unembodied theories to strong embodiment. Unembodied theory

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suggests no engagement of sensory and motor information in semantic representation, whereas strong embodiment suggests an activation of sensorimotor brain regions as a part of semantic processing (Meteyard, Cuadrado, Bahrami, & Vigliocco, 2012). This spectrum allows studies to be placed on this range rather than fully supporting or refusing embodied semantics as both sides of the spectrum may be wrong in their claims. In their study, Cardona et al. (2014) describe non-representational and representational embodied views including disorders representing peripheral motor system and brain motor system impairments. Non-representational embodied view suggests that sensorimotor information is retrieved automatically and unconsciously through peripheral sensory organs for the execution of the motor programs and fine tuning without semantic representations. In contrast, representational embodied view highlights the part of neural mechanisms in motor representation claiming that motor activity and action language are co-dependent at the brain level (Meteyard et al., 2012). Action language being preserved in patients with peripheral motor system impairments, but disrupted in patients with brain motor system impairments supports representational view; as action verb processing relies on an intact cortico-subcortical motor network (Cardona et al., 2014).

Studies focusing on these theories report contradictory findings. Lexical stimuli referring to different body parts were used in neuroimaging studies involving functional magnetic resonance imaging (fMRI) (Aziz-Zadeh, Wilson, Rizzolatti, & Iacoboni, 2006; Esopenko, Borowsky, Cummine, & Sarty, 2008; Kemmerer, Castillo, Talavage, Patterson, & Wiley, 2008; Pulvermüller, Kherif, Hauk, Mohr, & Nimmo-Smith, 2009), event-related potentials (ERP) (Shtyrov, Hauk, & Pulvermüller, 2004), transcranial magnetic stimulation (TMS) (Buccino et al., 2005), and positron emission tomography (PET) (Tettamanti et al., 2005). These studies revealed activations in somatotopically-organized regions which are originally activated during action execution and observation. Nevertheless, these somatotopic coordinates failed to overlap with previously defined maps of motor and premotor cortices (Cardona et al., 2013; Kemmerer & Gonzalez-Castillo, 2010). In addition, Postle, McMahon, Ashton, Meredith, and de Zubicaray (2008) did not report any somatotopic activation to action-words in their fMRI study. In a combined electroencephalography/magnetoencephalography (EEG/MEG) study, Mollo, Pulvermüller, and Hauk (2011) used words related to arm or leg movements, and asked the participants to respond by using their fingers or feet. They reported a congruency effect between word type and the effector used to respond, and that this effect was not only limited to motor cortex but also present in left posterior superior temporal area. This suggests that the related motor regions are crucial in action language, but action language requires recruitment of various other brain areas as well. Aravena et al. (2010) conducted an ERP study using action-sentence compatibility effect (ACE) to investigate motor language coupling. They reported that cortical markers of motor and comprehension processes are modulated by each other. They claimed that a motor-language integration occurring during the verb onset points to the engagement of sensorimotor information in action language. Amoruso et al. (2013) reported that action meaning and language meaning lead to similar N400 modulations and that this semantic process is related to fronto-temporo-parietal network. A TMS study by Pulvermüller, Hauk, Nikulin, and Ilmoniemi (2005) showed arm area TMS leading to faster arm than leg word responses and the reverse effect for leg area TMS only in the left hemisphere. Motor cortex lesions have also been reported not to lead to action-language deficits (Saygin, Wilson, Dronkers, & Bates, 2004). Another lesion study by Arevalo, Baldo, and Dronkers (2010) suggested a complementary rather than a central role for premotor, motor cortices, several frontal and temporal cortices in action related language. These results suggest there are more brain regions involved in semantic processing without disregarding the engagement of sensorimotor information.

Over the years, studies have revealed the language function of basal ganglia (BG), which were originally considered to have solely motor functions (Murdoch, 2001). Basal ganglia consist of neostriatum, globus pallidus, substantia nigra, and the subthalamic nucleus (STN). The output from the BG terminating in thalamic regions, reaches a wide region of the frontal lobe including both motor and non-motor areas. Through these series of parallel, multi-segregated loops; BG can affect behavior, cognition and language in addition to motor function (Murdoch, 2001). Basal ganglia structures have also been shown to be engaged in reward processing (Antzoulatos & Miller, 2011; Yin & Knowlton, 2006), acquisition of implicit learning and habit formation (Yin & Knowlton, 2006). These structures have been suggested to work together with motor areas during motor-semantic information integration underlying action-verb processing (Abdullaev & Melnichuk, 1997; Cardona et al., 2013; Copland, 2003; Crosson et al., 2003). Selective semantic and lexical deficits were reported in multiple neurodegenerative motor diseases including motor neuron disease (Bak & Chandran, 2012; Bak & Hodges, 2004; Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Bak et al., 2006), progressive supranuclear palsy (Bak, O'Donovan, Xuereb, Boniface, & Hodges, 2001; Bak et al., 2006), corticobasal degeneration (Cotelli et al., 2006; Silveri & Ciccarelli, 2007), and Huntington's disease (Kargieman et al., 2014) which point to the crucial role of frontobasal structures in action language.

Disruptions in different BG structures lead to a variety of movement disorders causing both motor and non-motor symptoms. Parkinson's disease (PD), the second most prevalent neurodegenerative disorder, is a hypokinetic movement disorder characterized by loss of voluntary movement control, bradykinesia, resting tremor and postural instability (Tanner & Goldman, 1996). It is caused by nigrostriatal dopamine deficiency and related BG dysfunctions (Rodriguez-Oroz et al., 2009).

Parkinson's disease patients frequently suffer from neuropsychiatric disturbances including depression, apathy, cognitive deficits alongside motor symptoms causing an important decline in quality of life (Alvarado-Bolaños et al., 2015). Patients are also reported to have deficits in working memory (Beato et al., 2008) and executive functions (McKinlay, Grace, Dalrymple-Alford, & Roger, 2010) as well as speech and other language disturbances (Lieberman et al., 1992). Moreover, regarding action related language; action-word naming (Bertella et al., 2002; Cotelli et al., 2007; Peran et al., 2009), action-verb production (Crescentini, Mondolo,

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