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Does observation of a disabled child's action moderate action execution? Implication for the use of Action Observation Therapy for patient rehabilitation

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ABSTRACT

Background: Research investigating action observation-execution priming has mainly manipulated congruent versus incongruent action, and aspects of action expertise/capability. More specifically, the literature suggests enhanced performance priming following action observation by actors closely matched to participant expertise. The aim of the present study was to extend the understanding of action expertise effects by investigating action priming in healthy participants after observing a mild hemiparetic child actor versus a neurologically healthy child actor.

Methods: 16 healthy right-handed children, aged 6–13 years were tested. Several motor assessments were performed, including gross and fine manual motor ability, and upper limb kinematics measured using a precise robotic device. A cross-over design consisted in two experimental conditions (observing actions performed by a child with hemiparesis versus observing actions performed by a healthy child) and a pre-observation double baseline control condition, with the data analyzed using repeated measures ANOVA.

Results: Relative to baseline, both types of action observation conditions enhanced fine manual dexterity, but observing the hemiparetic child enhanced gross manual dexterity and upper limb velocity kinematics relative to observing actions performed by a healthy child. No effects were shown on measures of smoothness and accuracy.

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Discussion: Contradictorily to hypotheses discussed in the literature, results here showed evidence of enhanced action execution when healthy children observed hemiparetic compared to healthy child actions. These results are discussed in terms of how patient compared to healthy actors may be useful for clinical action observation priming therapy.

1. Introduction

In 1992, neurons discharging both when a monkey executed an action and when he observed the same action being performed were discovered (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992). This population of neurons has been called "mirror neurons" and the discovery highlighted the link between perception and action, since the observed actions looked like being reflected in the motor representation of the observer (Buccino et al., 2001). With the technological and scientific progress, researchers have been allowed to precisely localize the mirror neuron system (MNS) in the human brain and support the matching system of action execution and action observation (AO) (Buccino et al., 2001; Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). These articles reported that observation and execution of actions showed recruitment of fronto-parietal circuits including inferior frontal gyrus (IFG), ventral premotor cortex (VPMC) and inferior parietal lobule (IPL).

Although much is known about the neuroscience of the MNS, the roles of the MNS in cognition remain lively debated in the scientific literature. In relatively early work, Rizzolatti (2005) proposed that the MNS was important for a variety of different cognitions, including action intention or goal understanding (Iacoboni & Mazziotta, 2007), imitation (Nishitani & Hari, 2000), empathy (Wicker et al., 2003) and language processing or speech production (Fadiga, Craighero, Buccino, & Rizzolatti, 2002). Investigations into action priming focus on goal understanding and imitation cognitive processes and consistently demonstrate that AO can moderate action execution (e.g., Edwards, Humphreys, & Castiello, 2003; Hardwick & Edwards, 2011; Salama, Turner, & Edwards, 2011; Gianelli, Dalla Volta, Barbieri, & Gentilucci, 2008; etc.). For example, in Edwards et al. (2003), participants observed the experimenter making a prehensile action to an object, and then the participant made an action to the same or a different object. In 20% of the trials, the observation and execution was to the same object (which they termed a valid prime) and in the other 80% of trials, the prime was invalid (for example, observation of an action to a small object, but action execution to a large object; and vice versa). Results showed a priming effect for the valid compared to invalid prime, where actions executed by the participant were more rapidly initiated and other kinematic indices were improved (peak velocity, time to peak grasp, etc.). Importantly, these effects cannot be explained by expectation, where performance should have been better for the invalid than valid prime.

The action priming effect considers that AO activates MNS networks through an internal motor simulation of the observed action, and that subsequent action execution is facilitated by the prior neural activation and internal motor simulation. This re-activation of the MNS and the internal motor simulation for execution causes neural efficiencies in action planning cognition (see Edwards et al., 2003). Based on this premise, expertise ought to moderate action priming. The observer might only benefit from AO if they are able to perform the observed action. Some researchers have investigated what happens in the MNS when a physically impossible action is observed (Longo, Kosobud, & Bertenthal, 2008; Stevens, Fonlupt, Shiffrar, & Decety, 2000). In a PET study (positron emission tomography), Stevens et al. (2000) showed that observing physically impossible actions showed no MNS activation, whereas observing physically possible actions did show MNS activation. This finding suggests that action priming should only be possible following observation of possible actions.

The contrary investigation of the correspondence between AO and the observers action expertise or capability comes from research where participants observe skilled actions. Calvo-Merino, Glaser, Grèzes, Passingham, and Haggard (2005) showed that participant's motor experience (experts versus novices) caused moderated MNS activity. When expert compared to novice dancers observed dance in which they had expertise, there was greater MNS activation compared to observing a dance that they were not expert in performing, or in comparison to novice participants. They proposed that the observed actions were represented in the participant's personal motor repertoire, and that expertise moderated the amount of MNS activity during observation. Similar results have been reported in music expertise (Haslinger et al., 2005; D'Ausilio, Altenmüller, Olivetti Belardinelli, & Lotze, M, 2006), Parkinson disease (Castiello, Ansuini, Bulgheroni, Scaravilli, & Nicoletti, 2009) and comparing babies that can or cannot walk (van Elk, van Schie, Hunnius, Vesper, & Bekkering, 2008).

In the present paper, we questioned what would happen in action priming when participants observed actions performed by a person with unilateral impaired action caused by brain damage in early infancy (unilateral cerebral palsy; CP). The condition is defined as "a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behavior, by epilepsy and by secondary musculoskeletal problems (Rosenbaum, Paneth, Leviton, Goldstein, & Bax, 2006)". The contralesional movements of these patients are impacted by limb spasticity and a loss of motor control, leading to reduced, slower and sometimes abnormal acceleration profiles (Rosenbaum et al., 2006). However, even if these

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