Human Movement Science 32 (2013) 400–411

Contents lists available at SciVerse ScienceDirect

Human Movement Science

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

The relationship between the motor system activation during action observation and adaptation in the motor system following repeated action observation

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ARTICLE INFO

Article history:
Available online 28 April 2013

PsycINFO classification:
2330
2343

Keywords:
Observational training
Action observation
Motor system
Transcranial magnetic stimulation
Corticospinal tract
Motor representation

ABSTRACT

Repeated action observation has been shown to alter the cortical representation of the observed movement in the motor system. This change in cortical representation is thought to reflect a motor adaptation to observational training (observational training effect). One factor that may impact the observational training effect is the degree of motor system activation that occurs during the observation of the action (i.e., individual differences in the responsiveness of the motor system during action observation). The present study was conducted to test this hypothesis by assessing the relationship between the change in motor system activity during action observation and the change in cortical representation of action following repeated action observation. To this end, transcranial magnetic stimulation (TMS) was used to evoke contractions of thumb muscles in two different protocols: 1) during the observation of thumb movements to assess the responsiveness of each individual's corticospinal system during action observation; and, 2) after the observation of 1800 thumb movements to assess the amount of adaptation in the representation of the thumb following repeated action observation. The key finding was the significant positive relationship between the level of corticospinal system activation during action observation and the amount of change in the direction of TMS evoked thumb movements. These data support the hypothesized relationship between motor system activation

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http://dx.doi.org/10.1016/j.humov.2012.02.003

during action observation and the motor systems adaptation following observational training. They are also consistent with the notion that a common neural mechanism underlies these effects.

1. Introduction

One of the primary ways we expand and hone our motor capabilities is the observation of other people's actions. Scientific support for this method of enhancing motor performance through action observation comes from a series of behavioral studies which have consistently revealed that the repeated observation of a model performing a movement is an effective way of enhancing the performance of that motor skill (for reviews see: Vogt & Thomaschke, 2007; Greer, Dudek-Singer, & Gautreaux, 2006; Hodges, Williams, Hayes, & Breslin, 2007). The changes in performance that occur as a result of action observation is clearly a complicated process with many steps and the neurophysiological processes that contribute to these changes in motor performance are not well understood. There is some evidence, however, that physical training and observational training rely on common neural regions such as the premotor cortex and inferior parietal lobule (Cross, Kramer, Hamilton, Kelly & Grafton, 2009). In the present paper, we report a study designed to provide some insight into a neurophysiological process that might influence the adaptation to the motor system that occurs following the repeated observation of an action.

One neurophysiological process that may influence how the motor system adapts following observational training is the amount of corticospinal system activation that occurs during action observation. If the changes in performance, related to motor adaptation, occur because multiple activations of a specific neural representation lead to the alteration of a corticospinal network and/or the excitability of a network (Bi & Poo, 2001), then it is possible that stronger neural activation on each action observation would lead to greater changes in the network than weaker activation. The relationship between corticospinal activation during action observation and the subsequent degree of change in cortical movement representation following repeated action observation has yet to be explored. This relationship is supported, however, by two separate lines of evidence: (1) there is an increase in activity in the corticospinal system during action observation (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995); and, (2) there are changes in the primary motor cortex following repeated action observation (observational training effect) (Stefan et al., 2005; Stefan, Classen, Celnik, & Cohen, 2008). The following paragraphs contain a brief review of these separate lines of research.

One source of evidence that supports the modulation of corticospinal activation during action observation comes from transcranial magnetic stimulation (TMS) studies. The common finding of these studies is that motor-evoked potentials (MEP), which are thought to reflect overall corticospinal system activation, are larger during action observation than at rest (Aziz-Zadeh, Maeda, Zaidel, Mazziotta, & Iacoboni, 2002; Brighina, La Bua, Oliveri, Piazza, & Fierro, 2000; Clark, Tremblay, & Ste-Marie, 2004; Strafella & Paus, 2000). Notably, the greatest change in MEP amplitude has been shown to occur in muscles that would be active during the physical execution of the movement (e.g., Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). In addition, the timing of the MEP modulations is congruent with the specific phases of muscle involvement in the observed movement (Gangitano, Mottaghy, & Pascual-Leone, 2001). The muscular and temporal similarity of the increases in MEP amplitude (i.e., facilitation effects) during action observation are thought to arise because the observation of an action results in a subthreshold activation of the same motor representation that is activated during actual motor performance. Because the same motor representation may be activated during both performance and observation, it is possible that alterations in motor system networks via observational training are caused by the same mechanisms that are associated with physical training (i.e., repeated activation of a specific motor representation).

Although a number of studies have examined changes in corticosospinal activation during observation (e.g., Fadiga et al., 1995; Gangitano et al., 2001), fewer studies have investigated changes in