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Proneness for exercise, cognitive and psychophysiological consequences of action observation

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ABSTRACT

Objectives: Physical exercise has benefits that go beyond health and well-being, namely in cognitive, motor and psychophysiological areas. The discovery of a shared neural network between action observation and execution (Action-Observation Network) led us to hypothesize that watching human motor action might improve cognitive and motor aspects of performance and proneness for exercise.
Design/Methods: Sixty participants viewed a Motor (M) ($n = 30$) or a Non-Motor (NM) ($n = 30$) movie with strong or weak content of motoric features of human action, respectively. Performance in d2 Attention test, Fitts' Motor task, and a Proneness for Exercise Visual Analog Scale was assessed before and after movie visualization, in a cross-sectional study. Psychophysiological measures were recorded throughout the experiment.
Results: Our results demonstrate an increase in proneness for exercise, and greater improvement in attention-related cognitive aspects in the M group. The aforementioned benefits of action observation did not modulate motor performance. A mental effort deployment was associated to the decrease in heart rate variability after visualization of the NM movie. This was not conducive to attention channeling on task performance. Conversely, M movie observation seemed to be associated to a cognitive load release, affording attention deployment for the resolution of the subsequent tasks.
Conclusions: It seems that some benefits associated to physical practice can result from the mere visualization of movies with human motor action content. These are the improvement in attention-related cognitive skills associated to psychophysiological changes that support a disengagement from mental effort. Crucially, the observation of exercise behavior seems to be a key factor for exercise adherence.

Physical exercise offers many well-known benefits. For instance, cognitive benefits of physical exercise have been documented (e.g., Budde, Voelcker-Rehage, Pietraßyk-Kendziorra, Ribeiro, & Tidow, 2008; Hopkins, Davis, Vantie Ghem, Whalen, & Bucci, 2012). Budde et al. (2008) showed that short periods of coordination exercise improved attention aspects of cognitive performance. Furthermore, aerobic exercise has been shown to be responsible for better performance of various aspects of cognition and brain function, namely, executive control functions in adults and academic performance in children (for review see Hillman, Erickson, & Kramer, 2008). On the other hand, and concerning the motoric benefits of exercise, Davranche, Burle, Audiffren, and Hasbroucq (2006), demonstrated that exercise on a cycle ergometer improved performance in a reaction time task. Moreover, Benwell, Byrnes, Mastaglia, and Thickbroom (2005), showed that a fatiguing exercise in one hand led to reduced activity in the sensorimotor cortex corresponding to both fatigued and non-fatigued hands. Finally, it is largely known that there exist certain physiological responses during physical exercise (e.g., Janssen & Ross, 2012; Warburton, Nicol, & Bredin, 2006). It is known that, for example, for low exercise intensities, there is an increase of heart rate (HR) due to vagal (or parasympathetic) withdrawal. For moderate and high exercise intensities, on the other hand, there is vagal withdrawal and sympathetic activation (e.g., Mendonça, Fernhall, Heffernan, & Pereira, 2009). Furthermore, early works report that, during exercise, there is skin and muscle vasodilatation that is dependent on the heat load, which contrasts with the non-active muscles where there is a vasoconstriction (Casa, 1999). Crucially, Heart Rate Variability (HRV), i.e., the autonomic modulation of HR (e.g., Wood, Maraj, Lee, & Reyes, 2002), is positively affected by the level of exercise (e.g., Wood, Wood, Welsch, & Avenal, 1998). More recently, and in line with previous findings, it has been shown that physical exercise increases HRV (Castello-Simões et al., 2012).

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In a related line, sports scientists have long been interested in imagery, showing that it is related with the enhancement of performance (Driskell, Copper, & Moran, 1994). However, only recently has research on the functional correlates of motor imagery led to the suggestion that imagined and executed actions share some of same central structures (e.g., Decety, 1996). Specifically, new data from neuroimaging has offered a unifying theory of neural simulation of action, suggesting that covert (imagined and observed) and actual actions share some of the same cortical areas (Jeannerod, 2001). Since the early imagery studies, the development of imaging techniques has led to the discovery of a shared neural network subtending action observation and execution and came to explain how observed action is mapped onto the observer's own motor system and vice versa (Fabbri-Destro & Rizzolatti, 2008). This network, involving fronto-parietal areas of the brain is known as the Action-Observation Network (AON) (e.g., Neal & Kilner, 2010). A class of neurons possessing "mirror" or double-duty properties underpins the AON. These neurons are activated when performing a particular action and when observing another perform the same action (Cattaneo & Rizzolatti, 2009; Fabbri-Destro & Rizzolatti, 2008).

Support for a shared neuronal network between action execution and action observation (the AON) is adjudged by the embodiment mechanisms, whereby observation of specific actions can lead to corticospinal excitation (e.g., Urgesi, Moro, Candidi, & Aglioti, 2006) of the muscles involved in the observed action. The Embodied Cognition Theory comes from findings showing that by perceiving gestures of another, for example, one is able to reactivate or reenact, in one's own motor system (motor arousal), the observed action (e.g., Barsalou, 2008). Aligned with the Action-Observation Network (AON) (e.g., Neal & Kilner, 2010), the 'Motor Resonance Theory' states that experts have greater motor and sensory ability, as well as greater capacity to anticipate the behavior of others' (Abreu et al., 2012; Aglioti, Cesari, Romani, & Urgesi, 2008), possibly arising from an attuned reenactment (i.e., reactivating) system. Importantly, arousal and motivation are strongly linked (e.g., Mellalieu, Hanton, & Thomas, 2009). Since observation of human motor action leads to the arousal of the sensorimotor system (corticalspinal excitation of specific muscles) of the observer, such motor excitation could lead to motivation for physical exercise, which leads to proneness for exercise, crucial for the engagement in physical activity.

Further research in Neuroscience has given evidence sustaining the notion that action and observation are not decoupled (e.g., Calvo-Merino, Grèzes, Glaser, Passingham, & Haggard, 2006). Hence, it is possible that observation of motoric features of human action might induce not only motor arousal (Candidi, Vicario, Abreu, & Aglioti, 2010), but also positive affects, already demonstrated to be associated to habitual physical activity (e.g., Pasco et al., 2011). However, the question of whether the mere observation of action would lead to cognitive, motoric and physiological responses, as well as proneness for exercise, still remains. Here, we propose to investigate this question. We ask if observing movies where motoric features of human action are salient may improve specific cognitive aspects related to attention, motor aspects related to speed and accuracy and proneness to perform physical exercise, as well as present associated psychophysiological changes. Ultimately, we investigate how action observation might constitute a possible key factor for exercise adherence.

What consequences then, would we expect to occur during the mere observation of human motor action and how should we go about testing these? As a mean of measure of selective attention, Budde et al. (2008) used an Attention Test – d2 test, to study the influence of two types of exercise in cognitive performance. This test has been used to determinate the participants 'ability to sustain attention during task performance, selecting the relevant visual stimuli while ignoring other stimuli and is important to note that selective attention is required for the success of this task (Brickenkamp, 1998). Some authors view selective attention as cognitive control that is located in the prefrontal cortex (Miller & Cohen, 2001). By making use of this task, we aim to verify if the mere observation of motoric features of human action should lead to a difference in selective attention. We would expect, given the shared networks between action and action observation that viewing salient motoric features of human action would lead to similar improvement in attentional performance as that obtained by Budde et al. (2008) after acute coordinative exercise.

On the other hand, Sirigu et al. (1995) showed that the same temporal constraints exist when someone imagines themselves tapping on a target with different sizes (e.g., Fitts' task) and when he/she actually executes it. Fitts' law has been referred as a means of determining the relationship between speed and accuracy (Fitts, 1992). Fitts' task and its different adaptations constitute a great means of tapping into human voluntary movements and the vicissitudes of motor control (e.g., Christe, Burkhard, Pegna, Mayer, & Hauert, 2007). Here, using Fitts' task, a motor skill test (Fitts, 1992), we aim to investigate if the observation of motoric features of human action should lead to an improvement in performance according to the Fitts' Law (i.e., the speed-accuracy index). Marmeleira, Soares de Melo, Tlemcani, and Godinho (2011), for example, show improvement of older drivers' speed of behavior following an exercise program. Exercise has also been shown to improve motor performance, in a reaction time task (Davranche et al., 2006). Thus, we would expect that observing human motor action should lead to a greater improvement in the speed-accuracy tradeoff of a motor task when compared to the observation of a narrative condition.

Would these putative cognitive and motoric benefits of human motor action observation entail psychophysiological changes? Kreibig (2010), in a literature review concerning the physiological responses during imagery and film visualization, referred that the induction of 'happy' emotions through the visualization of films, caused an increase in heart rate (through a reduction in vagal activity), vasodilation, increased electrodermal activity and an increased respiratory activity. In response to the induction of 'joy' emotions, through visualization, there was an increase in the vagal activity control that co-occurred with an increased β-adrenergic sympathetic activation. This increase in sympathetic activity has been associated with an increased emotional involvement (Kreibig, 2010). Hence, we would expect that the observation of human motor action movies should lead to similar physiological responses associated to happy emotions driven from motor arousal.

Finally, it is of paramount importance for exercise promotion, namely for exercise adherence, to understand if the mere observation of exercise behavior would stimulate a similar behavior. We would expect that observing human motor action packed movies should lead to an increase in proneness for exercise.

Material and methods

Participants

Sixty participants (30 females), aged 18–29 years ($M = 21.55$ years, $SD = 2.41$ years) were randomly divided into two groups (30 per group – 15 females), henceforth referred to as Motor group (M group) and Non-Motor group (NM group).

All participants practiced physical activity at a high level in both M ($M = 6861.44$ MET min/week, $SD = 5254.12$ MET min/week) and NM groups ($M = 5936.38$ MET min/week, $SD = 5182.25$ MET min/week) as measured by the International Physical Activity