Cognition 146 (2016) 431–438

Contents lists available at ScienceDirect

Cognition

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

Believe it or not: Moving non-biological stimuli believed to have human origin can be represented as human movement

E. Gowen [a,*], E. Bolton [a], E. Poliakoff [b]

[a] Faculty of Life Sciences, University of Manchester, UK
[b] School of Psychological Sciences, University of Manchester, UK

ARTICLE INFO

Article history:
Received 9 December 2014
Revised 28 July 2015
Accepted 13 October 2015

Keywords:
Visuomotor priming
Automatic imitation
Mirror neuron system
Stimulus response compatibility
Human–robot interaction

ABSTRACT

Does our brain treat non-biological movements (e.g. moving abstract shapes or robots) in the same way as human movements? The current work tested whether the movement of a non-biological rectangular object, believed to be based on a human action is represented within the observer's motor system. A novel visuomotor priming task was designed to pit true imitative compatibility, due to human action representation against more general stimulus response compatibility that has confounded previous belief experiments. Stimulus response compatibility effects were found for the object. However, imitative compatibility was found when participants repeated the object task with the belief that the object was based on a human finger movement, and when they performed the task viewing a real human hand. These results provide the first demonstration that non-biological stimuli can be represented as a human movement if they are believed to have human agency and have implications for interactions with technology and robots.

1. Introduction

It is well known that observation of a human action can influence the observer's own motor system. For example, observing another person's action activates brain areas involved in execution of that action (Gazzola & Keysers, 2009; Kilner, Neal, Weiskopf, Friston, & Frith, 2009) and can interfere with or facilitate movement production (Brass, Bekkering, & Prinz, 2001; Sturmer, Aschersleben, & Prinz, 2000). These effects are thought to be due to the mirror neuron system (MNS) present within the premotor cortex and inferior parietal lobe that responds during both observation and execution of an action (Buccino et al., 2001; Rizzolatti & Craighero, 2004; Van Overwalle & Baetens, 2009). Recently, there has been increasing interest in whether non-biological stimuli (e.g. abstract shapes or robots) are processed in a similar way to human actions, leading to non-biological movements being represented within the observer's motor system (Gowen & Poliakoff, 2012; Press, 2011). Measuring whether non-biological movements are represented in a similar way to human actions could indicate the success of human–robot interaction which is particularly relevant as humanoid robots are likely to increasingly play a role in society, such as in healthcare, education and entertainment (Andrade et al., 2014; Chaminade & Cheng, 2009; Dautenhahn, 2007; Tapus, Mataric, & Scassellati, 2007). More controversially, representing the action of a non-human agent may suggest the attribution of characteristics associated with humans such as mental states to non-human stimuli (Chaminade & Cheng, 2009). In this work, we address whether belief that a non-biological stimulus is based on a human action produces action representation, using a behavioural visuomotor priming task.

In visuomotor priming, also termed Automatic Imitation, observing and performing a *compatible* action (e.g. lifting one's index finger while observing another index finger move upwards) facilitates reaction times, whereas reaction times are slowed when observing a movement *incompatible* with a performed action (e.g. lifting one's index finger while observing a finger press; Brass et al., 2001). As visuomotor priming is likely to result from activation of the MNS (Catmur, Walsh, & Heyes, 2009; Heyes, 2011), it provides a behavioural measure of whether an action is represented within the observer's motor system. Although previous studies have compared visuomotor priming for human and non-biological movements (Gowen, Bradshaw, Galpin, Lawrence, & Poliakoff, 2010; Jansson, Wilson, Williams, & Mon-Williams, 2007; Press, Bird, Flach, & Heyes, 2005) these are confounded by Stimulus Response Compatibility effects, whereby responses are faster to spatially or directionally aligned stimuli (Cho & Proctor,

* Corresponding author at: Carys Bannister Building, Dover Street, Manchester M13 9PL, UK.
E-mail address: emma.gowen@manchester.ac.uk (E. Gowen).

http://dx.doi.org/10.1016/j.cognition.2015.10.010
0010-0277/

2003). Consequently, visuomotor priming to non-biological stimuli could result purely from stimulus response compatibility effects in the absence of action representation (Jansson et al., 2007).

Models of visuomotor priming share the idea that priming occurs along a visuomotor route, transforming visual input into a motor response and that priming produced by stimulus response compatibility and imitative compatibility are dissociated with the latter involving the MNS (Gowen & Poliakoff, 2012; Heyes, 2011; Wang & Hamilton, 2012). This visuomotor route is modulated by top-down factors such as attention, prior knowledge and social cognitive processes which can exert influence at the early sensory input stage or at the later motor, output stage (Gowen & Poliakoff, 2012; Heyes, 2011). One top-down influence, termed belief refers to prior knowledge or assumptions that a person has about the observed stimulus. For example, visuomotor priming is greater if a person believes (having received explicit instruction) that the non-biological stimulus is created from a human movement (Liepelt & Brass, 2010; Shen, Kose-Bagci, Saunders, & Dautenhahn, 2011; Stanley, Gowen, & Miall, 2007), whereas belief that a hand is virtual can reduce priming (Longo & Bertenthal, 2009). A more spontaneous or implicit form of belief could also occur for non-biological stimuli that have human characteristics (e.g. a robot) or for non-biological stimuli that are presented in a similar context to a previous human stimulus (Stanley et al., 2007). On the one hand, these results could suggest that belief produces action representation for non-biological stimuli by activating the MNS at the input stage or enhancing the MNS at the output stage. However, it could be that implicit or explicit belief merely alters attention to the stimulus movement, which either enhances or reduces stimulus response compatibility effects via the input route, without activating the MNS (Heyes, 2011; Press, 2011). Consequently, it is still unknown whether a non-biological movement can produce action representation equivalent to a human movement.

The aim of this work was to resolve these issues by separating imitative compatibility, due to action representation, from more basic stimulus response compatibility effects. We used a modified version of the visuomotor priming task where participants observe an index finger or blue rectangular object moving upwards or downward and must respond when they observe a go signal in the form of a yellow flash (Fig. 1). Participants viewed a right hand rotated 90 degrees counter clockwise (from the participant's viewpoint), in a "thumb up" orientation and were required to make a key press response with their left hand. This stimulus orientation and response combination separated three stimulus response compatibility effects from imitative compatibility (Fig. 2). Directional stimulus response compatibility effects were removed by rotating the hand so that up/down index finger movements now became left/right movements. However, rotating the hand introduces two further potential stimulus response compatibility effects (i) left-down and up-right stimulus response pairings are faster (orthogonal stimulus response compatibility; Weeks & Proctor, 1990); (ii) an advantage when the stimulus and response are on the same side of space (Simon effect; Simon, 1990).

By using a "thumb up" orientation together with a left handed pressing response (Fig. 2) we were able to isolate imitative compatibility from both orthogonal stimulus response compatibility and the Simon effect. Thus, when the finger moves leftward across the screen, this is compatible in terms of the Simon effect (left advantage due to using left hand to response) and orthogonal stimulus response compatibility (down-left advantage when pressing button), but is imitatively incompatible (downward response, observing upward finger movement). However, when the finger moves rightward across the screen, this is incompatible in terms of the Simon effect and orthogonal stimulus response compatibility, but is imitatively compatible (downward response, observing downward finger movement).

Participants responded to the go signal under three stimulus conditions. Firstly, they carried out the task while observing the object (object condition). Next, they responded while observing the object following a belief manipulation informing them that the object was based on the movement of a human index finger (belief condition). Lastly, they performed the task with the real human hand (hand condition). We hypothesized that orthogonal spatial compatibility/Simon effects would be present in the initial object condition and that imitative compatibility would be present for the hand stimulus. However, in the belief condition, there were two possibilities: (1) There would be an increase in orthogonal

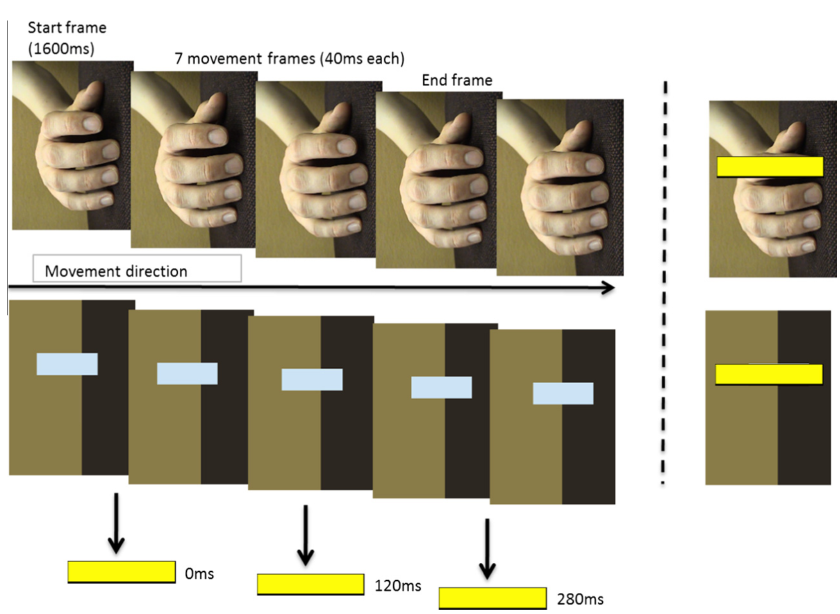

Fig. 1. Time course of one trial for the hand (top) and object stimuli (bottom). Trial starts at left of picture in neutral position and shows a downward movement for both stimulus types. The yellow go signal is presented for 80 ms at 0, 120 or 280 ms following the start frame. A second end frame is presented for the 280 ms go signal. Pictures to right of dashed line show position of flash on stimuli. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)