Human Movement Science 32 (2013) 314–327

Contents lists available at SciVerse ScienceDirect

Human Movement Science

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

Effects of model orientation on the visuomotor imitation of arm movements: The role of mental rotation

Daniel Krause *, Sven Kobow

Movement Science, Department of Sports and Health, Faculty of Science, University of Paderborn, Germany

ARTICLE INFO

Article history:
Available online 25 April 2013

PsycINFO classification:
2330
2340

Keywords:
Imitation
Mental rotation
Instructions

ABSTRACT

An experiment was conducted to examine whether visual perspective has an effect on visuomotor imitation. The experiment presented varied visual perspectives in terms of spatial disparity between a model and an observer (model-observer-disparity) on six levels. Female participants were asked to imitate different arm movements presented in videos by animated models. These arm movements were elbow-extension-flexion movements with one (lower complexity) or three (higher complexity) reversals of movement direction. The results showed that model-observer-disparity affects spatial trajectories and velocities in the performance of motor imitations. The movements' complexity did not affect orientation dependence. Due to the non-linearity of the data, it is questionable if orientation dependence can be at least partially explained by mental rotation processes or differential ideomotor effects. According to these results, high model-observer-disparity should be avoided when using visual instructions in visuomotor imitation.

1. Introduction

Visual instructions are frequently used to support motor learning processes in improving sports performance (e.g., Magill & Schoenfelder-Zohdi, 1996) or motor learning in rehabilitation (e.g., Ertelt

* Corresponding author. Address: Movement Science, Department of Sports and Health, Faculty of Science, University of Paderborn, Warburger Str. 100, 33095 Paderborn, Germany.

E-mail address: daniel.krause@upb.de (D. Krause).

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http://dx.doi.org/10.1016/j.humov.2012.10.001

et al., 2007). The underlying process, called visuomotor imitation, is defined as "to copy visually demonstrated movements or postures of human body parts by one's own body parts" (Makuuchi, 2005, p. 563). This work, in particular, addresses true imitation (Ferrari, Bonini, & Fogassi, 2009), which is defined as imitating a nearly exact kinematic copy of a movement, instead of imitating an action irrespective of its distinct movement characteristics. In this process of imitation, the imitator must transform the visual perception of a model's movement into an executable motor representation. This is called the "correspondence problem", and can be elucidated by the question: "How does the imitator know what pattern of motor activation will make their action look like that of the model?" (Brass & Heyes, 2005, p. 489). To solve this problem, an imitator may transform the allocentric visual perspective of movement kinematics into an egocentric perspective (Jackson, Meltzoff, & Decety, 2006). In other words, the spatial reference frame of the model's movement must be transformed into an egocentric spatial reference frame of the observer. This transformation may use mental rotation processes (Brass & Heyes, 2005; Heyes & Ray, 2004). From this point of view, the amount of mental rotation increases with the spatial disparity between the model's and the observer's egocentric perspective (model-observer-disparity). Fig. 1 illustrates two possible rotation paths for a mental representation of a models' movement. The first step is a rotation clockwise (light grey) or counter-clockwise (dark grey) in the picture plane. The second step is a rotation around the medio-lateral axis of the model.

In general, response times and discrimination errors show linear increases with increasing spatial disparity between pairs of abstract stimuli like cube figures (so called "Shepard-Metzler-Figures") when subjects are instructed to respond with a *same* or *different* decision. Shepard and Metzler (1971) were the first to show these effects with mirrored or non-mirrored stimulus pairs. They postulated that, in accordance with subjects' verbal reports, detection of similarity is based on mentally simulating the rotation of a physical object, attempting to align one mental representation with the other. The effects of mental rotation proved to be robust and have been replicated with different stimulus sets (cube figures: Metzler & Shepard, 1974; Parsons, 1987b; complex irregular polygons: Cooper, 1975, Experiment 1; faces: Valentine & Bruce, 1988; letters: Jordan, Wüstenberg, Heinze, Peters, & Jäncke, 2002; Steggemann, Engbert, & Weigelt, 2011; Weiss et al., 2009) and other tasks like lateral discrimination of human body parts (Cooper & Shepard, 1975; Parsons, 1987a, 1994). For the lateral discrimination of body parts, response times and error rates increase as a function of disparity from a retinocentric depiction of the body part as it is perceived in everyday situations (e.g., while grasping for an object). This coheres with the assumption that mental rotation takes place when people perceive body parts or whole body poses which they must map onto a mental representation of their own body (Amorim, Isableu, & Jarraya, 2006). Remarkably, studies that use body parts (e.g., Parsons, 1994) or alphanumeric stimuli (Weiss et al., 2009) do not show a linear function for mental rotation effects. Familiarity with the stimuli, leading to stimulus-specific perceptual expertise, seems to flatten

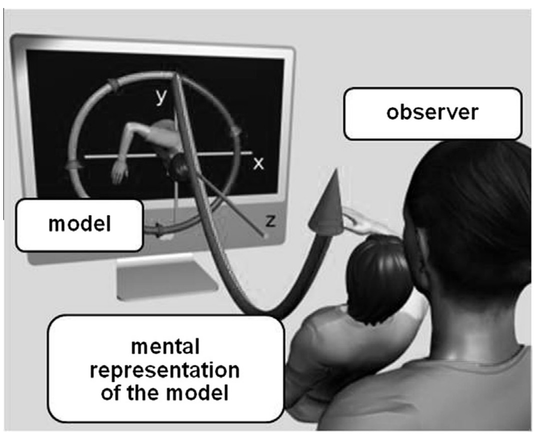

Fig. 1. Illustration of a possible rotation path of a model's mental representation.