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The effect of modeled absolute timing variability and relative timing variability on observational learning

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ABSTRACT

There is much evidence to suggest that skill learning is enhanced by skill observation. Recent research on this phenomenon indicates a benefit of observing variable/erred demonstrations. In this study, we explore whether it is variability within the relative organization or absolute parameterization of a movement that facilitates skill learning through observation. To do so, participants were randomly allocated into groups that observed a model with no variability, absolute timing variability, relative timing variability, or variability in both absolute and relative timing. All participants performed a four-segment movement pattern with specific absolute and relative timing goals prior to and following the observational intervention, as well as in a 24 h retention test and transfers tests that featured new relative and absolute timing goals. Absolute timing error indicated that all groups initially acquired the absolute timing, maintained their performance at 24 h retention, and exhibited performance deterioration in both transfer tests. Relative timing error revealed that the observation of no variability and relative timing variability produced greater performance at the post-test, 24 h retention and relative timing transfer tests, but for the no variability group, deteriorated at absolute timing transfer test. The results suggest that the learning of absolute timing following observation unfolds irrespective of model variability. However, the learning of relative timing benefits from holding the absolute features constant, while the observation of no variability partially fails in transfer. We suggest learning by observing no variability and variable/erred models unfolds via similar neural mechanisms, although the latter benefits from the additional coding of information pertaining to movements that require a correction.

1. Introduction

Behavioural data has shown that observing demonstrations of a novel motor skill can facilitate the learning of that skill (Ashford, Bennett, & Davids, 2006; Hayes, Elliott, & Bennett, 2013; Larssen, Ong, & Hodges, 2012; Ste-Marie et al., 2012). This finding is most often explained by the shared neural resources that are responsible for the coding of observed and executed actions (Jeannerod, 2001; Vogt & Thomaschke, 2007). Indeed, neuro-imaging studies have revealed that many of the same cortical regions that are active during motor planning and execution, namely, the inferior frontal gyrus (IFG), inferior parietal cortex (IPL) and ventral premotor cortex (vPM), are also active during action-observation (Buccino et al., 2001; Cross, Kraemer, Hamilton, Kelley, & Grafton, 2009; Dushanova & Donoghue, 2010; Higuchi, Holle, Roberts, Eickhoff, & Vogt, 2012; Rizzolatti & Craighero, 2004). Moreover, these common cortical regions are sensitive to the observation of the precise spatio-temporal dynamics of human movement (Gangitano, Mottaghy, & Pascual-Leone, 2001; Sartori, Bucchioni, & Castiello, 2012) with a resolution that reflects processing of individual muscles (Alaerts, Swinnen, & Wenderoth, 2011; Alaerts et al., 2010).

Interestingly, research has also consistently shown that observation-based learning is not only mediated through demonstrations that present the hallmark consistency and accuracy of expert performance (Al-Abood, Davids, & Bennett, 2001; Bandura, 1986; Blandin, Lhuisset, & Proteau, 1999; Buchanan & Dean, 2010, 2014; Hodges, Chua, & Franks, 2003), but also by way of demonstrations that contain the error and variability inherent to novice performances (Black & Wright, 2000; Blandin & Proteau, 2000; Blandin et al., 1999; Buchanan & Dean, 2010; Buchanan, Ryu, Zihlman, & Wright, 2008;

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Hayes, Hodges, Huys, & Williams, 2007). The findings associated with the observation of an expert model support the idea that these demonstrations provide learners with a perceptual representation of the correctly performed movement, which in turn serves as a standard of reference against which their own performances can be compared (Bandura, 1986; Sheffield, 1961). This is a notion that is also consistent with current accounts of motor control that include a role for anticipatory processing whereby response-associated visual feedback is compared against internal models of sensory expectations (Elliott et al., 2010). Alternatively, observation of novice models is purported to help learners make sense of the range of errors that can surround a motor task. That is, learning involves coming to understand the association between different movement patterns and their outcomes relative to the goal (Adams, 1986), such that the observation of novice performances presents the relationship between errors and their consequences. This information is important to learners as they come to generate strategies for executing movements that are designed to alleviate the costs of a potential error (Elliott, Hansen, Mendoza, & Tremblay, 2004; Lyons, Hansen, Hurding, & Elliott, 2006; Grierson, Gonzalez, & Elliott, 2009; Grierson & Elliott, 2009). Notably, learning appears to be best facilitated when observation includes a combination of both novice and expert performance demonstrations (Andrieux & Proteau, 2013; Rohbanfard & Proteau, 2011).

Incidentally, the positive impact of observing errors has called into question the straight one-to-one subthreshold activation of motor neurons during action-observation as a complete explanation for the observational learning phenomenon (e.g., Buccino et al., 2001; Cross et al., 2009; Higuchi et al., 2012). Indeed, a recent study from Buckingham and colleagues (Buckingham, Wong, Tang, Gribble, & Goodale, 2014) has shown that the corticospinal excitability elicited during the observation of variable motor errors was modulated by the subsequent learning or parameterization of required forces rather than the observed movement kinematics. That is, the observation of motor errors, as indicated by greater grip force rates for large-compared to small-sized objects that were the same weight, resulted in comparatively similar corticospinal responses during cortical stimulation. In other words, the neural codes responsible for the observation and execution of object-lifting were contingent upon the implicit understanding of the force parameters required to execute the task rather than the motor parameters manifesting in error. In addition, the behavioural data collected after the observation of variable motor errors reflected a similar outcome as the neurophysiological data with a more limited size-weight bias, and thus reduced motor error, compared to the observation of consistent error-free trials. Thus, it appears our understanding of the behavioural and neural underpinnings of learning through observation may be greatly benefitted from investigations of mixed or variable models consisting of at least some error.

With this in mind, it is relevant to consider what aspects of learning are benefitted most by the observation of variable or erred models, along with the precise features of observed movements that require variability in order to uphold a learning advantage. Indeed, the current consensus of observing a combination of mixed models for the enhancement of learning may operate at a number of different levels including the coordination of relative motion features (e.g., segmental timing of movements) and/or the parameterization of the absolute movement dynamics (e.g., combined timing or force specification) (Scully & Newell, 1985; see also Shea & Wulf, 2005). To date, evidence has shown that the observation of a mixed combination of expert and novice models results in better relative and absolute timing at immediate and delayed (24 h) retention tests, as well as enhancing the ability to transfer to a novel absolute timing pattern (Rohbanfard & Proteau, 2011). In a similar vein, it has been shown that the enhanced retention of relative and absolute timing following variable model observation is contingent upon a period of physical practice (Andrieux & Proteau, 2013). Meanwhile, the observation of variable/erred trials helps the observer to accurately parameterize force during novel object manipulation (Buckingham et al., 2014) and force-field pattern (Brown, Wilson, Obhi, & Gribble, 2010) tasks. Taken together, there is some evidence that variable model observation can enhance either relative and/or absolute features of a skill, although it remains to be seen what affect varying these corresponding features within observation has on overall skill development.

Accordingly, the aim of the current study was to examine the characteristic features of variability or performance error that were required in order to enhance motor learning. More specifically, we investigated the effect of varying relative and absolute timing on the learning of corresponding features of a skill. To this end, we challenged participants to learn specific relative- and absolute-timing of a four-segment movement pattern through the observation of demonstrations that were characterized by degrees of error in relative and absolute timing performance. The models featured either accurate absolute and relative timing with no error, constant accuracy in absolute timing but variable error in relative timing, constant accuracy in relative timing but variable error in absolute timing, or variable error in absolute and relative timing. The learners were tested on their ability to generate the criterion time in immediate and retention post-observation tests, and also in tests that required them to transfer to new absolute and relative timing goals.

In accordance with previous literature (for e.g., Al-Abood et al., 2001; Blandin & Proteau, 2000; Buchanan et al., 2008; Buchanan & Dean, 2010, 2014; Hayes et al., 2007; Hodges et al., 2003), we hypothesized that participants would learn both relative and absolute timing features following the observation of accurate absolute and relative timing with no errors. Of even greater interest was the impact that the observation of performances containing relative timing errors and/or absolute timing errors had on the learning of the relative timing and absolute timing. In general, we anticipated the learning of absolute and relative features to be even greater following the observation of demonstrations that included errors within these relevant or corresponding features. That is, the learning of absolute timing would be benefited most by the observation of models consisting of variable error in absolute timing, and the learning of relative timing would be benefitted most from models of variable error in relative timing. Lastly, we explored the degree to which the absolute and relative timing could be transferred to new absolute and relative timing goals. If the variability of model demonstrations enhances the detection and amendment of errors (Andrieux & Proteau, 2013; Blandin & Proteau, 2000), over and above constant accurate models consisting of no error, then we may predict the variability of observed absolute and relative features to promote transfer to novel absolute and relative timing patterns, respectively.

2. Materials and methods

2.1. Participants

Forty volunteers (21 males, 19 females, mean age = 23.72 ± 2.86) were recruited to take part in the study. All participants were free of any upper limb injuries or neurological disorders, had normal or corrected-to-normal vision, and were self-reported right-handers. Consent was obtained from each of the participants and the study was conducted in accordance with the guidelines set out by the McMaster University Research Ethics Board and the Declaration of Helsinki (2013).

2.2. Apparatus and task

Stimuli were presented on a computer monitor (57 cm × 34 cm) with a temporal resolution of 60 Hz and spatial resolution of 1024 × 768 pixels. The monitor was fixed onto a stand that was adjusted to each participant's hip height and presented in the horizontal axis so as to face upwards with respect to the participant's view. Each