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Intention in motor learning through observation

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The purpose of this experiment was to assess whether learning an action through observation is enhanced by the intention to reproduce the observed behaviour. Two groups of participants observed a model practise a timing task and performed a 24-hour delayed retention test. Participants in the first group of observers were explicitly instructed that they would be required to execute the timing task that they had observed as accurately as possible during the delayed retention test. Observers in the second group were instructed that they would be required to describe as accurately as possible the behaviour that they had observed. A control group of participants, who did not observe the model, was also administered the delayed retention test. The results of the retention test indicated that absolute timing (parameterization) was learned by the observers to the same extent with or without intention to reproduce the task. Indeed, on the retention test absolute timing for the two groups of observers was as effective as that for the models. However, observing with an intention to reproduce the task was beneficial for learning the movement's relative timing structure. Results are discussed with respect to a potential mechanism by which intention enhances observation.

Recent neuroimaging experiments report that a set of common neural structures are activated during both action production and action observation (Gallese & Goldman, 1998; Grèzes & Decety, 2001; see Jeannerod, 1999, for reviews). The shared neural structures included the premotor cortex, supplementary motor area, the inferior parietal lobule, cingulated gyrus, and the cerebellum. This finding has led a number of researchers (Jeannerod, 1999, 2001) to suggest a degree of functional equivalence between action generation, action simulation, action verbalization, and perception of action. For example, Jeannerod (1999) proposed that "Activation of motor structures might therefore represent a plausible neural basis for motor representations subserving, not only motor imagery, but also imitation and observational learning" (p. 10).

The activation of cognitive and motor neural structures in the absence of overt action provides a possible explanation for the beneficial effects of observation on motor learning. According to Bandura (1986), observation of a model's performance enables the observers to acquire a representation of the task to be learned. Afterwards, when the observers are required to physically perform the motor task, this representation is used to select and to programme the required

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response. The representation developed through observation also functions as a reference of correctness that serves as the basis for the detection and correction of errors. The movement representation and associated processing mechanisms acquired via observation are thought to be similar to those developed during physical practice (Schmidt, 1975; Schmidt & Lee, 1999). On this basis, it was suggested that observational learning and learning through physical practice may be mediated by similar cognitive processes (Adams, 1986). This notion is consistent with results that have shown that variables affecting learning through physical practice tend to affect observational learning in a similar way. For example, the schedule of practice experienced during observation (Blandin, Proteau, & Alain, 1994; Wright, Li, & Coady, 1997), the sensory information available during observation (Shea, Wulf, Park, & Gaunt, 2001b), and the relative knowledge-of-results (KR) frequency (Badets & Blandin, 2004) have produced similar patterns of results in learning for models and observers. Therefore, it was suggested that both "observation" and "physical practice" participants engage in similar cognitive processes responsible for action planning and control.

Importantly, recent results suggest that intention to reproduce the observed action plays a major role in observational learning. Using Positron Emission Tomography measures, Decety et al. (1997) reported that observation with the intent to reproduce the observed action was associated with cerebral activation in the regions involved in the planning and in the generation of actions (see also Grèzes, Costes, & Decety, 1999). These findings led Decety and Grèzes (1999) to propose: "The strong conclusion that the neural substrate for action planning is activated during perception of action holds true only when the goal is to imitate that action" (p. 178). Consequently, at a behavioural level, instructions that explicitly inform the observer that the behaviour has to be reproduced following observation should be beneficial when compared to no specific instruction. However, experimental evidence in this area is lacking.

The purpose of the present experiment was to assess the effect of intention (to reproduce the observed behaviour) on the observer's capability to learn a timing task. A three-element timing sequence was used because observation effects have been demonstrated for this task (e.g., Black & Wright, 2000; Black, Wright, Magnuson, & Brueckner, in press). In addition, performance on this task can be evaluated in terms of both relative and absolute timing. This is important because a number of traditional (e.g., Adams, 1971; Schmidt, 1975; Scully & Newell, 1985) and more recent (e.g., Keele, Jennings, Jones, Caulton, & Cohen, 1995; Verwey, 1994, 1999, 2001) theoretical perspectives make clear predictions regarding the effects of observation on learning relative and absolute timing. Recent theorists (Keele et al., 1995; Verwey, 1994, 1999, 2001), for example, have proposed two processing modules or mechanisms: one that defines the relationship between elements in the movement sequence, which can be evaluated by relative timing errors, and another independent processing module/mechanism responsible for the articulatory activities required for scaling of the individual elements, which can be evaluated by absolute timing errors. Numerous studies have been undertaken that demonstrate the empirical dissociation between the higher level processes that govern the planning and organization of the elements in the sequence and the lower level processes that produce the actual movement details. Further, these experiments have demonstrated that some practice variables/conditions that affect the learning of the relative timing have little effect (or even negative effect) on absolute timing learning, and vice versa. For example, Shea, Lai, Wright, Immink, and Black (2001a) reported that constant or blocked practice enhanced relative timing learning when compared to variable practice (see also, Lai, Shea, Wulf, & Wright, 2000). However, variable practice led to enhanced learning of absolute timing. De Jeager and Proteau (2003) reported that verbal knowledge of results is a very effective source of information to promote learning of a new imposed relative timing pattern when compared to auditory feedback. In an observational learning context, Blandin, Lhuisset, and Proteau (1999) reported that observation of an expert model was the only observation condition that promoted the learning of a newly imposed relative timing pattern. Finally, Shea et al., (2001b) have shown that the auditory information available during observation of a timing task is essential to the learning of the relative timing of the task, but has little, if any, effect on absolute timing. Altogether, the results of these experiments provide evidence that absolute and relative timing are processed by independent mechanisms or modules that can be developed in parallel.

In the present experiment, two groups of participants observed models while physically practising the timing task. Participants in both groups were instructed that they would be required to learn the relative and absolute timing constraints of the task, but one group of participants was explicitly informed that they would be required to reproduce the task during a subsequent retention test, while the other group was informed that they would be required to describe the observed behaviour (see Method for details). A control group that did not take part in the observation phase, but was administered the delayed retention test, was also included. We predicted that both types of observation will increment the learning of absolute timing when compared to the control group. It is important to obtain such a result for two reasons: (a) to replicate numerous experiments demonstrating a beneficial effect of observation on absolute timing learning and (b) to be sure that both groups of observers paid attention to the task performed by the model. More importantly, regarding the purpose of the experiment, we anticipated that intention to reproduce the observed behaviour would activate additional levels in the processing network, and the additional processing would be reflected in the enhanced learning of relative timing. We predicted that relative timing would be affected by intention because processing of this aspect of the task would require the retrieval and processing of the action plan, which we hypothesized would require intention to produce the movement sequence. In the absence of intention to perform the action, an action plan is not retrieved and processed—thus, only superficial aspects of the task would be enhanced. Finally, in order to assess the effect of observation and intention on the ability to detect timing errors in their own performance, participants in each group were asked to verbally estimate (in milliseconds) their performance during the retention test. Recently, Blandin and Proteau (2000, Exp. 1) and Black and Wright (2000) reported that the absolute difference between the participant's estimation of his/her performance and the actual performance is a useful tool in assessing the efficiency of the error detection mechanism that is thought to be developed during both physical and observation practice (Bandura, 1986).

Method

Participants

A total of 48 undergraduate students (mean age 20 years, $SD = 2.1$ years; 24 males and 24 females) participated in this study. Each participant completed an informed consent form prior to completing the experiment. All participants were self-declared right-handed and were unaware of the goals of the experiment.

Apparatus, task, and error measures

An illustration of the apparatus is presented in Figure 1. It consisted of a wooden board (50×50 cm) and nine microswitches (2.5 cm in diameter) connected to a PC computer for measurement and storage. When physically practising the task, the participants were seated in front of the apparatus and were asked to sequentially depress four microswitches with their right hand in a prescribed order, with a pattern of relative timing goals (RTG) and a prescribed absolute timing goal (ATG; see Figure 1). The RTGs for each movement segment (segments being defined by two consecutive microswitch presses) were 22%, 45%, and 33% of the ATG (Segments 1 to 3, respectively). The ATG was 900 ms. The RTG and ATGs were illustrated on a poster located in front of the apparatus and visible during all the experimental phases. Thus, the

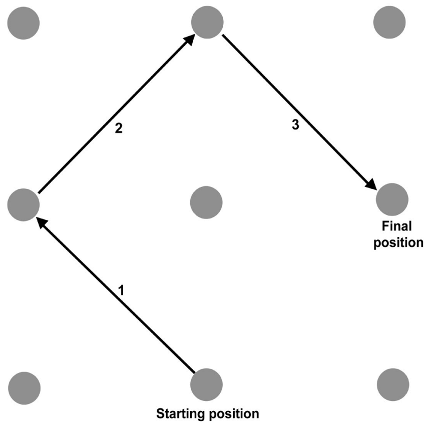

Figure 1. *Illustration of the apparatus. The total movement time was 900 ms (from the starting to the final position), and the segment ratios were 22%, 45%, and 33% of the total movement time for segments 1, 2, and 3, respectively.*

goal of the task was to learn the RTG and ATG as accurately as possible.

The RTGs were achieved when movement time was distributed across the three elements in .22, .45, and .33 proportions. Formula 1 was used to determine relative timing error (AE prop).

$$\text{Relative timing error (AE prop)} = |R_1 - .22| + |R_2 - .45| + |R_3 - .33| \quad 1$$

where R_n = (the actual MT of the element$_n$/total MT); MT = movement time. Thus, $R_1 - R_3$ are the proportions of total movement time utilized in Elements 1–3, respectively. Relative timing stability (Std) was computed as the standard deviation of relative timing errors (AE prop) across blocks of trials.

The ATG of the movement sequence was maintained when the movement was completed in 900 ms. For the ATG, total error (E) was chosen because this measure best characterizes absolute timing accuracy (Schmidt & Lee, 1999). E was computed considering both the bias and the stability of the difference between the ATG and the actual movement time across a block of trials. This measure provides an estimate of the accuracy with which the movement sequence was scaled in time. Formula 2 was used to compute total error (E).

$$\text{Total error (E)} = \sqrt{(\text{CE}^2 + \text{VE}^2)} \quad 2$$

where CE is a measure of response bias, which is computed as the average of the signed differences between actual total movement time and the ATG, and VE is a measure of response variability, which is computed as the standard deviation of the signed errors.

Finally, we used absolute error of estimation (AE Estim), which represents the absolute difference between the actual total movement time and the participant's estimation. AE Estim was a measure of the participants' ability to detect errors in their own performance.

Relative timing error (AE prop), relative timing stability (Std), and total error (E) were used in all phases of the experiment. However, the absolute error of estimation (AE Estim) was used only during the retention test.

Experimental groups and procedures

Three experimental groups ($n = 12$ for each group) and one control group ($n = 12$) participated in the experiment. All participants received verbal instructions regarding the goals of the task before beginning the experiment. During the acquisition phase, three participants were randomly assigned to one of the three experimental conditions (model, observer without intention, observer with intention). During the observation phase, the two observers were just behind and to the side of the model while he or she physically practiced the task: one on the left and one on the right. The side of observation was counterbalanced between each group of observers. Each trio (one model and two observers) was composed of three men or three women.

Each participant assigned to the model group physically practiced the task for 75 trials and received verbal KR about the actual absolute movement time (in ms) and about the actual relative timing pattern (in percentages) after each trial. Each participant in the "observers with intention" group (OBS+I) observed the trials performed by the model and received the verbal KR provided to the model. Before the observation phase (acquisition), participants in the OBS+I group were explicitly informed that they were to learn the observed behaviour because they would be required to reproduce the movement sequence with the prescribed relative and absolute timing on the following day (retention phase). Each participant in the observers without intention group (OBS−I) also observed the trials performed by the model and received the verbal KR provided to the model. However, before the acquisition phase, participants of the OBS−I group were explicitly informed that they were to learn the observed behaviour because they were instructed that they would be required to come back to the laboratory on the following day to describe both the relative and absolute timing of the model's performance. Therefore, during the acquisition phase, a trio composed of a model, an OBS+I, and an OBS−I either performed or observed 75 acquisition trials. The participants of the two groups of observers were instructed to not move their arm, hand, or fingers during the acquisition of observation, and the experimenter made sure that this instruction was respected by all observers.

To assess the effect of observation on learning, a control group that did not participate in the acquisition phase performed only the retention test. Participants in the control group received verbal instructions regarding the goals of the task (ATG and RTG constraints) before the retention test. The retention phase was conducted approximately 24 hours following the end of the acquisition phase. All participants (model, OBS+I, OBS−I, control) performed 15 retention trials without KR. Following each trial, they had to verbally estimate (in ms) the actual total movement time produced. This verbal estimation was used to assess the participant's capability to detect timing error in his/her own performance (Blandin & Proteau, 2000).

In the retention phase, all participants were permitted to consult the poster located in front of the apparatus and were given the time needed to prepare the appropriate response. Trials for which the participant made errors in the pattern of movement or where they missed one target were repeated immediately.

Results

For the acquisition and retention phases, the data were grouped into blocks of 15 trials. The dependent variables of interest were relative timing error (AE prop), relative timing stability (Std), total error (E) for the acquisition phase, and AE prop, Std, E, and AE Estim for the retention phase. The dependent variables were submitted to separate analyses of variance (ANOVAs), and post hoc comparisons of the means were computed using the Newman−Keuls technique.

Acquisition

To assess the effect of physical practice, data collected from the models during the acquisition phase were submitted to repeated measures ANOVA with repeats on blocks (1−5). For the relative timing error (AE prop), the analysis revealed a significant effect of blocks, $F(4, 44) = 3.74$, $p < .05$, (Figure 2A, left). Not surprisingly, post hoc comparisons indicated that AE prop was higher for Block 1 (15.64%) than for Blocks 2, 4, and 5 (mean of 12.47%). For relative timing stability, the ANOVA revealed a significant effect of blocks, $F(4, 44) = 2.94$, $p < .05$, (Figure 2B). Post hoc comparisons indicated that relative timing stability was lower for Block 1 (7.47%) than for Blocks 3, 4, and 5 (mean of 5.21%). Finally, the analysis of E revealed a significant effect of blocks, $F(4, 44) = 6.40$, $p < .05$, (Figure 2C). Post hoc comparisons indicated that E was higher for Block 1 (163 ms) than for all subsequent blocks (mean of 82 ms).

Retention

To compare the effects of practice on learning (physical practice and two contexts of observation) with the control condition (no practice), data from the 24 hours delayed retention test were submitted to separate one-way ANOVAs on group (models,

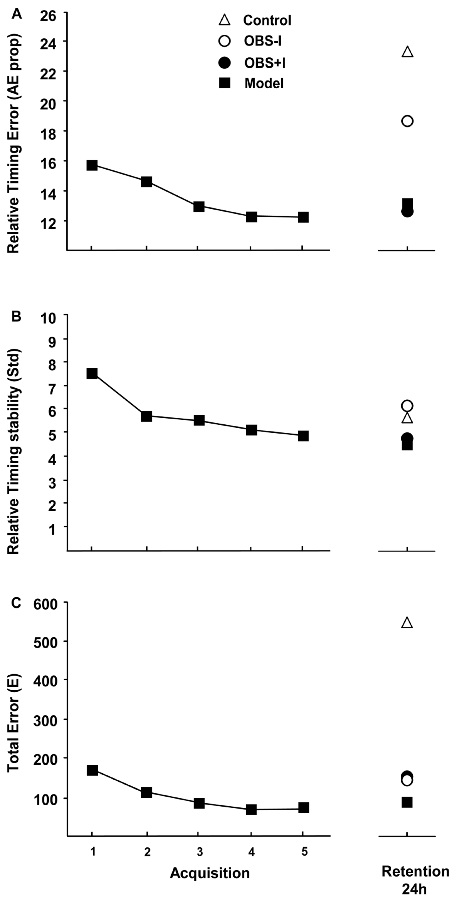

Figure 2. *Relative timing error (AE Prop), relative timing stability (Std), and total error (E) for the models (acquisition) and following observers of a model with intention or without intention on the retention test. Note that the control group only participated in the retention test.*

OBS+I, OBS−I, control). For relative timing error (AE prop), the analysis revealed a significant effect of group, $F(3, 44) = 10.06$, $p < .05$, (Figure 2A, right). Post hoc comparisons indicated that the models and OBS+I groups outperformed the OBS−I group, which in turn outperformed the control group. For the relative timing stability, the analysis did not reveal an effect of group, $F(3, 44) = 0.92$, $p > .05$, (Figure 2B). The analysis for E revealed a significant main effect of group, $F(3, 44) = 5.42$, $p < .05$. Post hoc comparisons indicated that the models, the OBS+I, and the OBS−I groups were more accurate and less variable than the control group (Figure 2C).

A similar result was obtained for the absolute error of estimation (AE Estim). The analysis revealed a significant effect of group, $F(3, 44) = 4.91$, $p < .05$. Post hoc comparisons indicated that the models, the OBS+I, and the OBS−I groups were more accurate in detecting absolute timing errors than were the control group (82, 127.8, 134.9, and 507.8 ms, respectively).

Discussion

The purpose of the present experiment was to assess the effect of intention on the observer's ability to learn a simple timing sequence with specific relative and absolute timing requirements. We hypothesized, based on recent behavioural and neuro-imaging research, that observers with the specific intent to reproduce an observed movement sequence would activate neural mechanisms/substrate more similar to that activated during physical practice than observers simply attempting to extract movement information. At a behavioural level, this activation should enhance retention performance especially in relative timing.

With or without intention, the learning of absolute timing was enhanced through observation of a model's performance (observation effect: OBS+I and OBS−I vs. control). This result reproduces numerous previous results demonstrating the beneficial effects of observation on motor learning (Schmidt & Lee, 1999). However, with the specific intention to reproduce the observed behaviour, the observers learned the required relative timing pattern much more accurately than without intention (intention effect: OBS+I vs. OBS−I). Intention in the observational learning process did not seem to directly impact relative timing stability or the capability to accurately scale the response sequence. The scaling of the movement sequence was enhanced through observation with no further enhancement when participants were provided with intention instructions. Only the OBS+I participants were able to produce the relative timing pattern as accurately as the models. Indeed, the control group simply produced a relative timing that reflects the constraints of the apparatus (i.e., amplitudes between targets location) and did not respect the relative timing goals imposed. The control group spent 25.8%, 37.1%, and 37.2% of the total movement time (TMT) for Segments 1, 2, and 3 respectively; this relative timing pattern approximates what has been called "natural timing" because it reflects the constraints of the task (see also Blandin et al., 1999; Wright & Shea, 2001). That is, a natural timing pattern is one that is typically observed when a goal relative timing pattern is not imposed. During the first block of acquisition, within five practice trials with KR, models were able to move away from this natural timing and to produce a relative timing pattern approaching the goal pattern (22.3%, 38.5%, and 39.2% of the TMT for the Segments 1, 2, and 3, respectively). During the retention test, the relative timing pattern produced by the models and the OBS+I matched very closely the goal pattern (22%, 45%, and 33%). More specifically, the models spent 23.2%, 39.1%, and 34.2% of the total movement time, and the OBS+I spent 24.1%, 41.3%, and 34.5% of the total movement time (for the Segments 1, 2, and 3 respectively). On the other hand, the participants in the OBS−I group produced a relative timing pattern that was closer to the natural timing produced by the control group than to the required timing (25.1%, 38.2%, and 36.7% of the total movement time for Segments 1, 2, and 3 respectively). Furthermore, the accuracy of the relative timing pattern achieved by the models and OBS+I groups was not obtained at the expense of relative timing stability or the learning of the absolute timing requirements.

One explanation for the beneficial effect of intention has been provided by Goschke and Kuhl (1993). They reported a series of results that suggested that intention to perform some action produce a higher state of activation of the action plan stored in memory. Briefly, in this paradigm, participants first learn scripts of various actions to criterion (e.g., distribute the cutlery for setting a table), and, secondly, they were instructed which of the scripts they would have to perform. In a recognition test, response latencies were faster for the designated script than for the other scripts. This effect has been called the "intention superiority effect" (see also Marsh, Hicks, & Bryan, 1999). However, in the present experiment, the instructions to reproduce the task (or not) were given prior to observation rather than prior to physical practice. Therefore, in an observation learning paradigm, such as that used in the present experiment, the beneficial effect of intention is probably mainly due to encoding and retrieval processes related to the action plan as opposed to the activation of the action plan as described in the intention superiority effect. Recent data reported by Leynes, Marsh, Hicks, Allen, and Mayhorn (2003) support this proposal. In their experiment, participants were explicitly informed that some actions (i.e., "bend the wire") have to be encoded with the intention to perform it during a subsequent retention test while others actions simply have to be memorized. After encoding, participants performed a discrimination test where they had to decide whether each action was to be performed or not. They reported shorter reaction time for the to-be-performed actions than for the to-be-remembered actions and concluded that encoding and retrieval processes differ with an intention to reproduce the action when compared to the sole memorization. In the present experiment, as in the Leynes et al. experiment, participants knew at encoding whether actions would or would not be performed, and we believe that the performance differences found in our experiment reflect the cognitive processing associated with the intention to reproduce the observed behaviour.

However, one could argue that the beneficial effect of intention reported in the present experiment could only reflect "more" (deeper) processing at encoding. However, if the intention to perform an activity only produced a more elaborate form of encoding, then no difference would have been found between the learning of the timing parameter and the learning of the relative timing pattern. Therefore, our results suggest that forming an intention to reproduce an action differs from encoding information into explicit memory and that intention is not simply the result of "more elaborate processing" (see also Leynes et al., 2003, for similar conclusion).

On a more general level, our results are consistent with numerous theoretical proposals and empirical results indicating a dissociation between the two memory states (or processing mechanism or module, depending on theoretical perspective) governing a movement's relative structure (e.g., relative timing) and the memory state (or processing mechanism or module) responsible for scaling (e.g., absolute timing) the entire movement sequence. To our knowledge, the present data represent the first time that this dissociation becomes apparent through the intention effect. Consequently, our results provide additional clarity to the conditions that favour the learning of a movement's relative structure—conditions that remain at the present time relatively unknown (Schmidt, 2003; Sherwood & Lee, 2003). However, as suggested by Clark, Tremblay, and Ste-Marie (2004), intention to produce a task enhances motor learning if the task is complex enough or novel for the learner. Clearly, if participants had been asked to produce a timing sequence with a relative timing pattern that approached the pattern that would typically be adopted without instruction (natural timing pattern) the benefits of intention would not be expected to be observed (see Wright & Shea, 2001). Furthermore, the behavioural results of our experiment also agree with Decety and colleagues' proposal that different neuronal structures are involved with intention and without intention to reproduce the observed behaviour (Decety & Grèzes, 1999; Decety et al., 1997; Grèzes et al., 1999). Recently, Iacoboni et al. (2001), using functional magnetic resonance imaging demonstrated that action memorized for delayed reproduction activates the right anterior parietal cortex, an area that was involved in the formation of a kinaesthetic copy of the movement (see also Iacoboni et al., 1999). These results are consistent with the motor-simulation theory according to which perceiving actions involve internal simulation of the movement to be produced (Jeannerod, 1999, 2001). This internal simulation involves, on the one hand, specific action preparation and programming and, on the other hand, the generation of a copy of the movement to be reproduced.

Finally, it must be emphasized that the discovery of ways to enhance the effectiveness of observational practice are important for a number of applied and theoretical reasons. While we have concentrated on the impact of the present results on theory, the fact that effective observational practice can reap large benefits in terms of practice efficiency should not be discounted. A participant engaged in observational practice does not risk injury, utilize equipment, or expend the same amount of energy as in physical practice. Thus, the total amount of time that a learner can practically be engaged in task-related practice can be functionally increased by combining physical and observational practice.

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