

Demonstration as a rate enhancer to changes in coordination during early skill acquisition

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Abstract

We compared the nature and rate of change in intra-limb coordination in participants who observed a video model (model) with those who practised based on verbal guidance only (control). Sixteen male novices threw a ball towards a target with maximal velocity using a back-handed, reverse baseball pitch. Participants in the model group immediately changed their intra-limb relative motion to more closely resemble the model's relative motion pattern. This new coordination pattern, and concomitant changes in ball speed, was maintained throughout acquisition, without further change. In contrast, the control group showed no change in coordination or ball speed across acquisition. Our findings suggest that demonstrations act as a rate enhancer, conveying an immediate movement solution that is adopted early in acquisition. A model may constrain the learner to perceive and imitate the model's relative motion pattern as suggested by Scully and Newell (1985). The stability of this new movement pattern questions accounts of learning, which suggest that prescriptive, directed learning may result in the "soft assembly" of an inaccurate and temporary movement solution.

Keywords: *Skill acquisition, modelling, practice, constraints*

Introduction

A review of the observational learning literature suggests that demonstrations vary considerably in their effectiveness as a method of facilitating skill acquisition. This conclusion would appear at odds with the widespread acceptance of this technique as an effective method of instruction by coaches. Researchers have presented several explanations for the mixed effectiveness of demonstrations. These include the type and novelty of the task employed (e.g. Southard & Higgins, 1987), whether the demonstration portrays a clear strategy for action (e.g. Burwitz, 1975), or whether the task requires a new coordination pattern to be learned (Magill & Schoenfelder-Zhodi, 1996).

Another consideration that may explain the disparity between anecdotal support and empirical evidence is the time-scale over which demonstrations are employed. In practical settings, the effectiveness of a demonstration is often gauged by how well the learner adopts the demonstrated behaviour in that practice session. However, since most demonstration

research has been couched in learning theory, and the widely accepted definition of motor learning includes a permanent or semi-permanent change in behaviour (see Schmidt & Lee, 2005), much recent research has gauged the efficacy of demonstration primarily using delayed retention measures, often after a prolonged period of acquisition (e.g. Al-Abood, Davids, Bennett, Ashford, & Martinez Marin, 2001b; Blandin, Lhuisset, & Proteau, 1999; Blandin, Proteau, & Alain, 1994; Breslin, Hodges, Williams, Curran, & Kremer, 2005; Herbert & Landin, 1994; McCullagh & Caird, 1990). Although the use of delayed retention tests should be encouraged, it should not be at the expense of examining any meaningful changes in early acquisition. The issue of whether demonstrations provide an advantage over alternative methods in the first few trials of skill acquisition such as discovery learning or verbal guidance is typically not addressed. Moreover, any early advantage that may be offered by demonstrations is likely to be reduced or disguised over prolonged periods of physical practice (see, for example, Martens, Burwitz, & Zuckerman, 1976).

Thus, an important question that has received limited investigation in the observational learning literature is: Can demonstrations act as a *rate enhancer* early in acquisition? Horn and Williams (2004) highlighted the potential benefits of demonstrations as rate enhancers, imparting immediate benefits in acquisition regardless of long-term benefits. They argued that although long-term changes are considered to be the benchmark for skill acquisition, there are important implications for accelerated early acquisition. Applied practice sessions rarely mimic learning experiments. Coaches and teachers use feedback, verbal guidance, and many different types of practice (see Williams, Horn, & Hodges, 2003). In everyday motor learning environments, the efficiency of demonstrations may place learners in a position to receive further augmented information or coaching to guide skill acquisition earlier than those not receiving a demonstration (Horn & Williams, 2004). Perhaps more importantly, in these environments the learner may have only a limited time to practise a skill before it must be transferred to a different context. Unless the skill is acquired efficiently, the learner will not be able to adapt to the new task constraints.

In theoretical terms, the role of demonstrations in accelerating the rate of skill acquisition is not a novel concept. In social-cognitive accounts of observational learning, the formation of a perceptual *blueprint* (Sheffield, 1961) or cognitive representation (Bandura, 1969) of the action is assumed to be required to guide subsequent imitation. The development of the cognitive representation is thought to be accelerated via demonstrations. In turn, demonstrations are thought to accelerate acquisition by conveying structure and the underlying rules of behaviour (Carroll & Bandura, 1985; see also Martens *et al.*, 1976). Bandura (1965) considered demonstration to be so potent that behaviour could be observed on one occasion, and re-enacted later, in the absence of a model. This concept of “no-trial learning”, like all effects related to observational learning, is dependent on the complexity of the task and the method of assessing learning (e.g. kinematics vs. outcomes), but suggests that observation of a demonstration may essentially replace physical practice.

In the domain of ecological psychology, Scully and Newell's (1985) visual perception perspective suggests that observers pick up the model's relative motion, and in later re-enactment become constrained by the informational or instructional constraint it imparts (see Newell & McDonald, 1991; Warren, 1990). Although Scully and Newell (1985) did not directly suggest that demonstrations act to increase the *rate* of skill acquisition, they did predict that the model's effects would be greatest in early

learning. Similarly, Newell (1985) argued that in early learning the emphasis is on the assembly of a new movement topology (i.e. coordination). In this early period of learning, Scully and Newell (1985) suggested that the perception of the model facilitates the pick up of relative motion between body parts. Later in learning, when the parameterization of the movement pattern dominates (i.e. control), the influence of the model is assumed to subside.

Dynamical systems accounts of early learning have promoted the idea of *searching* (Fowler & Turvey, 1978; Newell, Kugler, van Emmerik, & McDonald, 1989; Newell & McDonald, 1991) for task solutions in the *perceptual-motor workspace*. Newell (1985) and Thelen (1995) described the acquisition of coordination as a perceptual search or flow through the potential range of degrees of freedom by which the motor system can be configured (see also Williams, Davids, & Williams, 1999). Al-Abood, Davids, and Bennett (2001a) suggest that observation of a demonstration guides this search for optimal task solutions in the workspace. However, guidance that is overly prescriptive is assumed to discourage search, leading to the adoption of a motor solution that is neither elaborate nor easily transferred to a different performance context (Handford, Davids, Bennett, & Button, 1997). It has also been suggested that guidance, in the form of a demonstration for example, leads to the acquisition of solutions that are “soft-assembled”, providing only a temporary and imprecise solution to the movement problem (Handford *et al.*, 1997; Zanone & Kelso, 1994). Accordingly, discovery methods of learning might be viewed more favourably than overly prescriptive, solution-based methods (such as demonstrations).

Thus far, few researchers have examined the immediate effects of a model in early acquisition because most experiments were designed to examine other issues, such as the effect of various characteristics of the model (e.g. status, skill level). Moreover, in experiments designed to compare performance between pre-test, acquisition, and delayed retention periods, many researchers have provided only a single (group) mean score to represent the first block of acquisition (e.g. Blandin *et al.*, 1994; Herbert & Landin, 1994; Weeks & Anderson, 2000; Wuyts & Buekers, 1995). This approach makes it difficult to examine the immediate effect of the model, the rate of acquisition, or the trial-to-trial variability early in acquisition.

Newell and McDonald (1991) have argued that a preference for measuring outcome data (using group means) has led to indifference in relation to the trial-by-trial changes in performance that reflect the search for solutions in learning. Those researchers who have included trial-by-trial assessments of changes in performance have typically used outcome

data to examine the effect of the model's skill level (e.g. Pollock & Lee, 1992), or the mode of the demonstration (e.g. Doody, Bird, & Ross, 1985), although some researchers have examined trial-by-trial changes in perceived movement form (e.g. Gray, Neisser, Shapiro, & Kouns, 1991; McCullagh & Meyer, 1997).

Few researchers have employed kinematic measures to infer the nature of the information picked up by a learner from a model. These measures have included changes in joint angles (e.g. Williams & Thompson, 1994), relative timing (e.g. Scully & Carnegie, 1998), and relative motion (e.g. Schoenfelder-Zhodi, 1992). Recently, several researchers have more closely examined the constraints imparted by a demonstration by quantifying changes in the learner's coordination relative to the model. Al-Abood *et al.* (2001a, 2001b) reported that the relative motion (upper and lower arm segments) of participants observing a model performing an under-arm dart throw was closer to the model than that of a control group. However, in the former study the authors found a test period effect over blocks of 10 trials, while this effect was not reported in the latter study. Similarly, in comparing the efficacy of demonstrating an absolute motion end-point against a relative motion model in changing learners' relative motion in a soccer chip/scoop task, Hodges, Hayes, Breslin, and Williams (2005) showed that the end-point model allowed closer approximation of the model's knee-hip relative motion than did observation of the model's whole leg. However, Breslin *et al.* (2005) found that observation of just a wrist marker when learning a cricket bowling task led to poorer learning of the model's relative motion than did observation of the whole body.

In another recent study designed to quantify changes in the learner's coordination relative to the model, Horn, Williams, Scott, and Hodges (2005) assessed changes in knee-hip and knee-ankle coordination in a soccer-chipping task. Kinematic data were collected in clusters of three trials in a pre-test, in the first three trials of acquisition (immediately after observation of the model), at the start of a second acquisition period, and in post- and retention tests. Coordination was quantified for variability using normalized root mean squared error (NoRMS; Sidaway, Heise, & Schoenfelder-Zhodi, 1995) and for proximity to the model using an adapted version of NoRMS (NoRM-D; see Horn *et al.*, 2005). In partial support of Scully and Newell's (1985) visual perception perspective, participants observing a point-light or video model changed their relative motion to become more like the model. However, the changes occurred exclusively between the pre-test and the first three acquisition trials. Participants showed little change thereafter. In contrast,

participants in a no-model control group (who practised based on pre-test instructions and then by unguided discovery) failed to change their movement patterns across practice.

Horn *et al.* (2005) questioned the appropriateness of ecological explanations of early skill acquisition. They argued that if a demonstration constrains learners to rapidly assemble a new relative motion pattern, which in turn consistently approximates a model, then early acquisition may not be about a broad search for task solutions as suggested by Newell *et al.* (1989) and Handford *et al.* (1997). Although this would clearly be dependent on the task constraints and the learner's experience, for the chipping task of Horn *et al.* (2005) the constraints of the model appear to act as a rate enhancer, allowing the learner to *refine* rather than *broadly search*. Using Newell's (1985) terms, this implies that demonstration accelerates the shift in emphasis from coordination to control.

Although Horn *et al.* (2005) have provided evidence for the immediate effect of a model, some verification is required. First, the powerful effect of the model shown by Horn *et al.* (2005) occurred in the absence of task-intrinsic visual feedback. The removal of this powerful source of information during practice may have encouraged faster and larger changes in coordination, since feedback would have likely encouraged the parameterization of the task outcome (see Horn, Williams, & Scott, 2002). Second, Horn *et al.* (2005) used intermittent clusters of kinematic trials. This allowed the measurement of immediate changes in coordination after viewing a model, but did not show the stability of those changes (since the next kinematics were collected 17 trials later).

In this paper, we examine Scully and Newell's (1985) prediction that learners observe and are constrained by the model's movement pattern (in particular, the relative motions within and between joints) by examining the rate at which parameters related to movement coordination change in early acquisition. Also, we examine the prediction that the changes induced by a model are temporary, inaccurate solutions to the movement problem. It was predicted that participants who observed a demonstration would show a significant change between the pre-test and first three trials of acquisition to more closely approximate the model's relative motion patterns. In contrast, the no-model control group was expected to show no such change. After this immediate change, it was predicted that the participants in the demonstration group would not change their movement pattern for the remainder of the acquisition trials, while the no-model control group were expected to show a gradual change in coordination from the pre-test to the last trials of acquisition.

Variability was anticipated to be higher in acquisition for the control group than the model group, reflecting the participants' search for an optimal movement solution. Finally, for movement outcomes it was predicted that since the model demonstrated the optimal movement pattern, those observing the model would show a significant change from pre-test to early acquisition, and significantly higher ball speed and accuracy in acquisition than the no-model control group.

Methods

Participants

Sixteen male participants (mean age 31.9 years, $s = 10.2$) provided informed consent before taking part in the experiment. All participants were volunteers, novice at the task, and right-side dominant. The experiment was carried out according to the ethical guidelines of Liverpool John Moores University.

Task and test films

The task was to throw a ball to a square 1.7×1.7 -m vertical target placed 5.0 m away. The target was unmarked. The model was a 28-year-old male. After several days of practice, a throw was conceived that was judged to be novel to the participants. The throw was considered to be a reversed, backhand baseball pitch. For a right-handed thrower in baseball, the left knee and hip flex to bring the left leg across the body and the left shoulder points to the target. In this task, summarized in Figure 1, for a right-handed thrower, the ipsilateral foot crosses the body with hip and knee flexion, pointing the right shoulder at the target. This movement puts the thrower in position to throw backhand. The arm is then pulled through with the elbow leading toward the target. As the right arm comes through, the back of the hand faces the target until release. Several other factors indicate that this technique mimics a reversed mature baseball pitch. As with a baseball pitch, the thrower takes a long forward step to increase the distance over which force can be applied. In the current task, the long step

was with the ipsilateral foot. The thrower also utilizes the open kinetic chain. The forearm segment lags to reach peak velocity after the upper arm segment, when the trunk has rotated forward. The trunk in turn shows differentiated rotation, with the lower portion rotating forward before the upper trunk. This combination of differentiated rotation and arm lag allows high speed to be imparted on the ball.

The model was filmed in the sagittal plane performing a successful throw using a video camera (Panasonic M-40, Tokyo, Japan). The video of the model's throw was then edited and repeated on tape several times. On the same throw, the spatio-temporal positions of retro-reflective markers placed on the model were registered using four infrared cameras (Pro-Reflex, Qualisys, Gothenburg, Sweden) sampling at 240 Hz.

Procedure and design

On arrival in the laboratory, participants were assigned to the model or control group. Retro-reflective markers were placed on the participant's right side at the acromion process (shoulder), lateral epicondyle (elbow), ulnar process (wrist), greater trochanter (hip), lateral condyle of the femur (knee), and the lateral malleolus (ankle). Two markers were placed on the ball to provide a reference point for ball release.

Before the pre-test, participants were given standardized instructions and were positioned with their feet on two floor markings, 35 cm apart. They were told that the task was to throw the ball for maximum speed, ensuring that the ball hit the target. Three additional task constraints were then described. First, they were told that the back of the hand should face the target until ball release. Second, they were informed that they were free to move how they wanted as long as they did not step over the line placed on the floor 1 m in front of them. Third, to prevent underarm throwing, the participants were told that the ball should be released from a position in which the wrist was located above the height of the elbow.

After three pre-test trials, participants in the control group continued to practise based on their



Figure 1. Illustration of the reversed baseball pitch.

initial verbal instruction. The model group observed five demonstrations of the model, which was projected as a life-size image onto a 3.5×3.0 -m Cinefold screen (Draper, Spiceland, Indiana). Before viewing the demonstration, the participants were informed that after seeing the model, they should continue to throw at the target for maximal velocity, while trying to replicate exactly the model's form in all subsequent trials. In addition to the five consecutive demonstrations of the model, the model group observed one demonstration after each of the first five acquisition trials.

Participants in both groups performed 18 acquisition trials in the absence of augmented feedback. This number was selected to mimic typical practice ecologies for maximal throwing sports such as baseball, in which pitch counts in practice are limited to prevent overuse injuries and allow maximal in-game performance (see Washington, 2001). Also, a greater number of trials may produce changes in technique as a result of fatigue, which could inappropriately be charged to instability in movement form. Outcome and kinematic data were collected on all trials.

Dependent measures and data analysis

Outcome scores. Ball speed was assessed with a JUGS Doppler radar gun (Decatur Electronics, Decatur, Illinois). The gun can measure ball velocities from 32 to 320 $\text{km} \cdot \text{h}^{-1}$ via a microwave transmitter. Accuracy was tested on each day of testing using a calibration fork, vibrating at 110.6 $\text{km} \cdot \text{h}^{-1}$. Across all test days, the maximum error did not exceed 0.4 $\text{km} \cdot \text{h}^{-1}$. An experimenter stood with the radar gun next to the target on each trial to minimize the angle between ball approach and radar direction. This approach minimized radar error and allowed the gun to pick up the ball throughout its flight until just before contact with the target. The experimenter also kept track of the number of times the thrower missed the target.

Coordination. The data from five randomly selected participants in each group were used for kinematic analysis. The effect of viewing a model on the immediacy and stability of changes in coordination was assessed at a local, intra-limb level of analysis. At a local, intra-limb level, coordination was assessed as relative motion between the right shoulder and elbow, and the right knee and hip. For the elbow–shoulder relative motion, the start and end-points of the analysis were aligned to begin at the initiation of shoulder flexion, and end after ball release at maximal elbow extension. For knee–hip relative motion, the data were aligned to end at maximal elbow extension, since this represented the end of the

meaningful portion of movement. However, to account for differences in movement technique, knee–hip motion was aligned to start at the initiation of knee flexion. Data were smoothed with a recursive fourth-order Butterworth filter with a cut-off frequency of 7 Hz. A linear interpolation was performed on the aligned, filtered data, to quantitatively normalize this period to 100 data points. This process did not alter the relative motion pattern as indicated in angle–angle plots.

Intra-limb coordination was quantified in two ways. First, variability was assessed using a modified version of Sidaway and colleagues' (1995) normalized root mean square error (NoRMS). In the original version of this technique, root mean squared error is calculated based on disparity of each trial with the mean trace pattern. The data are then normalized for number of trials and the excursion of the pattern. The reason for this procedure is that a larger movement pattern may exhibit greater variability than an equivalent, smaller plot. An interpretation of the NoRMS technique presented by Mullineux, Bartlett, and Bennett (2001) used range of motion as the measure of excursion. Horn *et al.* (2005) considered this to be a more appropriate measure of excursion since, for a plot normalized to 100 data points, its size is a product of its range of motion.

For proximity to the model's relative motion pattern, we used an adapted version of NoRMS in which the participant's mean trace is replaced by the model's trace. The resulting measure reflected the root mean squared difference (NoRM-D; Horn *et al.*, 2005) between the coordination patterns of the model and learner. The scores were then normalized for the number of trials and range of motion.

Statistical analysis

All outcome and coordination variables were analysed using separate factorial analyses of variance (ANOVA) in which group (model; control) was the between-participants factor and experimental test period was the within-participants factor (pre-test, A1–3, A4–6, A7–9, A10–12, A13–15, A16–18). Single trials were not used as the within-participants factor because NoRMS data require a cluster of trials for the analysis. Therefore, each trial represented by these measures contains data from two other trials.

Significant effects were followed up where appropriate using the Tukey HSD test ($P < 0.05$). Where violations of the assumption of sphericity for repeated measures ANOVA were observed, data were adjusted with a Greenhouse-Geisser epsilon factor. Also, where violations of the assumption of normal distribution were observed

(Kolmogorov-Smirnov Z -test), a logarithmic transformation (base 2) was used to correct the data. Effect size measures were calculated using omega squared (Tolson, 1980).

Results

Outcome scores

For ball speed, ANOVA revealed a main effect for Test Period ($F_{2.86,39.98} = 5.95$, $P < 0.05$, $\omega^2 = 0.47$) and Group ($F_{1,14} = 7.23$, $P < 0.05$, $\omega^2 = 0.10$). A Group $\times$ Test Period interaction was also observed ($F_{2.85,39.98} = 2.95$, $P < 0.05$, $\omega^2 = 0.18$). Figure 2 and *post hoc* analysis illustrate that differential changes in ball speed from the pre-test to the first three trials of acquisition primarily account for this effect. The control group showed no change in ball speed over this period or throughout acquisition. The model group showed a large, significant increase in ball speed from the pre-test to first three acquisition trials and no change in ball speed thereafter.

Proximity to model's relative motion – NoRM-D

Elbow–shoulder relative motion. Figures 3 and 4 show elbow–shoulder relative motion plots across all test conditions for single participants whose NoRM-D scores were representative of the model group and the control group. In Figure 3, the participant's (model group) three trials per period are shown against the model's movement pattern (dark trace). It shows a change in elbow–shoulder relative motion to more closely resemble the model's pattern from the pre-test to first period of acquisition. This pattern then remains stable throughout the remaining practice trials. For the control group participant in Figure 4, there is little change across trials and no apparent increase in proximity to the model's relative motion pattern.

For proximity to the model's elbow–shoulder relative motion, ANOVA revealed a significant main effect for Group ($F_{1,8} = 12.40$, $P < 0.05$, $\omega^2 = 0.22$)

and for Test Period ($F_{6,48} = 4.39$, $P < 0.05$, $\omega^2 = 0.42$). There was also a Group $\times$ Test Period interaction ($F_{6,48} = 2.49$, $P < 0.05$, $\omega^2 = 0.14$), which is illustrated in Figure 5A. Pre-test scores for both groups are shown to be close in value (model group mean = 36.74, $s = 8.58$; control group mean = 40.58, $s = 7.88$), but become markedly different in the first three trials of acquisition (model group mean = 24.03, $s = 5.47$; control group mean = 41.57, $s = 10.49$). The individual elbow–shoulder NoRM-D scores for each participant are shown in Figure 5B.

Knee–hip relative motion. Knee–hip relative motion patterns are presented for one participant whose NoRM-D data were representative of the model and control groups in Figures 6 and 7 respectively. Once again the participant observing the model (Figure 6) shows a substantial change in relative motion from pre-test to the first three trials of acquisition. This pattern is then refined in subsequent periods, but changes relatively little. The participant performing the throws without observation of the model appears to change neither range of motion (indicated by the size of the plots) nor relative motion (indicated by shape) across acquisition (Figure 7).

The results of ANOVA for proximity to the model's knee–hip relative motion indicated a main effect for Group ($F_{1,8} = 37.15$, $P < 0.05$, $\omega^2 = 0.18$) and for Test Period ($F_{2.86,22.85} = 14.25$, $P < 0.05$, $\omega^2 = 0.40$). A Group $\times$ Test Period interaction was also observed ($F_{2.86,22.85} = 12.93$, $P < 0.05$, $\omega^2 = 0.36$), as illustrated in Figure 8A. The control group showed almost no change across test periods, and almost identical scores in the pre-test (mean = 52.13, $s = 4.43$) and the last period of acquisition (mean = 54.00, $s = 5.20$). Participants in the model group showed a significant change from the pre-test (mean = 62.21, $s = 11.66$) to the first three trials of acquisition (mean = 30.29, $s = 8.75$), and then maintained a similar level of proximity until the end of acquisition (mean = 30.93, $s = 4.07$). The individual knee–hip NoRM-D scores for each participant are shown in Figure 8B.

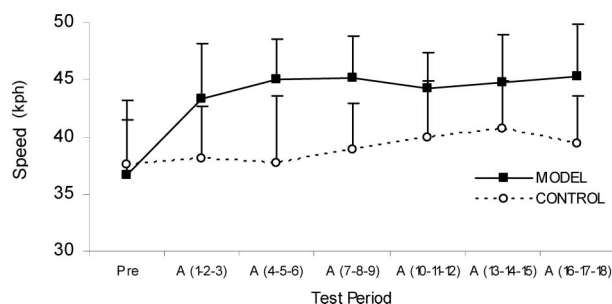


Figure 2. Ball speed for the model (■) and control (○) groups across acquisition.

Variability in relative motion – NoRMS

Elbow–shoulder. For variability in elbow–shoulder relative motion, the data were logarithmically transformed to correct to a normal distribution. The ANOVA revealed a main effect for Test Period ($F_{6,48} = 3.20$, $P < 0.05$, $\omega^2 = 0.44$). As indicated in Figure 9A, the participants reduced their variability from the first three trials of acquisition (mean = 3.38, $s = 1.05$) to acquisition trials 13–15 (mean = 2.46, $s = 0.76$). There was no effect for Group and no Group $\times$ Test Period interaction.

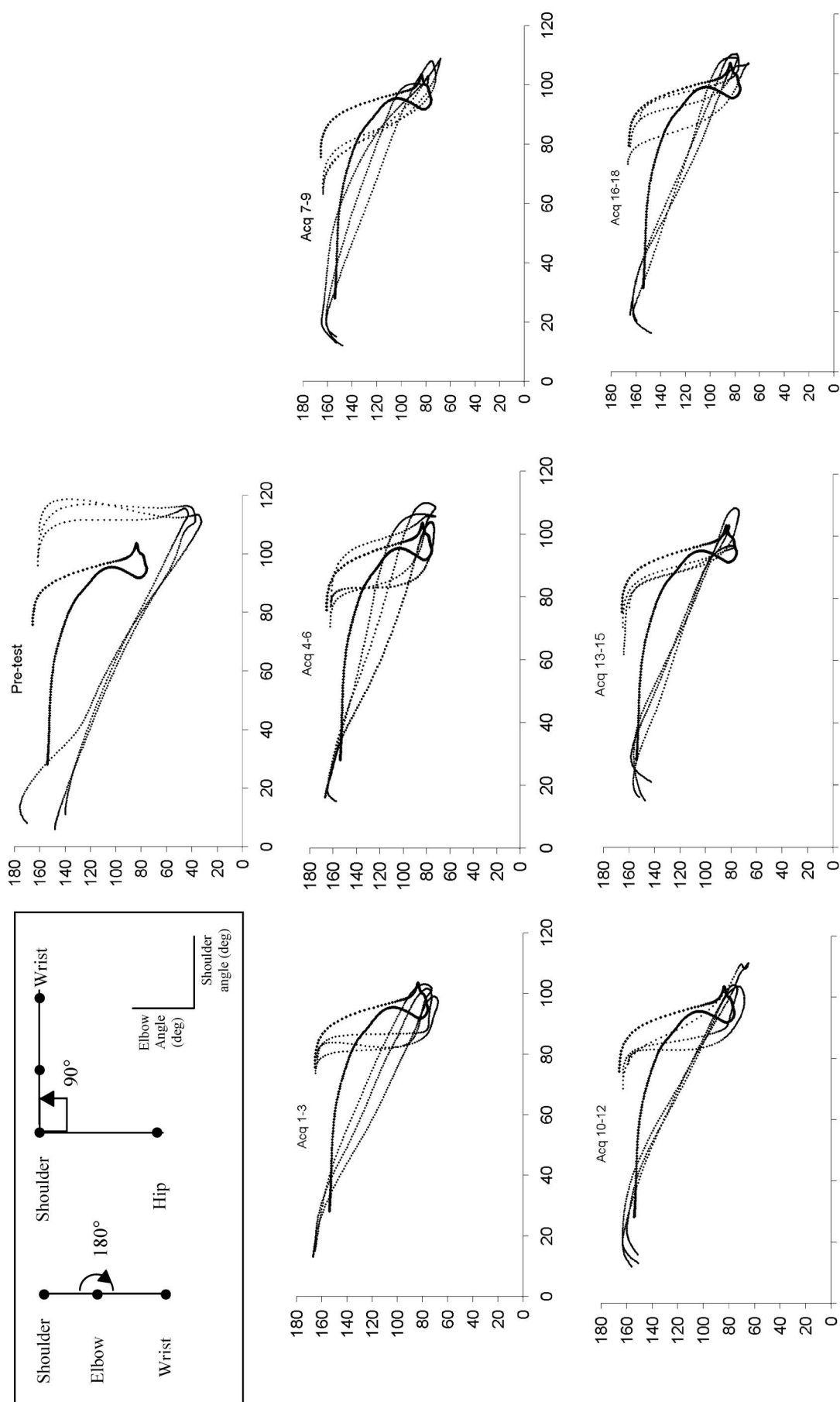


Figure 3. Elbow-shoulder relative motion across acquisition for a representative participant from the model group (the bold plot is the model's pattern; the three lighter plots represent the participant's three trials).

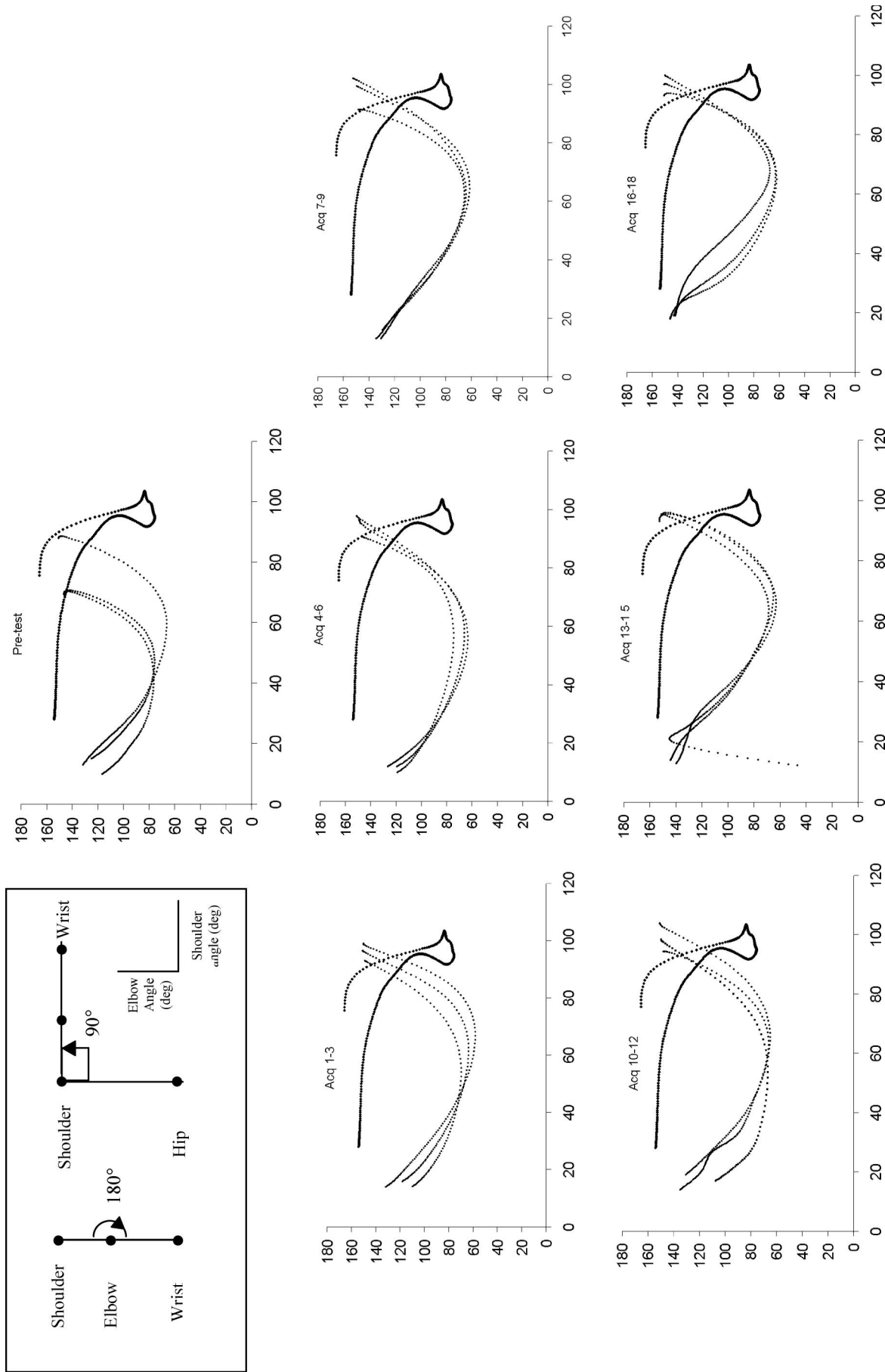


Figure 4. Elbow-shoulder relative motion across acquisition for a representative participant from the control group (the bold plot is the model's pattern; the three lighter plots represent the participant's three trials).

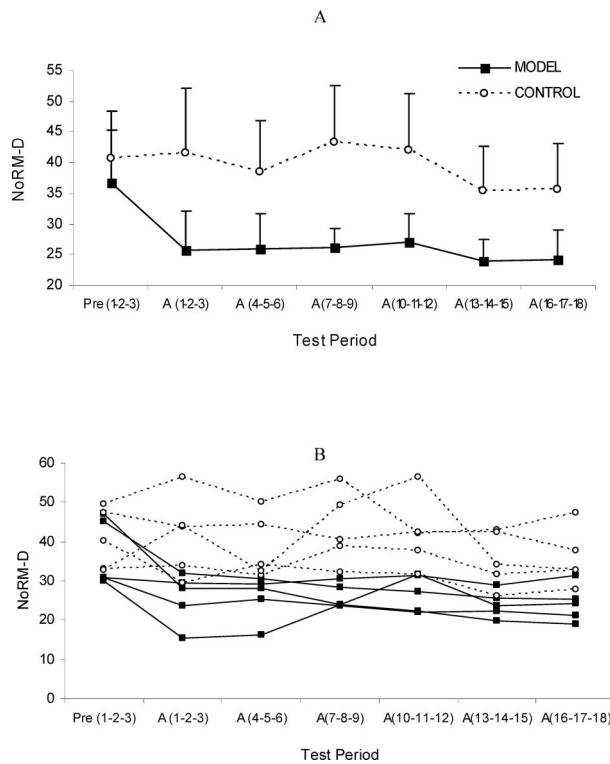


Figure 5. Group mean (A) and individual (B) elbow-shoulder NoRM-D scores across acquisition (lower scores indicate closer proximity to the model).

Knee-hip. The knee-hip NoRMS data were also corrected to a normal distribution using a logarithmic transformation. The ANOVA revealed a main effect for Group ($F_{1,8} = 20.30$, $P < 0.05$, $\omega^2 = 0.28$). Variability was lower for the model group (mean = 3.11, $s = 1.10$) than for the control group (mean = 3.96, $s = 1.16$). The results of ANOVA also revealed a significant main effect for Test Period ($F_{6,48} = 7.75$, $P < 0.05$, $\omega^2 = 0.58$). *Post hoc* analysis indicated that compared with the pre-test, participants showed lower variability in all subsequent acquisition periods (pre-test mean = 5.11, $s = 1.11$; A1-3 mean = 3.62, $s = 0.97$; A4-6 mean = 2.96, $s = 0.67$; A7-9 mean = 3.68, $s = 0.86$; A10-12 mean = 3.29, $s = 1.15$; A13-15 mean = 2.88, $s = 0.93$; A16-18 mean = 3.23, $s = 0.99$). This pattern is illustrated in Figure 9B. There was no Group $\times$ Test Period interaction.

Discussion

The adage “a picture paints a thousand words” has often been applied to observational learning to illustrate the efficiency with which demonstrations convey information for action. However, although demonstrations are widely endorsed, only recently have researchers highlighted the need to explore immediate and early acquisition effects (e.g.

Al-Abood *et al.*, 2001a; Schoenfelder-Zhodi, 1992). Moreover, traditional experimental designs have not enabled a thorough investigation of the coordinative changes that can rapidly occur in response to demonstrations. In this paper, our aim was to address this deficiency by comparing changes in relative motion over the first 18 trials of acquisition in participants observing a demonstration and those learning through discovery. Our first hypothesis predicted that participants observing the model would show immediate changes in relative motion to more closely imitate the model's coordination profile, while the control group would show no such change. Our second hypothesis predicted that following the immediate change for the model group, participants would show no further changes in proximity to the model, while the control group was predicted to make small changes to improve proximity to the model throughout acquisition. The third hypothesis predicted greater variability in coordination during acquisition for the control group than the model group. Finally, the fourth hypothesis predicted that the adoption of the model's movement pattern would facilitate faster ball speed for the model group than the control group.

Support was found for the first hypothesis. For knee-hip and elbow-shoulder relative motion, the model group became more like the model from the pre-test to the first three trials of acquisition. In comparison, no changes were observed in the control group across these trials. Given that the participants in the model group were not different to the control group in the pre-test, this finding directly implicates the model in immediately changing coordination. We consider this comparison between the pre-test and first acquisition trials comparison to provide important information that has not been forthcoming in several previous studies (e.g. Al-Abood *et al.*, 2001b; Gray *et al.*, 1991; Scully & Carnegie, 1998).

Our results corroborate previous studies in which early acquisition trials showed rapid coordination changes (e.g. Scully & Carnegie, 1998; Williams, 1989; Williams & Thompson, 1994) and quantified changes in the proximity of relative motion from the pre-test to the first trials of acquisition (Horn *et al.*, 2005). However, the results provide a more detailed picture of the changes in coordination via trial-by-trial analysis rather than intermittent measures. Additionally, the results advance the findings of Horn *et al.* (2005), who found immediate changes in coordination for those observing a soccer chipping action, in the absence of task-intrinsic visual knowledge of results. The present study illustrates that even with task-intrinsic visual information available, coordination changes can be immediate.

The changes in relative motion present in the model group support the ecological view that

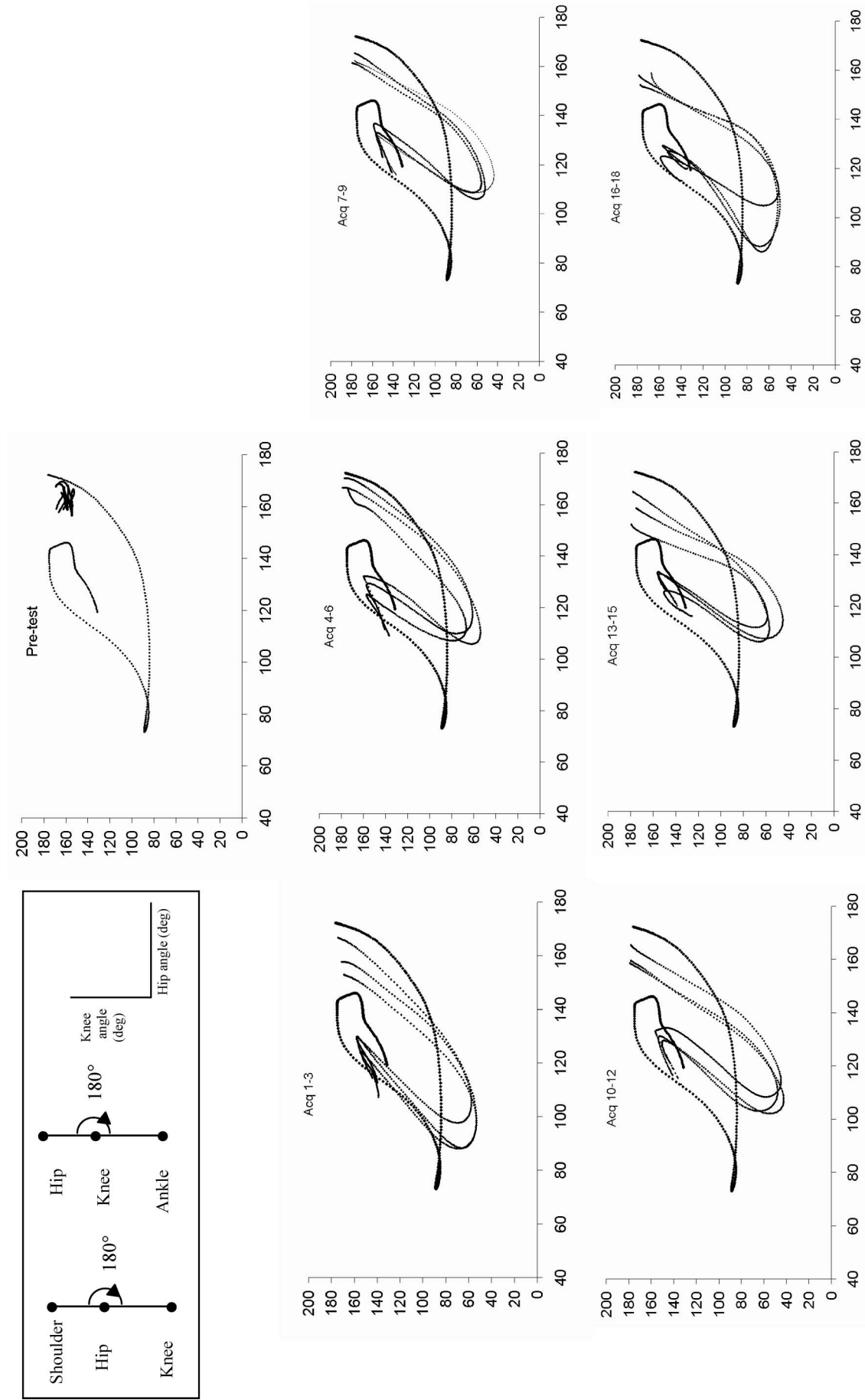


Figure 6. Knee – hip relative motion across acquisition for a representative participant from the model group (the bold plot is the model's pattern; the three lighter plots represent the participant's three trials).

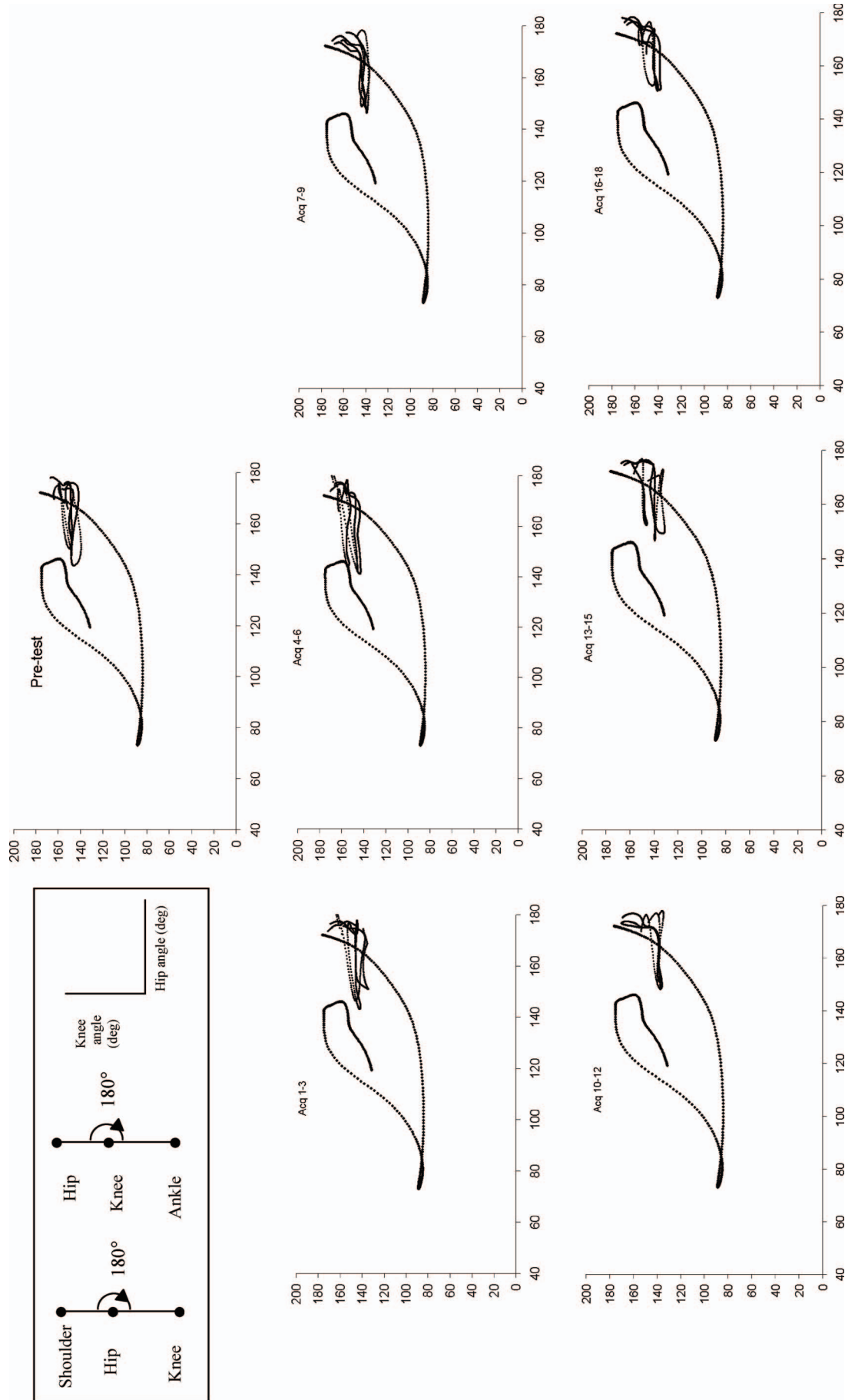


Figure 7. Knee-hip relative motion across acquisition for a representative participant from the control group (the bold plot is the model's pattern; the three lighter plots represent the participant's three trials).

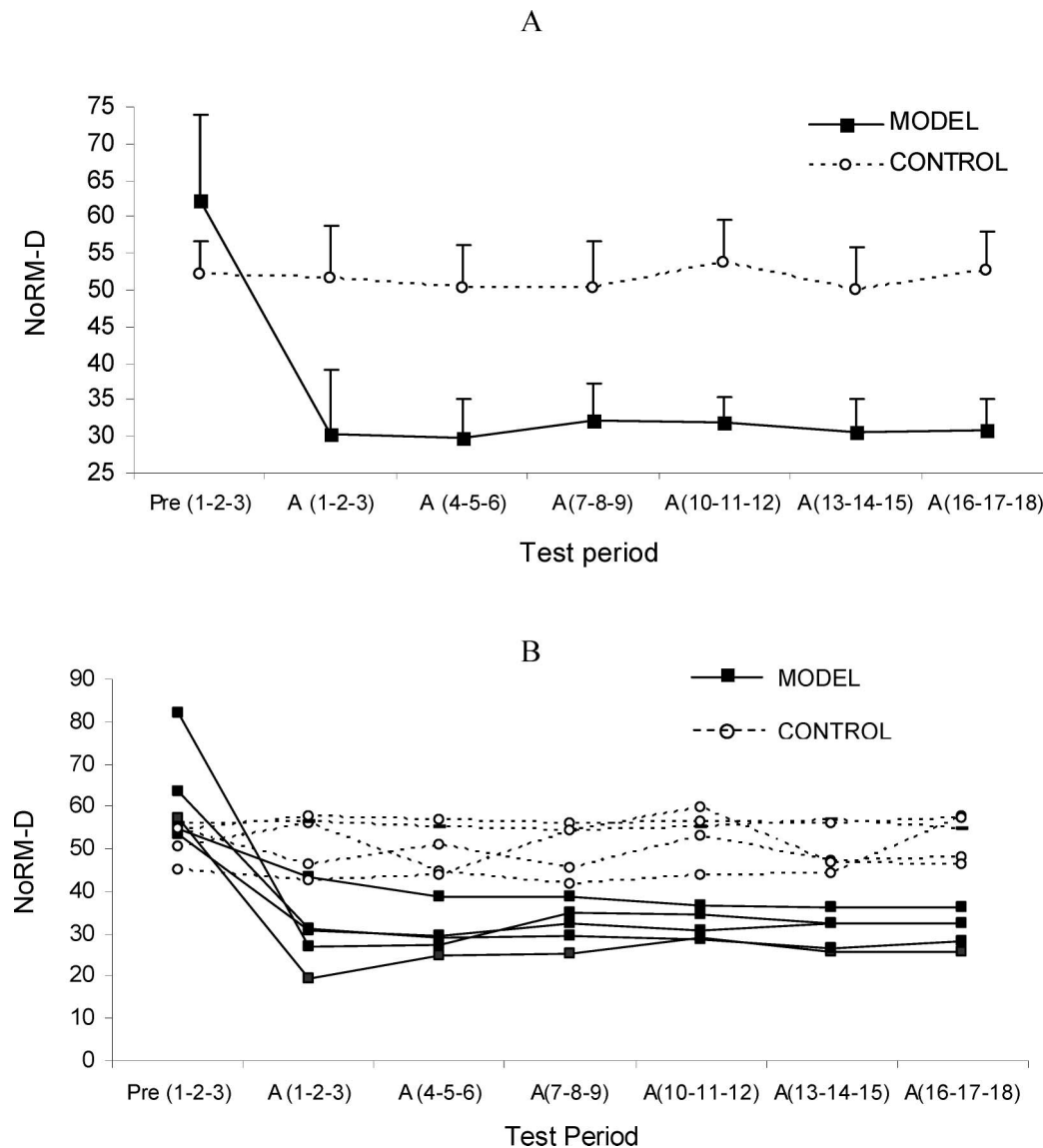


Figure 8. Group mean (A) and individual (B) knee-hip NoRM-D scores across acquisition (lower scores indicate closer proximity to the model).

observers become constrained by the topology of the model's actions (Al-Abood *et al.*, 2001a, 2001b; Horn *et al.*, 2002; Schoenfelder-Zhodi, 1992; Scully & Newell, 1985). The specific role of those constraints has received only modest research attention and it is suggested to influence behaviour through informational (Warren, 1990) and instructional (Newell & McDonald, 1991) properties. The current data suggest that a demonstration (perhaps the relative motion properties of a model and/or the movement strategy) may act as a rate enhancer in early learning. In motor behaviour, rate controllers have typically been effectively applied to developmental changes in, for example, the onset of walking (e.g. Thelen, 1986). It would appear to be an equally appropriate concept for early skill acquisition.

This role of demonstration as a rate enhancer in early acquisition has theoretical and practical implications. Using Newell's (1985) embedded hierarchy of coordination, control, and skill, the dominant function in the synergy between coordination and control in early learning is assumed to be coordination. Control in turn is assumed to become dominant once the topological relations between body parts are assembled. It is logical that by accelerating the acquisition of the new topology through demonstration, the learner can parameterize a technically appropriate movement pattern with less practice trials. In the current experiment, the relative motion at the knee-hip and elbow-shoulder shown by the control group after 18 acquisition trials was not close to the levels achieved on the first three acquisition trials by the model group.

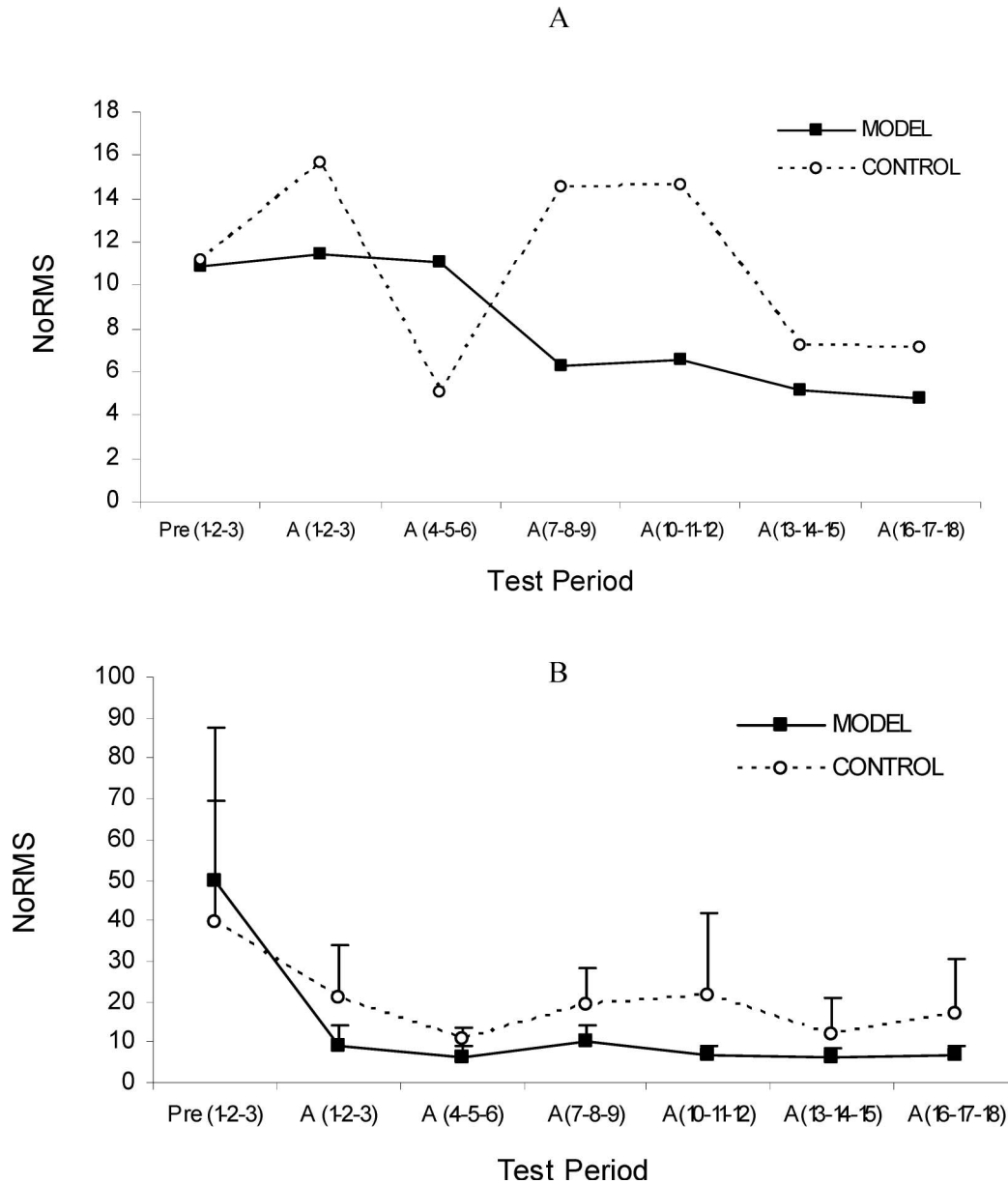


Figure 9. Group mean elbow-shoulder (A) and knee-hip (B) variability assessed by NoRMS across the acquisition period (lower scores indicate less variability).

Because the changes in proximity to the model's coordination shown by the participants observing the model occurred so rapidly and were followed by no change for the rest of acquisition, the data appear to reflect a negatively accelerated curve. It could be argued that this represents another example of the power law of practice (Snoddy, 1926). However, data supporting the power law of practice show rapid early improvements followed by an extended period of progressively decreasing improvement (e.g. Crossman, 1959). Our data do not strictly match this trend. Although our acquisition phase was deliberately short, there were no signs of improvement throughout acquisition once the large change in

coordination occurred after observing the model. It seems that the demonstration shifted coordination significantly closer to the model, but continued observation of the model and practice without verbal guidance does not support continued improvements. As indicated by Magill (2004), large changes early in acquisition and small changes later are constrained by ceiling effects, since there is less opportunity for large (coordination) changes once the learner gets closer to the criterion behaviour. This constraint may clearly have influenced the shape of our curve to mimic the power law of practice.

Partial support was found for the second hypothesis. As anticipated, participants in the model group

not only rapidly acquired the model's relative motion pattern, but they sustained this change over the entire acquisition period, without further changes in proximity to the model. However, in contrast to our prediction, the control group showed no change in proximity to the model's optimal coordination throughout the acquisition period. Change in performance for the two groups in acquisition trials 4–18 was somewhat similar, and is best described by a flat line. The difference between the groups is therefore simply that the model appeared to *shift* the learner's coordination between observation and the first three trials of practice. It is conceivable that the model constrained behaviour, moving it to a different and potentially more appropriate region of the perceptual motor workspace.

Our data provide no support for the proposition that interventions in early learning produce only softly assembled and hence somewhat temporary solutions to the movement problem. The fact that there was no further change in proximity after the immediate shift in coordination suggests that the constraints imposed by the model were enduring. It should be noted that the time scale of acquisition in the present experiment was relatively short to avoid the effects of fatigue. Nonetheless, the data are supported by the research of Horn *et al.* (2005), who found that learners' proximity to the model did not change from the first three trials to the end of 40 acquisition trials, and remained stable after a 48-h retention period. It could also be argued that the persistence of a temporary solution is dependent on its perceived effectiveness. If participants observing the model in the present experiment perceived that their imitation was appropriate, the absence of changes in relative motion after the first few trials of acquisition could reflect this perception. If so, this does not necessarily alter the notion that demonstrations lead to solutions that are enduring in nature, but may simply speak to the perceptual constraints associated with imitating movements.

In support of our fourth hypothesis, the model group demonstrated faster ball speed than the control group and demonstrated ball speed changes in tandem with coordination changes. Large changes in relative motion from the pre-test to the first trials of acquisition were accompanied by the greatest increases in ball speed. Stable relative motion patterns were associated with only small variations in ball speed.

We found little evidence to support the use of discovery learning in early acquisition. Participants in the discovery group neither increased ball speed nor changed their relative motion in reference to the model's pattern over the course of acquisition. This finding corroborates that reported by Al-Abood *et al.* (2001a) for an underarm dart throw and Horn *et al.*

(2005) for a soccer chip. Conversely, Schoenfelder-Zhodi (1992) found that discovery learners' relative motion did become more like the model after 5 days of practice (albeit at a slower rate than the model group) and Hodges and Franks (2002) have shown benefits for discovery methods in teaching a bimanual coordination skill. However, these latter findings might be explained by the high level of constraints imposed by the apparatus serving to facilitate movement solutions in the absence of a demonstration (Al-Abood *et al.*, 2001a).

Horn *et al.* (2005) alleged that if observing a model immediately changes a learner's relative motion, then early acquisition may become a time of refinement, rather than of the broad search for movement solutions as suggested by Newell and McDonald (1991). Although the proximity data for the model group support the concept of refinement, variability should also be considered. Our predictions regarding variability were partially supported. The participants in the model group showed less variability than the control group in their knee–hip, but not elbow–shoulder, relative motion. After displaying higher variability in the pre-test, the model group showed less knee–hip variability than the control group in all acquisition periods. This finding provides further evidence to support the concept that the constraints imparted by the model led to less *search* than learning through discovery. A main effect was not present for elbow–shoulder relative motion because the control group had surprisingly low variability for acquisition trials 4–6. However, in all other acquisition trials, the model group appeared to show less variability.

With regard to realistic practice environments, it was previously argued that rapid changes in coordination elicited by a demonstration may allow learners to be better prepared for changes in the constraints of the task that teachers and coaches often adopt. In contrast, discovery methods of learning have been suggested to facilitate transfer, since the more expansive search and probing of the workspace encourages results in more elaborate construction of the movements (e.g. Handford *et al.*, 1997; Newell & McDonald, 1991). However, in these naturalistic learning environments, there may be insufficient time for this elaborate search before transfer is required through changes in the task constraints. Further research is needed to compare learning through discovery and demonstration methods in environments that enforce regular task context changes to test these positions.

In conclusion, in this paper we have provided evidence for the role of demonstrations as rate enhancers in early acquisition. The trial-by-trial analysis extends previous research and supports the findings of Horn *et al.* (2005) that observation of a model affords learners with constraining information

to facilitate immediate and enduring changes in relative motion. This effect was not present in the absence of a model. The coordinative changes resulting from demonstration were associated with improved ball speed. These results suggest that learning from a model may not represent a soft-assembled, emergency solution, but an efficient and relatively stable behavioural change.

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