Modelling relative motion to facilitate intra-limb coordination

Gavin Breslin a,*, Nicola J. Hodges b, A. Mark Williams c,d, Will Curran a, John Kremer a

a School of Psychology, Queen’s University Belfast, David Keir Building, BT7 1NN, Northern Ireland, United Kingdom
b School of Human Kinetics, War Memorial Gym, University of British Columbia, 210-6081 University Boulevard, Vancouver, BC, Canada V6T 1Z1
c Research Institute for Sport and Exercise Sciences, Liverpool John Moores University, The Henry Cotton Building, 15-21 Webster Street, Liverpool, L3 2ET, United Kingdom
d Visiting Research Scientist, Human Performance Laboratory, Learning Systems Institute, Florida State University, United States

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Abstract

The importance of relative motion information when modelling a novel motor skill was examined. Participants were assigned to one of four groups. Groups 1 and 2 viewed demonstrations of a skilled cricket bowler presented in either ‘video’ or ‘point light’ format. Group 3 observed a single point of light pertaining to the ‘wrist’ of the skilled bowler only. Participants in Group 4 did not receive a demonstration and acted as controls. During 60 acquisition trials, participants in the demonstration groups viewed a model five times before each 10-trial block. Retention was examined the following day. Intra-limb coordination was assessed for the right elbow relative to the wrist in comparison to the model. The demonstration groups showed greater concordance with the model than the control group. However, the ‘wrist’ group performed less like the model than the ‘point light’ and ‘video’ groups, who did not differ from each other. These effects were maintained in retention. Relative motion information aided the acquisition of intra-limb coordination, while making this information more salient (through point lights) provided no additional benefit. The motion of the model’s bowling
arm was replicated more closely than the non-bowling arm, suggesting that information from the end-effector is prioritized during observation for later reproduction. © 2005 Elsevier B.V. All rights reserved.

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1. Introduction

Modelling is the process whereby an observer attempts to replicate a behaviour that has been demonstrated by another individual. The behaviour that is performed by the model is often perceived to be the optimal movement solution for accomplishing a specific task goal. The process of modelling has been given particular attention by movement scientists and has been interpreted as an efficient means of conveying the model's characteristics to the learner (e.g., Bandura, 1986). Scientists have considered modelling to be a powerful tool for demonstrating complex human movement patterns to individuals who are seeking to improve their performance on particular tasks (Gould & Roberts, 1981). Regardless, and despite their widespread use, the level of effectiveness of different types of demonstrations remains unclear. More specifically, the effectiveness of filmed demonstrations in conveying information relating to the model's coordination pattern is not well understood. This lack of clarity may be due, at least in part, to the contrasting nature of various methods and theoretical approaches adopted in the field and contradictory findings from recent studies where the type of information guiding observational learning has been explored (see Horn & Williams, 2004).

The aim in this paper is to determine the importance of relative motion information in guiding the acquisition of a novel and complex motor skill. This question is influenced by the visual perception perspective proposed by Scully and Newell (1985). They argued that relative motion information facilitates a learner's acquisition of coordination by providing transformational information. However, there have been few attempts to systematically manipulate the availability of relative motion information to determine its role within observational learning. Traditionally, researchers have interpreted the process of learning from demonstrations to be based on the formation of an appropriate 'perceptual blueprint' (Sheffield, 1961) or 'cognitive representation' (Bandura, 1969, 1977, 1986) of the model's action to guide skill acquisition during practice. As such, the efficacy of a demonstration is judged in terms of its ability to facilitate the development of this 'blueprint' or 'representation'. A shift in theoretical focus in observational learning research led to a change in the type of question being asked in this field and in the subsequent experimental manipulations employed. Researchers began to look at what information should be attended to when viewing a model, rather than how much attention is allocated to a model (see Scully & Newell, 1985; Williams, 1982, 1985).
Scully and Newell (1985) integrated research from the perception of biological motion (see Cutting & Proffitt, 1982; Johansson, 1971) with the ‘constraints led’ framework for skill acquisition (see Newell, 1986), formulating the visual perception perspective to explain what components of the demonstration are important for the acquisition of coordination. They highlighted the different types of motion information contained within a demonstration (i.e., absolute motion, common motion, and relative motion) and predicted, based on the work of Cutting and Proffitt (1982), that the visual system prioritizes the extraction of relative motion information (i.e., the motion of all the components within a configuration relative to each other) over other sources. Relative motion information specifies invariant characteristics of motion, specifically the coordination within and across joints. This dynamic, invariant information has been proposed to be critical to action-perception (see Gibson, 1979). This has led Newell (1991) to suggest that the development of motor skills is guided by the search for coordination patterns in dynamic displays or scenes both in action (i.e., whilst watching and performing) and out of action (i.e., when watching with the goal of later imitation).

In recent years there has been a resurgence of interest in the visual perception perspective, partly due to the more widespread availability of three-dimensional motion capture systems which enable accurate and objective measurement of coordination. Researchers have been interested in determining how learners perceive dynamic and complex motor skills and how they use this information in the observational learning process using measures of between and within joint coordination (e.g., Al-Abood, Davids, & Bennett, 2001; Horn, Williams, & Scott, 2002; Horn, Williams, Scott, & Hodges, in press; Scully & Carnegie, 1998). Researchers have examined the benefits of this information for observational learning by manipulating the saliency of relative motion information. Relative motion information has been made salient through the construction of point light displays (PLD). A PLD can be constructed by attaching reflective markers or light emitting diodes (LEDs) to the major joint centres of the body, recording the body in motion, then displaying the markers or points of light alone against a black background (see Johansson, 1971; Marey, 1972). In this way, structural and contextual information are removed in an attempt to isolate relative motion.

Using this technique, Scully and Carnegie (1998) required participants to view a model performing a 5-s ballet dance sequence presented as a PLD or video display. The group viewing a PLD replicated the model’s coordination pattern more accurately than a group viewing a normal video demonstration. This finding was taken as evidence that relative motion is both sufficient and beneficial for the acquisition of coordination. However, in subsequent research this effect has not been replicated. Al-Abood et al. (2001) failed to observe differences between PLD and video demonstration groups in the acquisition of a novel underarm dart-throwing skill. Since the PLD and video groups outperformed a control group in terms of measures of coordination, the authors proposed that learners were able to pick-up relative motion information to facilitate acquisition of the new coordination pattern. The difficulty in making this inference is that a coordination pattern similar to a skilled model could be a consequence of pick-up and use of absolute motion parameters, such
as the motion of the hand, rather than the complex interrelationships between and within joints.

Horn et al. (2002) showed, using an unusual soccer kicking action, that the pattern of coordination adopted by performers was primarily the result of task specific feedback and practice, rather than imitation of an expert model. A PLD and a video demonstration group were not significantly different, in terms of measures of coordination, than a no-demonstration, control group, despite instructions to imitate the model. In a second experiment, outcome-related feedback was removed through a visual occlusion screen (see Horn et al., in press). Under these conditions the two demonstration groups adopted a coordination pattern that was closer to the model than that observed by the control group. Although relative motion information might be responsible for this pattern of coordination, without a direct manipulation of this information (e.g., through its removal) it is difficult to determine whether common directional motion across and within joints, absolute motion of a single joint or perhaps even a general movement strategy (i.e., number of steps, see Horn et al., 2002), could be responsible for the acquisition of the model’s coordination pattern.

Relative motion was subsequently manipulated by Hodges, Hayes, Breslin, and Williams (2005) using a soccer kick task. The purpose of this experiment was to examine whether participants could perform an unusual kicking-type action from impoverished displays where only motions of the toe, the foot or the lower leg were displayed. Although participants in the toe-marker only group did not have access to relative motion information and no contextual cues were provided (i.e., a ball and target), this group showed a pattern of intra-limb coordination similar to the other partial information groups and in some cases (i.e., hip–knee coordination) more like the model. This finding raises doubts about the importance and use of relative motion information as an aid to motor skill acquisition. However, there were some issues with the previous experiment which could limit generalizability of the findings. First, although participants replicated a whole-body action after observation of only a single point of light, the action (i.e., a left footed kick) only required the use of a single limb. It is likely that movement complexity and novelty affects the perception and action reproduction process. Second, movement reproduction was only assessed across 12–20 trials in one performance session, such that without retention tests no conclusions concerning learning can be made.

The purpose of the current experiment therefore was to extend the existing research and further address the role of relative motion information in the acquisition and learning of a novel and complex motor skill involving a cricket bowling action. Relative motion was manipulated in two ways. As in previous research, we constructed a PLD of our cricket bowling action in an attempt to make relative motion information salient. Participants were asked to bowl a ball to a target in addition to replicating a model’s movement form. As in previous studies, the PLD group was compared to an unedited video display group. If relative motion information is important for the acquisition of coordination, and the perception of this information can be facilitated by making this information more salient, participants observing a
PLD should acquire the coordination profile of the model more effectively than those viewing an unedited video display. A second, more direct manipulation of relative motion information was performed by removing relative motion from a PLD demonstration. Participants in this group were asked to copy a whole-body action after observing a single point of light representing movements of the end-point of the bowling arm, in this case the wrist marker. Differences between the no relative motion (i.e., wrist group) and the two full body groups would provide information about the role of relative motion information in observational learning. All conditions were compared to a control group that did not receive any information describing a correct cricket bowling action, such that potential beneficial effects of demonstrations in general could be determined.

If relative motion is an important source of information for the acquisition of a complex coordination skill, the PLD and video groups will show a coordination profile more similar to the model than the no relative motion group (i.e., wrist marker only). If relative motion information can be more easily ascertained from a PLD, and this information is important for the acquisition of coordination, the PLD group will evidence less disparity from the model than the video group. If demonstrations are generally beneficial for skill acquisition, in particular the acquisition of a movement technique, then the three demonstration groups will perform better than the control group. These questions and hypotheses will be examined using pre-planned, orthogonal contrasts.

2. Method

2.1. Participants

Forty-eight participants, 29 male and 19 female (mean age = 23.4 years; SD = 5.4) volunteered to take part in the experiment. Participants were allocated to one of four matched-ability groups based on pre-test outcome scores over 10 trials such that there was a comparable number of males and females in each group. Outcome scores were assessed based on the mean number of times the participant hit the wicket. The groups were labelled: PLD; video; no relative motion PLD (i.e., wrist); and a no demonstration (control) group. Participants had no previous experience of cricket bowling. All were right side dominant and had normal or corrected-to-normal vision.

2.2. Demonstration tape construction

A cricket bowling action was chosen as the task for participants to replicate. This task posed a high level of difficulty and novelty for those unfamiliar with cricket and contained a complex combination of biological motion information (i.e., relative motion changes in upper and lower body limbs).
A semi-professional bowler modelled a front-on medium to fast bowling action (see Fig. 1a).1 A total of 17 reflective markers were placed on the major joint centres on the right and the left side of the model’s body, these included the acromion process (shoulder), lateral epicondyle (elbow), ulnar styloid (wrist), the meta carpal head (finger), the greater trochanter (hip) the lateral condyle of the femur (knee), the lateral malleolus (ankle), the distal head of the fifth metatarsal (toe) and one on the centre of the forehead. Six infrared cameras (Pro-reflex, Qualisystem, Savedalen, Sweden) captured the temporal–spatial positions of the model’s action. From the

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1 The characteristics of the front-on medium to fast bowling action included the model stepping forward with his right foot, lifting and flexing his left leg while reaching upwards with his left hand. During this time there is flexing than a full extension of the right bowling arm. The right bowling arm completes a circular motion until the ball is released above head height. Prior to the point of ball release the left leg touches the floor acting as a pivot. Immediately after ball release, the right leg steps forward to maintain balance while the bowling arm crosses over in front of the bowler’s torso flexing once more.
model’s action, a PLD was produced using Q-Trac Motion Viewer (Savedalen, Sweden). A video camera (Panasonic NV-M40, Tokyo, Japan) was used to record the model performing the bowling action. The camera was positioned in the sagittal plane capturing a side on image of the model's action. The PLD film and the normal video film were edited so that each action sequence lasted around five seconds and both were depicted in the sagittal plane. The no relative motion demonstration (i.e., the wrist) was constructed from the full body PLD by removing all but one of the reflective markers from the display, leaving only the wrist marker visible.

2.3. Task, procedure and apparatus

Reflective markers were placed on the major joint centres on both sides of each of the participant’s body. The positioning of these markers was the same as for the model. The task for all participants was to stand within a measurement area of $2 \times 4$ m and bowl a cricket ball towards a stationary target (i.e., cricket stumps that consisted of three wooden posts, 2.5 cm in diameter and 81.3 cm high, which were evenly spaced, 22.8 cm apart) positioned 8 m away. Before instructional manipulations participants were given 10 familiarisation trials. Data were collected at this time (i.e., movement kinematics and outcome success). Participants were asked to begin standing with their arms by their side and to place their arms back by their side after completing the action. These trials were designed to provide participants with the opportunity to familiarise themselves with the laboratory surroundings, task procedure, and newly attached markers, in addition to providing initial pre-test data.

Before experimental testing began, participants in the experimental groups were told that they would view a side on view of an expert model performing a successful bowling action and that they should copy the model’s action when performing the cricket bowl. Participants in the PLD group were told that they would see the major joints represented as points of light corresponding to the placement of reflective markers placed on their own body. The wrist group was told that it would only see one marker representing the movements of the wrist on the right bowling arm and that they were to use this information to guide their action when performing the cricket bowl. The demonstrations were presented via a 28 in. television screen (Panasonic TX-28G1, Tokyo, Japan). Acquisition of movement form and outcome attainment were emphasised to each participant.

Participants in the experimental groups observed the demonstration five times, while those in the control group listened to instructions five times via a tape player asking them to perform a cricket bowling action. None of the participants were instructed how to perform a bowling action. The timing of the audio tape was matched to the time it took participants to view the demonstration. Participants were then required to bowl the cricket ball to the target across six blocks of 10 trials each. Before each practice block, participants in the experimental groups viewed five demonstrations of the cricket bowling action, participants in the control group listened to the audio tape. Approximately 24 h following the last acquisition trial participants returned to the laboratory to complete a 10 trial, retention test. No demonstrations or instructions were provided at this time.
All trials were recorded using a video camera (Panasonic NV-M40, Tokyo, Japan). Kinematic data were collected for each trial using the six infrared cameras at a capture rate of 120 Hz. Q-Trac Motion Viewer (Savedalen, Sweden) was used to convert the participants’ action into x, y, and z three-dimensional coordinates. PC Pro Reflex software (Savedalen, Sweden) was then used to calculate angular displacement values for the participants’ elbows and wrists.

3. Data analysis

3.1. Outcome scores

On each trial a score of one was awarded to the participant if the ball hit the target.

3.2. Intra-limb coordination

Intra-limb coordination for the bowling and non-bowling arm was measured and compared to the coordination pattern of the skilled model. Intra-limb coordination was operationally defined as the angular displacement of the elbow relative to the wrist. The intra-limb coordination pattern of the model (i.e., elbow angle relative to the wrist) is illustrated in Fig. 1b (i.e., the solid line trace). Each participant’s coordination pattern was compared to the model across a selection of trials. The first three trials were from the familiarisation task, 18 trials were from the acquisition period (from which, three trials were selected immediately after each of the six viewings of the demonstration), the remaining three trials were from the retention test. The selection of the first three trials after each viewing of the demonstration was to assess immediate effects on the acquisition of the model’s coordination pattern after viewing the demonstration (see Horn et al., in press).

The start and end points of the movement were normalized across trials so as to eliminate variation in the time taken by participants to perform the movement. The start of intra-limb coordination movement was operationally defined as the point when the right elbow of the bowling arm started to flex, the end point was when the bowling arm fully extended after ball release and follow-through. A fourth order dual pass Butterworth filter with a cut-off frequency of 7 Hz (Winter, 1990) was applied to the displacement data prior to analysis and a linear interpolation was performed to normalise the kinematic data within 100 data points (allowing comparisons across trials and with the model). This process allowed a quantitative analysis to be conducted on the data. An adjusted version of the normalised root mean squared difference (NoRM-D) technique (see Horn & Williams, 2004; Horn et al., in press) was used to compare the proximity of each participant’s coordination profile with that of the model. More specifically, the relative spatial differences between the participant’s average coordination profile and the model’s profile were calculated at each point in time (i.e., across 100 points) to yield an average difference score. The closer the difference score is to zero, the greater the resemblance to the model.
3.3. Movement time

Absolute movement time (i.e., the time taken to perform the task) was used as a measure of movement control (see Newell, 1985). The absolute movement time of the model was compared to that of the participants on the familiarisation task and on the acquisition and retention tests.

3.4. Number of steps

The number of steps performed by each participant in comparison to the model’s 3-step approach was assessed for the familiarisation task and on the acquisition and retention tests as a measure of lower body movement approximation.

4. Statistical analysis

4.1. Familiarisation task and retention test

Intra-limb coordination for the bowling and non-bowling arm, absolute movement time, outcome attainment, and stepping profile were assessed using separate analysis of variance (ANOVA) procedures in which viewing condition (i.e., PLD, VIDEO, WRIST, and CONTROL) was the between-groups factor. Group effects were examined in terms of three pre-planned orthogonal contrasts. To examine the benefits of demonstrations, the three experimental groups were compared to the control group. To examine the importance of relative motion information, the wrist group was compared to the full body PLD and video groups. To determine whether there were benefits from making relative motion information salient, the video and full body PLD groups were compared to each other.

4.2. Acquisition period

The data in acquisition was analysed in a factorial ANOVA in which group (i.e., PLD, VIDEO, WRIST, and CONTROL) was the between-groups factor and trial block (1–6) was the repeated-measures factor. Group differences were examined according to the three pre-planned contrasts outlined above. Sphericity was assessed and adjusted using Greenhouse Geisser procedures. Partial eta squared ($\eta^2_p$) was calculated for each ANOVA as a measure of effect size and statistical significance was set at $p < .05$.

5. Results

5.1. Outcome scores

Fig. 2 shows the mean number of times participants hit the wicket (i.e., outcome scores). This variable did not differentiate across groups or across the test phases and no significant improvements in this measure were observed as a function of practice.
5.2. Intra-limb coordination

5.2.1. Familiarisation task

No significant differences were observed between groups for the bowling, $F(3,28) = 2.70$, $ns$, $\eta_p^2 = .22$, and non-bowling arm, $F(3,28) = .56$, $ns$, $\eta_p^2 = .06$.

5.2.2. Acquisition

The data are illustrated in Table 1. No significant differences were observed across the four groups as a function of trial block for the non-bowling arm. For the bowling arm, a significant main effect was observed for block, $F(3.14,87.99) = 5.08$, $p < .01$, $\eta_p^2 = .15$. All groups became more like the model across blocks. A significant group effect was observed, $F(3,28) = 7.64$, $p < .01$, $\eta_p^2 = .45$, but no Group × Block interaction, $F(9.43,87.99) = 1.81$, $ns$, $\eta_p^2 = .16$. The contrast analysis showed that the CONTROL group performed less like the model than the three demonstration groups, $(p < .01)$ and the wrist group performed less like the model than the VIDEO and PLD groups $(p < .01)$. The VIDEO and PLD groups were not significantly different from each other.

5.2.3. Retention

A group main effect was observed for the bowling arm, $F(3,31) = 6.45$, $p < .01$, $\eta_p^2 = .41$, but not the non-bowling arm, $F(3,28) = .12$, $ns$, $\eta_p^2 = .01$. For the bowling arm, the demonstration groups remained significantly more like the model than the CONTROL group, $p < .05$. The wrist group continued to perform less like the model than the two full body demonstration groups, $p < .05$, and there was no difference between the PLD and VIDEO groups.
<table>
<thead>
<tr>
<th>Groups</th>
<th>Test period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Familiarisation</td>
</tr>
<tr>
<td>VIDEO</td>
<td>27.21 (9.17)</td>
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<tr>
<td>PLD</td>
<td>26.43 (5.53)</td>
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<tr>
<td>WRIST</td>
<td>38.54 (14.38)</td>
</tr>
<tr>
<td>CONTROL</td>
<td>26.9 (9.2)</td>
</tr>
</tbody>
</table>
5.3. Movement time

5.3.1. Familiarisation task

As illustrated in Fig. 3, there was no significant main effect for group, $F < 1$, $\eta^2_p = .06$.

5.3.2. Acquisition

A significant group effect was observed, $F(3, 28) = 5.08$, $p < .01$, $\eta^2_p = .35$, as well as a Group $\times$ Block interaction, $F(15, 140) = 1.80$, $p < .05$, $\eta^2_p = .16$. The main effect for block was not significant, $F(5, 140) = 1.85$, $ns$, $\eta^2_p = .06$. Orthogonal contrasts comparing across the four groups showed that the CONTROL group performed less like the model than the three demonstration groups, $p < .01$, but that the wrist group was not significantly different from the VIDEO and PLD groups, neither were the VIDEO and PLD groups significantly different from each other. While the CONTROL group showed very little change in performance across practice blocks and remained slower than the model, the three experimental groups evidenced movement times at the end of practice which did not differ from those of the model. Separate contrast analysis on each block of practice showed that the CONTROL group was significantly different from the demonstration groups, $p < .01$ across all practice blocks.

5.3.3. Retention

While there was no significant overall group effect, $F(3, 28) = 2.31$, $ns$, $\eta^2_p = .20$, orthogonal contrasts comparing across the four groups showed that the CONTROL
group performed less like the model than the three demonstration groups, \( p < .01 \), but that the wrist group was not significantly different from the VIDEO and PLD groups, nor were the VIDEO and PLD groups significantly different from each other.

5.4. Number of steps

5.4.1. Familiarisation task

The data are presented in Table 2. No significant differences were observed between groups, \( F(3, 28) = 0.47, \text{ns}, \eta^2_p = .05 \).

5.4.2. Acquisition

No significant group effect was observed, \( F(3, 28) = 0.30, p < .01, \eta^2_p = .03 \), and no Group × Block interaction, \( F(6.77, 63.15) = 1.75, \text{ns}, \eta^2_p = .16 \). The main effect for block was not significant, \( F(2.26, 63.15) = 0.57, \text{ns}, \eta^2_p = .02 \).

5.4.3. Retention

No significant differences were observed between groups, \( F(3, 28) = 1.67, \text{ns}, \eta^2_p = .15 \).

6. Discussion

We examined the role of relative motion information in the acquisition of intra-limb coordination. It was hypothesized that participants who were able to watch and copy a skilled demonstration would approximate the model’s coordination pattern more closely than participants who were not shown a demonstration. It was also hypothesized that participants viewing a PLD, within which relative motion was made salient, would approximate a model’s coordination pattern more closely than participants who viewed a filmed demonstration. In a final manipulation, relative motion information was removed from a PLD. It was predicted that if relative motion is needed for the acquisition of coordination, viewers in this condition will not approximate the model’s coordination pattern.

Some support for the first hypothesis was obtained when intra-limb coordination for the bowling arm was examined. The demonstration groups performed more like the model than the CONTROL group and the presence of relative motion information (i.e., for the PLD and VIDEO groups) facilitated this process. However, there was no group × block interaction which would suggest that the benefits of viewing relative motion information within a demonstration are immediate and picked up during the first block of practice (see also Horn et al., in press). The absence of any practice effects and group differences for the non-bowling arm leads to the conclusion that only intra-limb coordination for the main effector was used to constrain movement in the early stages of skill acquisition. The fact that practice took place across only 60 practice trials on day 1 might also be a variable to consider in judging improvements as a function of practice. Due to the relative complexity of this action,
<table>
<thead>
<tr>
<th>Groups</th>
<th>Familiarisation</th>
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<th>Block 2</th>
<th>Block 3</th>
<th>Block 4</th>
<th>Block 5</th>
<th>Block 6</th>
<th>Retention</th>
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</thead>
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<td>2.29 (1.94)</td>
<td>3.13 (.35)</td>
<td>3.0 (0)</td>
<td>3.04 (.28)</td>
<td>3.04 (.12)</td>
<td>2.96 (.12)</td>
<td>3.04 (.12)</td>
<td>3.0 (0)</td>
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<td>PLD</td>
<td>2.46 (1.47)</td>
<td>3.38 (1.08)</td>
<td>3.46 (.67)</td>
<td>3.46 (.67)</td>
<td>3.25 (.71)</td>
<td>3.08 (.58)</td>
<td>3.0 (.53)</td>
<td>3.17 (.40)</td>
</tr>
<tr>
<td>WRIST</td>
<td>2.67 (1.82)</td>
<td>2.79 (1.84)</td>
<td>2.92 (1.6)</td>
<td>3.54 (1.62)</td>
<td>3.42 (1.54)</td>
<td>3.58 (1.79)</td>
<td>3.58 (1.71)</td>
<td>3.71 (1.79)</td>
</tr>
<tr>
<td>CONTROL</td>
<td>1.88 (1.62)</td>
<td>2.67 (1.18)</td>
<td>3.04 (1.3)</td>
<td>2.92 (1.23)</td>
<td>2.92 (1.29)</td>
<td>2.88 (1.21)</td>
<td>2.79 (1.18)</td>
<td>2.54 (1.05)</td>
</tr>
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</table>
additional practice might have been needed to observe changes in coordination across all measures.

These results provide some support for Scully and Newell’s (1985) hypothesis that the relative motion information present within demonstrations is both perceived and used for the acquisition of coordination. However, the effectiveness of demonstrations in conveying relative motion information seems to be restricted to certain components of the model’s action. Participants in the video and PLD groups replicated the model’s bowling arm yet failed to accurately replicate the motions of the non-bowling arm. These results suggest that the perceptual system prioritizes the extraction of some information over others. Additional manipulations of the perceptual display are necessary to establish what aspects of the action are more important to the viewer during acquisition of coordination skills.

Making relative motion salient through a PLD did not further facilitate replication of intra-limb coordination. We had predicted that due to the complexity of this task (i.e., a whole-body action including visual information pertaining to both intra-limb and inter-limb coordination) that attempts to make the purported critical information (i.e., relative motion) salient to the observer would facilitate observation and acquisition. However, this result, coupled with the fact that participants did not improve in their coordination across practice, leads to the suggestion that relative motion information is perceived early and used automatically to facilitate the acquisition of coordination. A global measure of movement replication (i.e., number of steps) was also assessed. It was shown that viewing a full body model did not affect the global actions of the lower body, that is the general adoption of a 3-step approach similar to the model.

The fact that the no relative motion group (i.e., wrist) did not perform as well as the two full body demonstration groups (in terms of intra-limb coordination) lends support to Scully and Newell’s (1985) claim that relative motion information is needed for the acquisition of coordination. This finding is contrary to that of Hodges et al. (2005) who found that participants were able to replicate motions of an unusual kicking action in the absence of relative motion information as effectively as participants who received this information. Perhaps due to the additional complexity and novelty involved in the cricket bowling task (i.e., whole-body motions) the motion of a single point of light moving on a monitor was not sufficient to bring about the coordination pattern of the model.

It is also important to point out that the amount of information for the wrist group was significantly less than that provided to the two full body groups. It is therefore not possible to determine whether relative motion information per se or the amount of information was responsible for the poor performance of the wrist group. In our previous work (Hodges et al., 2005), participants received either 1, 2 or 3 points of light representing the toe, ankle and knee joints respectively, such that differences in amount of information were minimised. In this current experiment, the amount of information was significantly different across the full body and wrist groups (i.e., a difference of 16 points), perhaps supporting the idea that a decrease in the amount of information (i.e., no information about the legs, trunk, non-bowling arm), rather than relative motion per se was the reason for this difference.
Further studies are needed where the amount of information (i.e., number of point lights) is kept constant in contrast to the type of information (i.e., relative motion). We also considered how various manipulations affected a measure of performance more associated with movement control (i.e., absolute movement time) as opposed to movement coordination. The three demonstration groups approximated the model's timing more closely than the control group (see Fig. 3). Because there were no differences between the three demonstration groups in terms of absolute movement time, spatial end-point information was sufficient to bring about the correct timing of the movement.

Despite the differences in kinematics between the groups, viewing a model did not help participants hit the wicket and improve outcome performance. A similar lack of improvement in outcome success has been observed in other studies where demonstration groups have been compared to control groups during the acquisition of coordination (e.g., Al-Abood et al., 2001; Hodges & Franks, 2000, 2002; Horn et al., 2002, in press). Although there might be a problem in limiting practice to only 60 trials across a single day, it is also likely that we observed a trade off between the acquisition of coordination and the attention given to achieving a high outcome score. A learner may concentrate on improving movement outcome on a more familiar task at the expense of correct replication of movement form. This is consistent with earlier research using a soccer kicking task (Horn et al., 2002). However when the task is novel, as in the cricket bowling action in this experiment, more attention is given to replicating the model's movement form and less to improving outcome. As a consequence, instructors should consider the effectiveness of demonstrations as a function of the task goals. It is also important to note limitations in our outcome success measures which could mask potential performance improvements. In this experiment we only assessed performance with a discrete measure of target attainment (either hit or miss) and hence we were unable to look at improvements in bowling distance from the wicket which may have provided a more sensitive measure of performance.

In summary, we have provided partial evidence in support of Scully and Newell's (1985) claim that relative motion information is picked up from film demonstrations and used to facilitate the acquisition of a model's intra-limb coordination pattern. While making relative motion salient through a PLD did not facilitate the pick-up and acquisition of intra-limb coordination, the removal of relative motion by providing only motion of the wrist was shown to impede the acquisition of movement form in relation to the pattern of coordination picked up from a full body display. Although we failed to observe differences between the full body demonstration groups, as a result of isolating relative motion information through PLDs, the question remains whether learning and movement reproduction improves through other manipulations to the display, such as highlighting certain patterns of coordination on a video demonstration. This is particularly important given that no practice effects across the acquisition period were observed (i.e., improvements in intra-limb coordination beyond the first practice block), nor improvements in the coordination of the non-bowling arm, which nevertheless was involved in the movement. It appears that some information is prioritized over others and that to facilitate
acquisition beyond the provision of regular video film displays other methods for providing this information should be explored. We can only speculate that methods which progressively increase both the amount (i.e., the number of markers representing the model’s movement) and type of information (relative motion versus endpoint information) provided during the learning process will help with this process.

References


