Body movement instructions facilitate synergy level motor learning, retention and transfer

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HIGHLIGHTS
- Instructions regarding body movement led to motor learning, retention and transfer.
- Instructions to maximize the movement outcome did not lead to motor learning.
- Results are interpreted with respect to Bernstein’s hierarchy of motor control.

ARTICLE INFO
Article history:
Received 3 May 2012
Received in revised form 7 June 2012
Accepted 9 June 2012

Keywords:
Attention
Constraints
Hierarchical control
Movement instructions

ABSTRACT
Prior work has suggested that the findings of research on attentional focus during human motor learning research generalize to the use of instructions regarding body movement. However, research on focus of attention has generally not included the use of instructions that prescribe body movement. The present study examined the effect of instructions regarding body movement or movement outcome in a motor task that principally relied upon the organization of an effective movement pattern, with little demand to adapt the movement to environmental task constraints. The use of instructions for efficient body movement produced an improvement in a seated turning range-of-motion task within the first 5 movement trials. This improvement was retained 24 h later and transferred across sitting positions. The instructions to optimize the movement outcome improved the turning range-of-motion significantly on the post-test but not on the retention or transfer tests. These findings indicate that instructions regarding movement form can be more advantageous than instructions regarding movement outcome in a task that relies upon the organization of an effective movement pattern with little demand to adapt this pattern to environmental constraints of the task. The results are interpreted with respect to task constraints and Bernstein’s (1996) hierarchy of control.

1. Introduction

Prior research has shown that instructions that focus attention externally can enhance motor performance and learning more than instructions that focus attention internally [for reviews see 12,23,24]. The constrained action hypothesis [22] proposes that the mechanism responsible for this phenomenon is a disruption of movement organization when attention is directed to body movements. In this hypothesis, attending to body movements interferes with automatic control processes that are better able to facilitate performance and learning than when movements are more consciously controlled.

Prior work has suggested that the findings of focus of attention research generalize to the use of instructions prescribing body movement. It has been claimed that motor skill instructors should avoid giving instructions regarding proper body movements in favor of instructions regarding the outcome of movements [6,18,20,21,26]. However, prior research on focus of attention has generally not included the use of instructions regarding proper body movement [see 21 for an exception].

Prior research has shown that the effectiveness of behavioral information in facilitating motor learning depends upon the task constraints [8–11]. It has been theorized that optimal behavioral information must be in terms of the optimization criteria defined by the task constraints [9]. Thus, it may be that the effectiveness of instructions regarding body movement and movement outcome depends upon the degree to which the information contained in these instructions defines task optimization criteria.

In Bernstein’s [1,16,17] theoretical hierarchy of motor control, internally consistent spatio-temporal coordination patterns are organized by a synergy level control structure. A space level of control adapts the output of the synergy level to meet environmental and task demands. In this way the organization of coordination patterns and the attunement of these to environmental and task
constraints are performed by two distinct control structures. Prior research has supported this theoretical view of hierarchical levels of control [4].

Tasks that require highly coordinated movements but little adaptation to environmental constraints will principally be organized by synergy level control. Tasks with stringent task requirements for adapting movement to environmental constraints will be primarily led by space level control. Information (i.e., instructions or feedback) regarding movement coordination can potentially enhance synergy level control but may interfere with space level control. Information regarding movement outcome can facilitate space level control. In this way, Bernstein’s hierarchy of control predicts that task constraints affect the utility of different forms of behavioral information.

Peh et al. [12] have recently noted that most studies on focus of attention have examined performance on motor tasks that have stringent requirements for adapting movement patterns to the environment (i.e., a high demand for space level control). Tasks that rely principally on the synergy level of control with little requirement for space level control have not typically been examined. The objective of the present study was to determine if instructions regarding body movement can produce greater motor learning than instructions regarding movement outcome. A task was chosen that principally consisted of organizing movement at the synergy level of control, with minimal organization necessary at the space level of control (i.e., attuning movements to the environment). According to Bernstein’s theoretical hierarchy of control, improvement in such a task depends upon learning at the synergy level of control. Therefore, the author hypothesized that instructions providing information regarding proper body movements (i.e., synergy level control) would better facilitate the learning process than instructions to maximize external task performance (space level control).

2. Methods

2.1. Participants

Young adult participants (N = 24; M = 23.63 years; SD = 4.74 years) were recruited from the University student body. All participants provided informed consent, and all procedures were in accordance with guidelines of the Institutional Review Board of the University.

2.2. Task and apparatus

The participants were randomly assigned to either a body movement (n = 12) or movement outcome (n = 12) instruction group. They were instructed to sit on a carpeted floor in two different positions. These consisted of the position depicted in Fig. 1 (‘feet left position’) and the mirror image position (‘feet right position’). A hat was placed on the participant’s head that had a laser pointer attached to it that pointed directly in front of the participant. The room in which participants sat had 180° marked in 1° increments on the surrounding three walls behind and to the sides of where the participant sat. The participants sat with his or her right (for the feet left position) or left (for the feet right position) ischium on a marker on the floor from which the angles marked on the surrounding walls were measured. The angles were marked on the walls through the use of the arctangent function to determine the proper position for each degree marking.

The participants were instructed to focus on the wall and to turn to see as far as they comfortably could to the left and the right, pausing for 3 s at the end of each movement until the researcher instructed him or her to turn in the other direction. Turning once to the right and left constituted one movement trial. The researcher recorded the minimum degree that the participant maintained during the 3 s pause at the end of each movement in each direction.

One pre-test block of 5 trials was performed in both the feet left and right positions. The starting position (feet left or right) and direction first turned (right or left) were counterbalanced across participants and 1 min of rest was provided between blocks. After performing the pre-test block in each sitting direction the participants assigned to the body movement instruction group performed 2 blocks of 5 trials in the feet left position with instructions regarding body movement. The body movement instructions were to turn left and right as in the pretest while intentionally turning the pelvis as well as the upper body, so as to allow the left hip to lift and turn to the right (when turning right) while remaining seated on the right buttock, and for the pelvis to rotate in the opposite direction when turning left. These instructions were chosen as the movement of the pelvis constitutes an essential element in a kinematic chain such as in turning movements [2,13–15]. After performing the 2 blocks with body movement instructions the participants in the body movement instruction group were instructed to focus on the wall and turning to look as far to the right and left as they comfortably could. With these instructions the participants performed another 5 blocks of 5 movement trials in the feet left position.

Participants assigned to the movement outcome instruction group were instructed to turn to look at the wall as far as they comfortably could in each direction (the movement outcome). After performing the pre-test block in each sitting position (feet left and feet right) those in the movement outcome group performed 7 blocks in the feet left position with the movement outcome instructions. In this way each group performed the same number of blocks and movement trials, but with the body movement instruction group performing 2 of these blocks with the instructions regarding body movement instead of the movement outcome instructions.

After these practice blocks all participants performed a post-test block in the feet left and right positions with the movement outcome instructions. In this way a total of 7 practice blocks were performed in the feet left position, with the feet right position used as a transfer test. On the following day all participants performed a 24 h retention test. This test consisted of performing 1 block of 5
movement trials in both the feet left and right positions with the movement outcome instructions.

2.3. Data analysis

The range of motion on each trial was calculated as the difference between the maximum right and left angular positions. As all range of motion values were positive and confined to a range of less than 180 degrees ANOVA were used in statistical analyses rather than circular statistics. A 2 (Group) × 2 (Feet Direction) × 3 (Test) repeated measures ANOVA was conducted for 3 blocks of average range of motion data. These were the first (pre-test) and the last (post-test) blocks performed on day 1 and the 24 h retention test.

A 2 (Group) × 3 (Test) repeated measures ANOVA was also performed on the seated feet left position data to determine if changes in performance on the first day occurred during or after the first block of practice, during which instructions regarding body movement were provided. A separate ANOVA was required for this analysis as the first block of practice was only performed in the feet left seated position. In all analyses a type I error of α = 0.05 was used to determine statistical significance. The calculation of the range of motion for each trial was performed in Microsoft Excel and ANOVA were conducted in SPSS. Pairwise comparisons were performed using Bonferroni corrections.

3. Results

3.1. Learning, retention and transfer

In the 2 (Group) × 2 (Feet Direction) × 3 (Test) repeated measures ANOVA a significant Group effect, F(1,22) = 6.16, p < .05, showed that the body movement instruction group had a greater range of motion than did the movement outcome instruction group. A significant Test effect was also found, F(2,44) = 41.29, p < .001. Post hoc analysis showed that greater turning movement was produced in the post- and retention tests than in the pre-test (p < .001) and that the post-test performance was greater than on the retention test (p = .001).

As shown in Fig. 2 there was a significant Test × Group interaction, F(2,44) = 20.61, p < .001. Post hoc analysis showed that this was due to greater turning movement by the body movement instruction group on the post-test (p < .01) and the retention test (p < .001) but with no significant difference between groups on the pre-test (p > .05). Post hoc analysis also showed that within the body movement instruction group the range of motion for both the post-test and retention tests was greater than in the pre-test (both p < .001) but with no significant difference between the post- and retention tests (p > .05). In the movement outcome instruction group the post-test range of motion was greater than in the pre-test (p < .05) and the retention test (p < .001) while there was no significant difference between the pre- and retention tests (p > .05). As can be seen in Fig. 2A (feet left sitting position) and 2B (feet right sitting position) there was no significant main effect for the direction of sitting, F(1,22) = 2.87, p > .05, which showed that the same changes in range of motion took place in the non-practiced (feet right) as on the practiced (feet left) position. No significant Direction × Group, F(1,22) = .02, p > .05, Test × Direction, F(2,44) = 2.56, p > .05, or Test × Direction × Group, F(2,44) = 2.89, p > .05, interactions occurred.

3.2. Improvement during practice

In the 2 (Group) × 3 (Test) ANOVA that included the pre-test, the first practice block and the post-test, the body movement instruction group had significantly greater turning range of motion than the movement outcome instruction group, F(1,22) = 5.01, p < .05.

There was also a significant main effect for Test, F(2,44) = 38.75, p < .001, that post hoc analysis showed was due to greater range of motion on the first practice block and on the post-test than on the pre-test (both p < .001) and that greater turning range-of-motion was performed on the post-test than during the practice block (p = .01). As shown in Fig. 3 there was also a significant Test × Group interaction, F(2,44) = 6.16, p < .05, for the body movement group.
interaction, \( F(2,44) = 12.64, p < .001 \). Post hoc analysis determined that this was due to there being no significant difference between groups in the range of motion on the pre-test, but that the body movement instruction group showed greater turning range-of-motion than the movement outcome instruction group in the first practice block \( (p < .01) \) and continued this significant improvement into the post-test \( (p < .05) \).

Participants in the movement outcome instruction group significantly increased their range of motion only on the post-test, compared to the pre- and practice tests \( (both \ p > .01) \). This group did not make a significant improvement in turning range of motion from the pre-test to the practice block \( (p > .05) \). However, the body movement instruction group showed an increased increase in the turning range of motion on the first block of 5 trials using the body movement instructions \( (p < .001) \). This group maintained their increased turning range of motion on the post-test, as compared to the pre-test \( (p < .001) \) while no significant improvement occurred between the practice and post-tests \( (p > .05) \).

4. Discussion

The use of only 10 movement trials with instructions regarding efficient body movement, in place of instructions to maximize external task performance, led to greater learning, transfer and retention in a turning range-of-motion task. These findings supported the hypothesis [1] that instructions regarding body movement would better facilitate performance than instructions to maximize external task performance. This was hypothesized to occur because: (a) the task consisted of the organization of an internally consistent movement pattern (synergy level control) with little task demand to attain movements to environmental demands (space level control), and (b) the instructions regarding body movement contained information directly useable by the synergy, but not the space, level of control [1].

Traditional definitions of motor learning stipulate that improvements in performance be relatively permanent [5]. According to this criterion, the use of only instructions regarding movement outcome did not lead to learning, as the post-test improvement with these instructions was not retained on the 24th retention test. The improvement on the post-test with these instructions was likely due to a warm-up effect. The absence of learning with only the movement outcome instructions supported the hypothesis that these instructions would target the space level of control, which was of little benefit in the present task that involved minimal requirements for this level of control.

In Bernstein’s [1,16,17] theory of hierarchical control, instructions regarding body movements bring the synergy level to be the leading level of control in movement. In tasks requiring space level control, instructions regarding body movements relegate the space level to a background level of control and interfere with its function of adapting coordinated movements to environmental demands [8]. The greater the task demands for attuning coordination patterns to environmental constraints the greater the interference will be. This theoretical view explains the numerous prior empirical findings of the benefit of using externally focusing instructions as being due to the greater ability of the space level of control to attune movements to external demands. However, in tasks in which little attunement of coordination patterns to environmental constraints is necessary attention to or instructions prescribing proper body movements may facilitate performance or learning through enhanced functioning of synergy level control. In this way, the effect of instructions on motor learning depends upon the properties of the instructions and the task constraints [8].

The interference of instructions that focus attention internally in tasks that demand a high degree of attunement between coordination patterns and the environment is the effect described by the constrained action hypothesis. However, the constrained action hypothesis does not account for the occurrence of instructions regarding body movements being more beneficial than those with an external focus, such as was found in the present study. Bernstein’s [1] hierarchy of control does predict such occurrences. In this theoretical view, the interference or benefit of internally and externally oriented instructions is a function of the degree to which the task demands synergy and space level control. This theoretical prediction was supported in the present study because it was shown that, in a task with minimal demands for attuning movement to the environment, greater learning, transfer and retention occurred with the use of instructions regarding body movement.

The results found in the present study differed from those of prior research regarding focus of attention e.g., [3,7,19–27] because of the level of control responsible for the tasks involved and the content of the information provided in each experiment. In the present study, the task was principally organized by the synergy level of control and the instructions provided regarding body movement were directly applicable to that level of control. The matching of this information to space level control led to greater performance, learning and retention. The tasks used in most prior studies of focus of attention have depended upon the use of space level control, which is enhanced by information regarding the attunement of movements to the environment.

References


