Journal of Applied Research in Memory and Cognition 2 (2013) 14–19

Contents lists available at SciVerse ScienceDirect

Journal of Applied Research in Memory and Cognition

journal homepage: www.elsevier.com/locate/jarmac

External focus of attention improves performance in a speeded aiming task

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ARTICLE INFO

Article history:
Received 24 May 2012
Received in revised form 6 November 2012
Accepted 7 November 2012
Available online 14 November 2012

Keywords:
Focus of attention
Skill acquisition
Retention and transfer

ABSTRACT

Athletic skills are often executed better when learners focus attention *externally* (e.g., on the trajectory of the ball after a tennis serve), rather than *internally* (e.g., on the position of their arm) (e.g., Wulf, 2007a). The current study explored the effects of attention focus on learning of speeded responses, and examined whether these benefits hold for retention and transfer. Participants performed a computerized speeded aiming task while focusing on the direction of the cursor (external focus) versus the direction in which their hand moved the mouse (internal focus). One week later, half of the participants performed the same task again (retention), and half performed the task under conditions in which the mouse movements were changed (transfer). Relative to internal focus, external focus led to faster acquisition and better maintenance of speeded responses over the retention interval.

Learning new motor skills often involves guidance from a coach or instructor that emphasizes certain aspects of performance. For example, instructions such as, “keep your feet planted,” or “keep your elbow straight,” direct a learner’s attention to particular features of the task. With athletic skills, learners are often encouraged to attend to aspects of their body position (Wulf & Prinz, 2001). However, recent research suggests this may *not* be the optimal way to promote learning of new motor skills.

This topic has been addressed through studies in which participants adopt either an *internal focus* of attention (i.e., focusing on body positions or movements) or an *external focus* of attention (i.e., focusing on effects of these positions or movements) while acquiring a new skill. Retention of these skills is often superior when acquired with an external focus rather than an internal focus (Porter, Nolan, Ostrowski, & Wulf, 2010; Shea & Wulf, 1999; Wulf, 2007a). For example, Wulf, Höß, and Prinz (1998) found that simulated ski training was retained better if participants focused on the simulator’s wheels (external focus), rather than on their own feet (internal focus), during learning. Similar results have been demonstrated for a number of more complex athletic skills such as golf (e.g., Bell & Hardy, 2009; Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007), basketball free-throw shooting (e.g., Zachry, Wulf, Mercer, & Bezodis, 2005), volleyball serves (e.g., Wulf, McConnel, Gärtner, & Schwarz, 2002), dart throwing (e.g., Lohse, Sherwood, & Healy, 2010; Marchant, Clough, & Crawshaw, 2007), and vertical jumping (e.g., Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010).

It is unclear whether these benefits are limited to tasks involving a relatively large range of motion, or whether they occur for simpler motor tasks as well. Although benefits of external focus have been well documented for *retention* of a previously-learned skill, relatively few studies have explored whether these benefits also occur for *transfer* of skills to novel but related tasks (but see Lohse, 2012; Totsika & Wulf, 2003). The current study explored the effects of attention focus on retention and transfer using a computerized speeded aiming task that offers precise controls and a variety of performance measures. This task, created by Pauli (e.g., see Pauli, Braun, Wiech, Birbaumer, & Bourne, 2005), has been used in past research (e.g., Wohldmann, Healy, & Bourne, 2008) and requires participants to move a mouse cursor to one of eight digits arranged around a center starting position (see Fig. 1). Once the cursor is positioned over the center X, one of the eight digits is presented above it, and participants must move the cursor to that digit as quickly as possible. Standard dependent measures are *initiation time*—time required to initiate the required movement, and *movement time*—time required to reach the target after movement has been initiated.

An added perceptual-motor learning component is introduced into this task by reversing the compatibility of mouse-cursor movements. For example, leftward movement of the mouse might produce rightward movement of the cursor on the screen (i.e., horizontal reversal), or upward movement of the mouse might

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http://dx.doi.org/10.1016/j.jarmac.2012.11.002

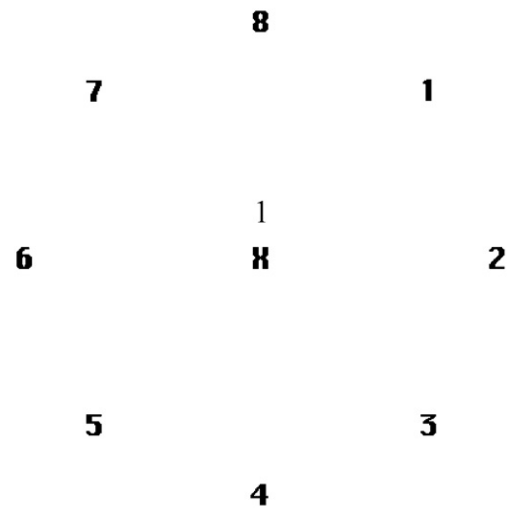

Fig. 1. Speeded aiming task used in the current study. In this example, the target digit is 1.

produce downward movement of the cursor (i.e., vertical reversal). Movements could also be reversed on both dimensions. Although performing the task under these reversal conditions is difficult at first, participants learn and retain this skill after sufficient practice (e.g., Healy, Wohldmann, Sutton, & Bourne, 2006). Previous studies have also demonstrated that training on the horizontal reversal facilitates later performance on both reversals (i.e., positive part–whole transfer), but training on both reversals can impede later performance on the horizontal reversal (i.e., negative whole–part transfer) (e.g., Healy, Wohldmann, & Bourne, 2011).

In the current study, participants learned this task under conditions of internal versus external focus of attention. In accord with previous research (e.g., Wulf, 2007a), we defined internal focus as attention to the part of one's body relevant to performing the task (i.e., mentally focusing on the direction in which one's hand moved the mouse), and external focus as attention to the effect of movements produced by the body (i.e., mentally focusing on the direction in which the cursor moved on the screen). Participants performed 400 trials of the task under these conditions. One week later, participants performed 400 additional trials under conditions in which the mouse reversal was the same (i.e., horizontal–horizontal or both–both) or different from before (i.e., horizontal–both or both–horizontal).

Based on the documented benefits of external focus in athletic skills (e.g., Lohse, Wulf, & Lewthwaite, 2012), one might predict that performance on the current task would benefit more from attending to the cursor than to the hand. These benefits are sometimes stronger during later tests than during initial training (e.g., Lohse, 2012; Wulf, 2007a), suggesting that they may take time and/or a sufficient amount of practice to develop. It is feasible that any effects of attention focus might therefore be stronger during the one-week delayed test than during training. Whereas past research has obtained benefits of external focus in relatively brief test sessions (e.g., Totsika & Wulf, 2003), it is unknown whether these benefits persist over a lengthy test session that involves extensive practice with the task. To more fully explore the time course of these effects, the current study provided participants with 400 trials of the task during training (in which attention focus was manipulated), and again during later testing (in which attention focus was not manipulated). Based on previous research, one might predict that the benefits of external focus would emerge over time and be most pronounced during the initial stage of the test phase. Whether or not these effects persist throughout the later stages of testing provides important information about the durability of these effects.

1. Method

1.1. Participants

Forty-eight undergraduate students participated for partial course credit.

1.2. Task and design

Participants were tested individually on Mac G4 computers. The task required them to move a mouse cursor to one of eight numerically labeled digits arranged equidistant in circular fashion around a central reference point (Fig. 1). Once the cursor was positioned over the center X, a digit was displayed above it, and the participant had to move the cursor to the corresponding digit on the display.

Movement of the cursor from the X to the target digit constituted one trial. In order to end the trial, the cursor was required to contact the target digit (but did not have to maintain stationary position over the digit). The trial did not end until the target digit was contacted, so accuracy was always 100%. Initiation time and movement time were recorded for each trial. Participants were not given any specific instructions about when to initiate movement, so the index of movement time is primarily a measure of execution but presumably includes some planning as well.

Two samples of eight target digits each (16 trials total) were displayed within each sub-block of trials, five of which constituted one block (80 trials total). Five blocks were completed, a total of 400 trials during the training session (Session 1). One week later, participants returned for a test session (Session 2) and completed another 400 trials arranged in the same fashion. During both sessions, presentation of specific digits was always randomized within a sub-block.

During both sessions, the relationship between mouse and cursor movements was made incompatible in one of two ways. The mouse and cursor directions were reversed only for right-left movements, but not for up-down movements (*horizontal* condition); or the mouse and cursor directions were reversed for both right-left and up-down movements (*both* condition). Participants were randomly assigned to perform either the same reversal during training and testing (e.g., horizontal–horizontal, both–both), or different reversals during training and testing (e.g., horizontal–both, both–horizontal). Measures of retention were therefore obtained for both reversal conditions, along with measures of part–whole transfer (horizontal–both) and whole–part transfer (both–horizontal).

During Session 1, half of the participants were asked to perform the task while "attending to the direction in which your hand moves the mouse" (internal focus), and half were asked to perform the task while "attending to the direction in which the cursor moves on the screen" (external focus). Half of the participants who were given internal focus instructions performed the task during Session 1 with the horizontal reversal, and half with both reversals. Likewise, half of the participants who were given external focus instructions performed the task during Session 1 with the horizontal reversal, and half with both reversals. Half of the participants within each of these four conditions then completed the task during Session 2 with the same reversal as before, and half with the other reversal. Six participants were randomly assigned to each of the eight resulting conditions. Two participants failed to return for Session 2, yielding five participants in the internal, horizontal, same and external, horizontal, switch conditions and six in the remaining conditions.