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Enhancing motor learning through external-focus instructions and feedback

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Abstract

The study examined the generalizability of the learning advantages produced by instructions that induce an external relative to an internal focus of attention (e.g., Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: Differential effects of internal versus external focus of attention. *Journal of Motor Behavior*, *30*, 169–179.) to the feedback provided to the learner. Four groups of participants practiced to maintain their balance on a stabilometer. Two of these groups were instructed to either focus on their feet (internal focus) or on markers attached to the stabilometer platform (external focus), while two other groups received concurrent feedback about their deviations from the horizontal on a computer screen and were informed that the feedback represented either their feet (feedback/internal focus) or the markers (feedback/external focus). Both external focus of attention and feedback enhanced learning, as measured by a delayed retention test without feedback. Thus, the learning benefits of an external attentional focus seem to generalize to the feedback given to the learner. In addition, feedback generally enhanced performance and learning, suggesting that one function of feedback might be to promote an external focus of attention. © 1999 Elsevier Science B.V. All rights reserved.

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1. Introduction

More than a century ago, William James (James, 1890) suggested that actions are controlled more effectively if attention is directed to the (intended) outcome of the action, or its "remote effects", rather than to its "close effects", such as the kinesthetic feedback. He illustrates this point in the following example of reaching movements: "Keep your eye at the place aimed at, and your hand will fetch [the target]; think of your hand, and you will likely miss your aim" (James, 1890, p. 520). There is also more recent anecdotal evidence indicating that paying attention to one's own movements can have detrimental effects on performance (Gallwey, 1982; Schmidt, 1988; Schneider & Fisk, 1983). Schmidt (1988, p. 223), for example, suggests you buy your golf opponent a golf book if she beats you on a regular basis to make her analyze and think about her swing, as this should disrupt her performance. Experimental evidence for the negative effects of directing the performer's attention to his or her movements has been provided by Wulf and Weigelt (1997), who showed that giving learners body-related instructions degraded the learning of a ski-simulation task, relative to no instructions.

These findings suggest that giving learners instructions that refer to the coordination of the their body movements – which are typically used in teaching motor skills – might not be optimal for learning. In a recent series of studies, Wulf and colleagues (Wulf, Höß & Prinz, 1998; Wulf, Lauterbach & Toole, 1999; Wulf, Shea, Gerhardt & Schuler, 1998) compared the effects of instructions that direct the learners' attention to the external effects of their movements (external focus of attention) with instructions which focus their attention on the movements themselves (internal focus of attention). The results of these studies consistently demonstrated that motor skill learning can be enhanced by an external compared to an internal focus of attention. For example, using a ski-simulator task, Wulf et al. (1998, experiment 1) found that instructing performers when to exert force on the *wheels* of the platform on which the performer was standing, and which were located directly under the feet, was more effective than instructing them to focus on when to exert force with their *feet*. Similarly, in learning to balance on a stabilometer focusing one's attention on markers on the stabilometer platform facilitated learning, compared to focusing on the feet (Wulf et al., 1998, experiment 2; Wulf, Shea et al., 1998). Finally, Wulf et al. (1999) showed that performance and learning in golf was enhanced by directing the learners' attention to the motion of the club, rather than to the swing of their arms.

Thus, the learning benefits of an external relative to an internal focus of attention appear to hold for a variety of tasks. These results are in line with the "action effect hypothesis" proposed by Prinz (1997), according to which actions are (best) planned and controlled by their intended effects. Prinz (1990) suggested that for perception and action to have commensurate coding systems, they must be represented in the form of "distal events", such as the (intended) outcome of the action.

The advantages of focusing on the outcome of one's movements, compared to focusing on the movements themselves, might be relevant for the formulation of instructions and could also have implications for the feedback that is given to the learner. Traditionally, the role of augmented feedback in the learning of motor skills has been viewed as being rewarding, motivational, or informational in nature (see Adams (1987) for a discussion). However, is it possible that the attentional focus that is induced by the feedback also affects the learning process. That is, it is conceivable that feedback is more effective if it directs the performer's attention away from his or her own movements and to the effects of these movements, i.e., if it induces an external focus of attention.

In the present study we therefore wanted to examine the effectiveness of feedback depending on whether it directed the learners' attention to their movements or to the effect of their movements. For this purpose, we used a stabilometer task and presented two groups of participants with the *same* feedback with one group being informed that the feedback represented their own movements (internal focus), and with the other group being told that the feedback referred to the movements of the platform (external focus). If the learning advantages of an external focus of attention that have previously been shown for instructions (Wulf et al., 1998; Wulf et al., 1999; Wulf, Shea et al., 1998) are generalizable to the feedback that is given to the learner, similar benefits should be found for the external focus, relative to the internal focus, feedback condition. This effect would be particularly convincing if it could be demonstrated for identical feedback conditions, but with participants being given different information about the interpretation of the feedback.

In addition, we wanted to determine whether augmented internal-focus or external-focus feedback provided during practice on the stabilometer task would result in additional benefits, compared to only providing performers with internal-focus and external-focus instructions, respectively. Some recent studies have indicated that feedback is ineffective if it is redundant with the performer's intrinsic feedback (Magill, Chamberlin & Hall, 1991; Vereijken &

Whiting, 1990). Vereijken and Whiting (1990) compared the effects of augmented feedback about movement amplitude, frequency, and fluency on the learning of the ski-simulator task to a control condition without augmented feedback and demonstrated that the additional feedback produced no learning benefits over and above those of practice without feedback. Presumably, the feedback did not provide any information that performers could not pick up directly. Also, Magill et al. (1991), who examined the acquisition of a coincidence-timing skill, found that providing learners with verbal knowledge of results (KR) during practice did not result in more effective performance or learning than practice without KR. Thus, if the feedback does not provide augmented information beyond what can be derived from the learner's intrinsic feedback, it does not seem to result in additional learning advantages. The feedback given in the present study could also be argued to be redundant with the performer's visual and kinesthetic feedback, as it only provides information about the deviations from the goal position (horizontal). However, it is also conceivable that the augmented feedback – independent of whether it supposedly refers to performer's own movements or the (external) movement effects – distracts the performer's attention away from their movements and tends to induce an external focus of attention. In this case, providing learners with feedback should generally be more advantageous than just giving them (external) focus of attention instructions. Another reason why feedback may be more effective than instruction alone is that the feedback is presented during trials, whereas instructions are typically provided only before a trial begins. Thus, the continuous nature of the feedback may provide a constant reminder to maintain the instructed focus.

Another interesting question was whether any advantages of feedback seen during acquisition would transfer to a (delayed) no-feedback retention test. Previous studies examining concurrent feedback (e.g., van der Linden, Cauraugh & Greene, 1993; Schmidt & Wulf, 1997; Winstein, Pohl, Cardinale, Green, Scholtz & Waters, 1996) have shown considerable performance decrements when feedback was removed in retention and transfer. Apparently, if the feedback presented to the learner becomes incorporated into the memories used to generate the movement, performance becomes dependent on the feedback and is disrupted when this feedback is withdrawn (Henry, 1968; Schmidt, 1991). This would be expected if the function of augmented feedback is mainly informational, as is probably the case in typical feedback studies, where other sources of visual feedback are "artificially" removed. However, if feedback also serves to direct the learner's focus of attention – as can be argued in the present study, where no additional information is gained from the feedback – no such decrements should occur.

In summary, we examined the effects of giving learners internal focus vs. external focus feedback, compared to internal focus vs. external focus instructions by having four groups of participants practice to maintain their balance on a stabilometer on two consecutive days. Learners were either provided or not provided with augmented feedback, and were either instructed to focus on their own movements (internal focus) or on the platform movements (external focus). Learning was assessed in a retention test on the third day.

2. Method

2.1. Participants

Thirty-two students of Texas A&M University served as participants in this experiment. None of the participants had prior experience with the task or was informed about the purpose of the study. All participants signed informed consent forms prior to the experiment. They were given extra course credit for their participation.

2.2. Apparatus and task

The task required participants to balance on a stabilometer. The stabilometer consists of a 65 × 105 cm wooden platform, with the maximum possible deviation of the platform to either side being 15°. The task was to remain in balance, i.e., to keep the platform in a horizontal position, for as long as possible during each 90-s trial. Two yellow lines (16 × 2.5 cm) were placed on the platform, 9 cm from the front edge and 14 cm from the midline of the platform. Participants were instructed to place their feet behind these lines. Feedback was provided on a computer monitor that was placed on a table (115 cm in height) about 1 m in front of the performer. The feedback consisted of two blue horizontal reference lines on the left and right of the screen and a pink line representing the deviations of the platform from the horizontal. Fig. 1 illustrates the feedback display when the platform is in the horizontal position (top) and when the right edge of the platform is below horizontal (bottom). If presented, the feedback was provided concurrently and for the whole duration of the trial. The movements of the platform were

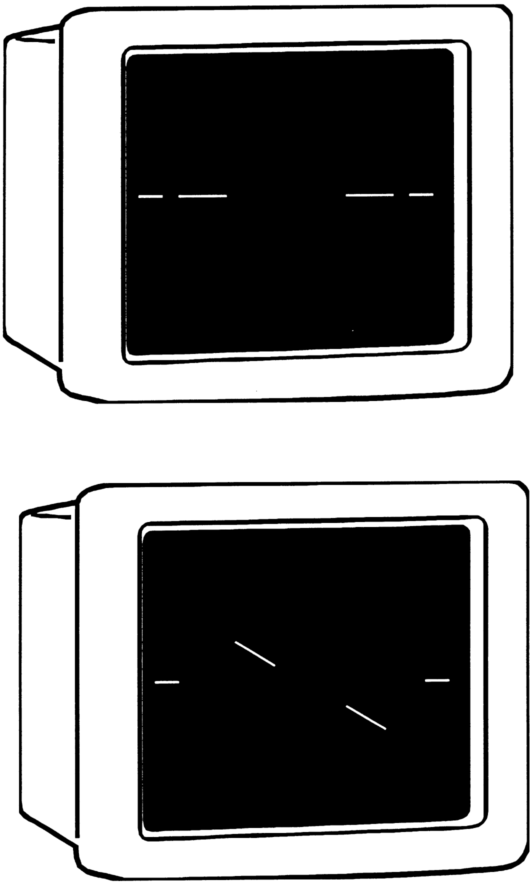

Fig. 1. Example of feedback display when the platform was in the horizonal position (top) and when the right edge of the platform was below horizontal (bottom). This latter position was recorded as a negative score while a positive score indicated the left edge of the platform was above the horizontal position.

monitored by a potentiometer (Novotechnik P4501, 5 kΩ resistance, and 0.1% linearity) that was linked to the platform. To analyze skill development, an analog signal from the potentiometer was recorded (50 Hz, 12 bit resolution) during each trial.

2.3. Procedure

All participants were informed that the task was to keep the platform in the horizontal position for as long as possible during each 90-s trial. Each trial started with the left side of the platform on the ground. Approximately 15 s before the start of a trial, the experimenter asked the participant to step on the platform and to keep the left side down until the start signal was given by the experimenter. At the start signal, the participant attempted to move the platform, and data collection began as soon as the platform crossed the horizontal.

Participants were randomly assigned to one of four practice groups in a 2×2 (feedback: feedback vs. no-feedback×attentional focus: internal vs. external focus) design. The two groups that did not receive feedback were instructed to try to keep their feet at the same height (*no-feedback/internal focus group*) or to try to keep the two yellow lines in front of their feet at the same height (*no-feedback/external focus group*). [1] The two feedback groups received the same internal- or external-focus instructions, but were also presented with concurrent feedback during each practice trial. The feedback display was the same for both groups. However, the *feedback/internal focus group* was informed that the pink line on the screen should be thought of as representing their feet, the *feedback/external focus group* was told that this line represented the yellow lines in front of their feet. Participants were given short reminders regarding the attentional focus before every other practice trial.

All participants performed 7 practice trials on each of two days of practice under the respective treatment conditions. On day 3, there was a retention test consisting of 7 trials without feedback or instructions (reminders) to assess the learning effects of the independent variables.

2.4. Dependent variables and data analysis

The potentiometer data were transformed into degrees out of balance. Participants' proficiency in performing the task was measured by root mean square error (RMSE), with the 0° position (platform in horizontal) as the criterion. Examples of data from the first trial on day 1, the first trial on day

[1] It should be noted that the attentional-focus instructions did not imply that the participants should visually focus on their feet or the reference lines on the platform. Rather, they were asked to focus their attention on the movement of the platform (external focus) or on controlling the position of their feet (internal focus). Indeed, none of the participants adopted a posture during stabilometer performance that suggested that they were visually monitoring their feet or the platform in any continuous or regular manner. Rather, participants typically used a visual fixation point such as the (blank) monitor in front of them.

2, and the first retention trial are provided in Fig. 2 RMSE during practice was analyzed in 2×2×2×7 (feedback×attentional focus×days×trials) ANOVAs with repeated measures on the last two factors. The retention data

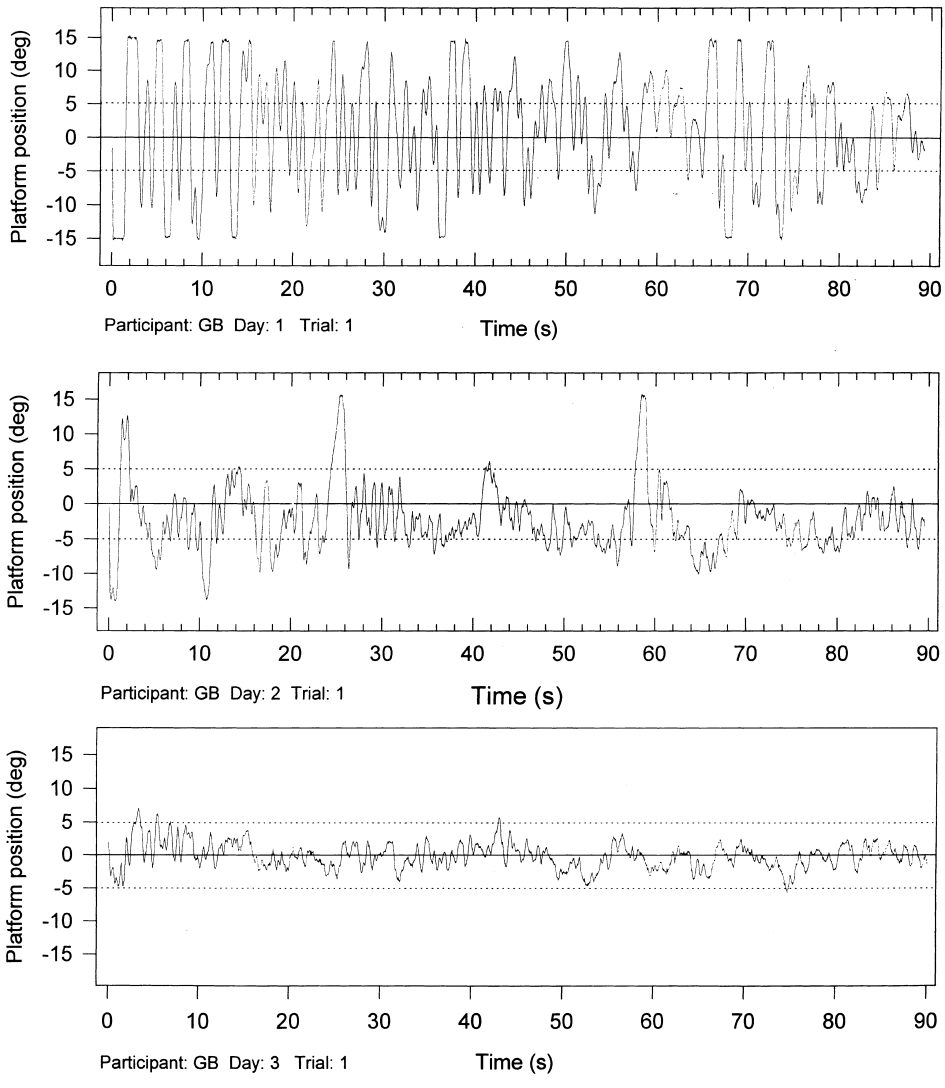

Fig. 2. Example of trials early in practice on day 1, mid-way through practice on day 2, and during the retention test on day 3.

were analyzed in a 2×2×7 (feedback×attentional focus×trial) ANOVA with repeated measures on trial.

3. Results

3.1. Practice

As can be seen from Fig. 3 (left and middle panel), all groups demonstrated an increased proficiency in performance over the two days of practice

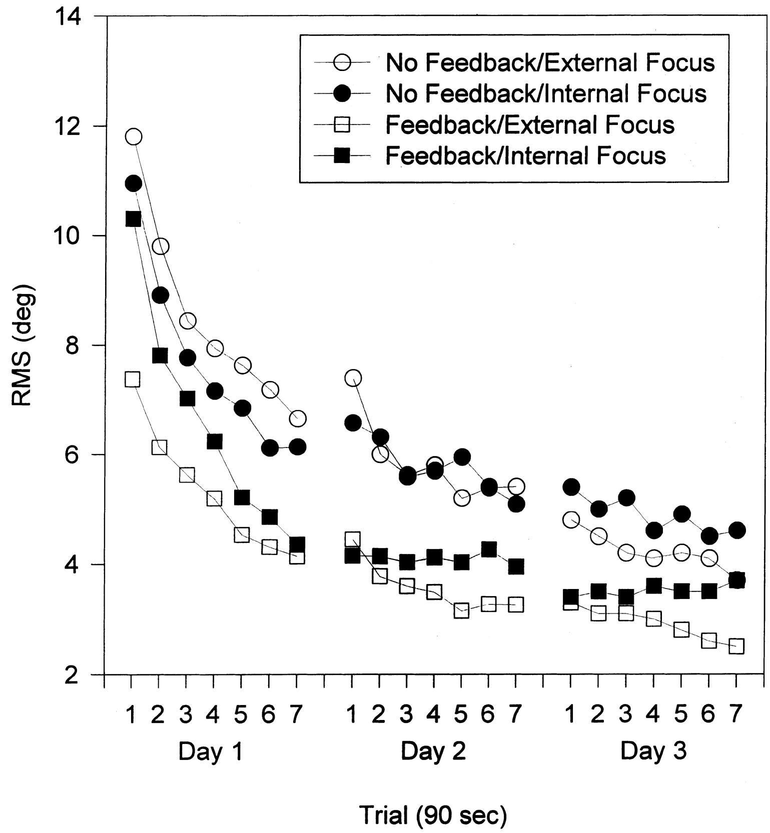

Fig. 3. Root mean square errors (RMSEs) of the no-feedback/external-focus, no-feedback/internal-focus, feedback/external-focus, and no-feedback/external-focus groups during practice (days 1 and 2) and retention (day 3).

Table 1
Root mean square errors (RMSEs) and standard errors (in parentheses) for the no-feedback/external-focus (no FB/EF), no-feedback/internal-focus (no FB/IF), feedback/external-focus (FB/EF), and feedback/internal-focus (FB/IF) groups during practice (days 1 and 2) and retention (day 3)

Trial	Group			
	No FB/EF	No FB/IF	FB/EF	FB/IF
Day 1				
1	11.81 (0.49)	10.95 (0.33)	7.38 (0.41)	10.30 (0.48)
2	9.80 (0.56)	8.90 (0.49)	6.13 (0.38)	7.81 (0.54)
3	8.44 (0.34)	7.77 (0.59)	5.63 (0.35)	7.03 (0.43)
4	7.94 (0.68)	7.17 (0.61)	5.20 (0.31)	6.24 (0.50)
5	7.63 (0.40)	6.86 (0.78)	4.53 (0.17)	5.22 (0.54)
6	7.19 (0.47)	6.12 (0.62)	4.31 (0.36)	4.86 (0.40)
7	6.66 (0.45)	6.14 (0.71)	4.14 (0.46)	4.35 (0.52)
Day 2				
1	7.40 (0.47)	6.58 (0.76)	4.45 (0.22)	4.15 (0.34)
2	6.00 (0.59)	6.32 (0.60)	3.78 (0.32)	4.14 (0.24)
3	5.62 (0.61)	5.59 (0.48)	3.60 (0.41)	4.03 (0.22)
4	5.80 (0.57)	5.70 (0.54)	3.49 (0.31)	4.12 (0.26)
5	5.20 (0.48)	5.95 (0.58)	3.15 (0.36)	4.03 (0.34)
6	5.39 (0.64)	5.41 (0.47)	3.27 (0.39)	4.26 (0.47)
7	5.41 (0.53)	5.09 (0.51)	3.26 (0.43)	3.95 (0.54)
Day 3				
1	4.80 (0.49)	5.49 (0.54)	3.32 (0.21)	4.30 (0.18)
2	4.51 (0.56)	5.04 (0.46)	3.14 (0.27)	3.54 (0.21)
3	4.23 (0.54)	5.27 (0.57)	3.12 (0.21)	3.44 (0.29)
4	4.11 (0.49)	4.65 (0.40)	3.06 (0.21)	3.69 (0.21)
5	4.21 (0.47)	4.90 (0.33)	2.86 (0.33)	3.54 (0.25)
6	4.17 (0.40)	4.52 (0.41)	2.67 (0.27)	3.55 (0.22)
7	3.73 (0.51)	4.63 (0.36)	2.54 (0.20)	3.79 (0.11)

(see Table 1 for group means and standard errors). Under no-feedback conditions, the internal-focus instructions tended to produce more effective performance on day 1, whereas there were no differences between the groups with different focus instructions on day 2. The two feedback groups had consistently lower error scores than the no-feedback groups throughout the whole practice phase. [2] Also, the external-focus instructions tended to be

[2] As there already appeared to be group differences on the very first trial, a feedback × attentional-focus ANOVA was performed on this trial. This analysis yielded a main effect of feedback, $F(1,28) = 10.23$, $p < 0.01$, indicated performance advantages for the feedback groups relative to the no-feedback groups. However, the main effect of attentional focus, $F(1,28) < 1$, and feedback × attentional focus interaction, $(1,28) = 2.56$, $p\text{s} > 0.05$, were not significant. Apparently the feedback enhanced performance very quickly, generally resulting in very rapid improvement in performance.

more effective under feedback conditions than the internal-focus instructions; this advantage was particularly pronounced early in practice on day 1 and late in practice on day 2. The main effects of day, $F(1,28) = 241.02$, trial, $F(6,168) = 117.28$, and feedback, $F(1,28) = 26.58$, $p\mathrm{s} < 0.001$, were significant. In addition, the interactions of feedback × trial, $F(6,168) = 3.10$, $p < 0.01$, day × trial $F(6,168) = 50.64$, $p < 0.01$, feedback × attentional focus × day, $F(1,28) = 7.18$, $p < 0.05$, and feedback × attentional focus × day × trial, $F(6,168) = 2.48$, $p < 0.05$, were significant.

To determine the nature of the interactions, separate 2 × 2 × 7 (feedback × attentional focus × trial) ANOVAs for the first 2 days were performed. For day 1, the analysis yielded significant main effects of feedback, $F(1,28) = 27.30$, $p < 0.001$, and trial, $F(6,167) = 118.21$, $p < 0.001$. In addition, the interactions of attentional focus × feedback, $F(1,28) = 6.27$, $p < 0.05$, and of attentional focus × feedback × trial, $F(6,167) = 2.20$, $p < 0.05$, were significant. As indicated by simple main effects analyses, the interactions were due to the fact that the internal focus group was more effective than the external focus group under no-feedback conditions on trials 1–6, whereas the feedback/external focus group was more effective than the feedback/internal focus group on trials 1–3.

On day 2, the ANOVA yielded significant main effects of feedback, $F(1,28) = 20.25$, $p < 0.001$, and trial, $F(6,168) = 15.64$, $p < 0.001$. Also, the feedback × trial, $F(6,168) = 3.47$, $p < 0.01$, and attentional focus × trial interactions, $F(6,168) = 4.36$, $p < 0.001$, were significant. Simple main effects analyses of the feedback × trial interaction indicated that the feedback groups had significantly smaller errors than the no-feedback groups on each trial (all $F\mathrm{s} > 9$, $p\mathrm{s} < 0.001$). Also, both the feedback and no-feedback groups consistently reduced their errors across trials on day 2, but the no-feedback groups showed a relatively greater improvement, $F(6,168) = 15.67$, $p < 0.001$, across trials than the feedback groups, $F(6,168) = 2.29$, $p < 0.04$. Furthermore, the simple main effects analysis of the attentional focus × trials interaction indicated that there were no significant differences between the internal- and external-focus conditions, $F\mathrm{s}(1,196) < 2, p\mathrm{s} > 0.05$, for each trial, but the externa focus groups demonstrated a greater error reduction across trials, $F(1,168) = 19.21$, $p < 0.001$, than the internal focus groups, $F(1,168) = 2.73$, $p < 0.01$.

3.2. Retention

The average performances during the retention test on day 3 are shown to the right of Fig. 3 (see also Table 1). The two groups that had received feedback on the first two days were again more effective than the groups that had no additional feedback during practice. Also, the external focus groups had generally lower error scores than the groups with an internal focus of attention, independent of whether or not they received feedback during practice. The main effects of feedback, $F(1,28) = 16.99$, $p < 0.001$, attentional focus, $F(1,28) = 4.48$, $p < 0.05$, and trial, $F(6,168) = 6.06$, $p < 0.01$, were significant. The feedback × attentional focus, $F(1,28) < 1$, the attentional focus × trial, $F(6,168) = 1.06$, $p = 0.38$, the feedback × trial, $F(6,168) = 1.86$, $p = 0.09$, and the feedback × attentional focus × trial, $F(6,168) = 1.69$, $p = 0.12$, interactions failed significance. Thus, the beneficial effects of both augmented feedback and an external focus of attention generalized to the retention test without feedback and instructions. In addition, the analysis indicated that participants generally continued to improve their performance across retention trials (with the exception of the no-feedback/internal focus condition), even though instructions and reminders concerning attentional-focus and/or feedback were not provided.

4. Discussion

The purpose of the present study was to examine whether the learning advantages of an external compared to an internal focus of attention, induced by the instructions given to the learner, would also hold for the feedback provided during practice. To determine whether the augmented feedback would have any additional benefits, over and above those of the instructions, we included groups that were only given internal or external focus instructions (similar to Wulf et al., 1998, experiment 2). The results replicated those of Wulf et al. in demonstrating more effective learning if the learners' attention was directed to an external effect of their movements (in this case, the movement of the markers on the platform), rather than to their own body movements. In addition, similar advantages were seen under feedback conditions. That is, even though the feedback display was *identical* for the two feedback groups, the feedback group with an external focus of attention had generally lower errors than the feedback group with an internal attentional focus. This was seen especially early in practice on day 1, even on the very first trial, and late in practice on day 2 while the feedback was present, but the advantages could still be seen in the retention test without feedback. Interestingly, Wulf et al. (1998, experiment 2), using the same task, also found advantages of external feedback emerge very early in practice. That is, the benefits of an external focus of attention and feedback appeared to independently increment learning. This suggests that the feedback given to performers during practice can be more effective if it directs their attention to the effects of their movements instead of to the movements themselves. [3]

Interestingly, the feedback provided to learners in the present study generally enhanced performers' ability to maintain their balance on the stabilometer – even though the feedback could have been argued to be redundant with their intrinsic feedback (Magill et al., 1991; Vereijken & Whiting, 1990). Obviously, learners had visual and kinesthetic feedback available to inform them about the platform's deviation from the horizontal. Yet, the visual display of the platform movements on the screen considerably benefited their performance. One possible reason for this added benefit of the feedback is that it might have incremented the degree to which learners were able to maintain an external focus of attention by providing a more "remote" (James, 1890) or "distal" (Prinz, 1990) fixation point – independent of the (internal- or external-focus) instructions given to learners. That is, the display information might have provided a constant and powerful reminder to maintain an external focus. The fact that the feedback seemed to have a greater influence on performance than the external-focus instructions per se might be a function of the "degree" to which the observed movement effect is directed away from the performer's body (McNevin & Wulf, 1998; Wulf et al., 1999). The difference inthe actual locus of attention induced by the instructions (feet vs. lines on the platform) was relatively small. Considering the spatial proximity of these cues, it might seem surprising that the instructions had an effect at all (see also Wulf et al., 1998, experiment 2). The visual display on the screen, on the other hand, appeared to induce a considerably more "remote" focus of attention, with respect to the body. In fact, using the same stabilometer task, McNevin and Wulf (1998) found that directing learners' attention to markers on the platform that were relatively far away from the feet was more effective than directing their attention to markers close to the feet. Thus, the degree to which attentional focus is directed away from the body

[3] It is interesting to note that the feedback/internal-focus group demonstrated larger errors than the feedback/external focus group at the beginning of practice. A possible reason for these initial group differences is that the former group might have experienced a conflict between the internal-focus instructions and the (external) feedback display. Apparently, however, this conflict was resolved fairly quickly, resulting in similar performances as those of the feedback/external focus group by the end of day 1.

seems to be a determining factor for the effectiveness of an external attentional focus in that more "remote" fixation points might generally increase the likelihood that the participants focus on the effects of the action (James, 1890) and not on the production of the action. This might explain why the augmented feedback generally appeared to be more influential than the instructions.

Another interesting point regarding the general effectiveness of concurrent augmented feedback in the present study is that it not only enhanced performance during practice, i.e., while it was provided, but that the beneficial effects of the feedback were also seen in the delayed retention test without feedback. That is, the feedback not only had a temporary effect on performance, but in fact enhanced the *learning* of this task. Based on previous findings, one would not necessarily have expected the beneficial effects of concurrent feedback to be retained when the feedback was withdrawn. For example, in the studies by van der Linden et al. (1993), Schmidt and Wulf (1997), and Winstein et al. (1996), concurrent feedback also clearly enhanced performance during practice; yet, a considerable performance decrement was seen when feedback was withdrawn in (delayed) retention and transfer. This was clearly not the case in the present study. The degrading effects of frequent and immediate feedback are usually explained with the "guidance hypothesis" (Salmoni, Schmidt & Walter, 1984; Schmidt, 1991), according to which the learner develops a dependency on the feedback, if she or he is heavily "guided" by the augmented information, which results in performance decrements when the feedback is not available anymore. The feedback in the present study also seemed to guide the learner to the goal response, as seen by the facilitating effects it had during practice; yet, learners apparently did not become dependent on it, as performance was maintained in its absence. This finding cannot be explained by the guidance hypothesis and suggests that feedback might also have other functions in the learning process, in addition to the informational role that is emphasized by the guidance hypothesis (see below).

Also, several studies by Proteau, Marteniuk, and others (e.g., Ivens & Marteniuk, 1997; Proteau, Marteniuk, Girouard & Dugas, 1987; Proteau & Cournoyer, 1992) have shown that performance is degraded when visual feedback is withdrawn after (extensive) practice with feedback, or if visual feedback is added after practicing without it. The present results do not, at first glance, appear to be consistent with this perspective because the sensorimotor representation that is developed through the specific practice conditions is not disrupted when the feedback is taken away. In the present study, participants who had practiced with feedback experienced little if any decrements in performance when they were switched to a no-feedback condition in retention. Thus, in the present case, the concurrent feedback does not appear to have been overly guiding, or to have become a part of the movement representation.

Both the fact that the feedback provided in this experiment considerably enhanced performance during practice, even though it was redundant with the performer's intrinsic feedback, and the fact that there was no performance decrement for the feedback groups when the augmented feedback was withdrawn in retention, indicate that the function of augmented feedback is not only informational (or motivational) in nature. Rather, these findings suggest that feedback can also have the capacity to induce an external focus of attention that benefits performance and learning. The remote fixation point provided by the feedback display may have been sufficient to direct the learners' attention away from engaging in the active control of their movements independent of the information, if any, provided by the feedback. Although no-feedback was presented during retention testing, the fixation point could have been maintained and could have continued to provide a reminder to maintain the attentional-focus utilized during acquisition because the monitor was still present. Thus, from this perspective, the finding that performance at the end of acquisition and on the retention were similar is consistent with the specificity point of view proposed by Proteau, Marteniuk, and others (e.g., Ivens & Marteniuk, 1997; Proteau et al., 1987; Proteau & Cournoyer, 1992) because the relevant stimulus conditions were similar.

The exact reasons for the beneficial effects of an external, relative to an internal, focus of attention are still unclear. However, this phenomenon is in line with the "common coding" theory proposed by Prinz (1990, 1997). Contrary to traditional views, which assume that there are different and incommensurate coding systems for afferent and efferent information (e.g., Welford, 1968; Sanders, 1980; Massaro, 1990), he argues that there is a common representational medium for perception and action. According to this view, efferent and afferent codes can be generated and maintained in a commensurate way only at a distant level of representation. That is, action planning and perception typically involves "distal events", as this is the only format that allows for commensurate coding, and thus for efficient planning of action (see Prinz, 1992). Therefore, actions should be more effective if they are planned in terms of their intended outcome, rather than in terms of the specific movement patterns.

It is conceivable that attempts to consciously control one's movements may actually interfere with control processes that would otherwise regulate the movement automatically. A study by Henry (1953) impressively demonstrates the ability of the motor system to control movements automatically. In his study, participants were to hold the position of a lever in a constant position, despite randomly changing pressure that was applied to it by a mechanical device. Henry found that performers responded to changes in pressure that were 20 times smaller than the pressure required for conscious perception. Thus, trying to exert conscious control over these processes might cause interference resulting in the performance decrements that are seen when performers direct their attention to their movements. This is also supported by findings of a recent study (Shea, Wulf & Whitacre, 1999), in which learners practiced the stabilometer task in dyads and exchanged strategies that they found helpful in performing this task. In that study, several participants indicated that "not concentrating too much", or "thinking of something else" facilitated performance.

It is also interesting to note that participants in the external focus groups, after some practice and particularly during the retention test, appear to move the platform generally more smoothly than the participants in the internal-focus group. Of course, smooth movement of the platform would be consistent with better performance, but this observation may also suggest that additional detailed analyses of the platform movement may reveal subtle characteristics of movement production that could be used to characterize performance under internal and external focus of attention. For example, it is possible that the internal focus participants may concentrate on specific body parts/joints – essentially reducing the total number of degrees of freedom utilized in an attempt to maintain platform position resulting in lower frequency changes in platform position, while external focus participants may dynamically incorporate more degrees of freedom permitting higher frequency changes in platform position. The higher frequency changes (provided the amplitudes are correspondingly reduced) would be perceived as relatively smooth performance while the lower frequency changes (provided correspondingly higher amplitudes) would resulting in more abrupt changes in platform position. Thus, future experiments may wish to more fully analyze the structure of the platform movement using, for example, time series (frequency) analysis (see Newell & Slifkin, 1998). Using upright bipedal stance, for example, Newell (1998) has found that the dimension of center of pressure, a measure of variability, increases during childhood through maturity and then declines again in aging participants. He suggests that low dimension estimates imply a dynamic organization by a system with few degrees of freedom while higher estimates suggest the coordination of more degrees of freedom.

Overall, the present results suggest that motor skill learning can be enhanced if the instructions and feedback given to learners refer to the effects of their movements, rather than the movements themselves. In addition, they show that feedback per se can be effective for learning by inducing an external focus of attention, even if – or especially if – the feedback appears to be "redundant". If, on the other hand, the feedback is necessary to learn the task, because other sources of feedback are artificially removed – as is often done in the laboratory – the detrimental effects of withdrawing the feedback that has essentially become a part of the task (Schmidt, 1991) might outweigh the potential benefits. In more "real-world" situations, however, feedback is often given in addition to the performer's intrinsic feedback. The results of the present study suggest that concurrent feedback can actually be beneficial in these cases if it induces an external focus of attention. Future research needs to determine the generalizability of these findings to different tasks and different types of feedback (e.g., post-response feedback).

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