

Enhancing the Learning of Sport Skills Through External-Focus Feedback

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ABSTRACT. The authors examined how the effectiveness of feedback for the learning of complex motor skills is affected by the focus of attention it induces. The feedback referred specifically either to body movements (internal focus) or to movement effects (external focus). In Experiment 1, groups of novices and advanced volleyball players ($N = 48$) practiced “tennis” serves under internal-focus or external-focus feedback conditions in a 2 (expertise) \times 2 (feedback type) design. Type of feedback did not differentially affect movement quality, but external-focus feedback resulted in greater accuracy of the serves than internal-focus feedback during both practice and retention, independent of the level of expertise. In Experiment 2, the effects of relative feedback frequency as a function of attentional focus were examined. A 2 (feedback frequency: 100% vs. 33%) \times 2 (feedback type) design was used. Experienced soccer players ($N = 52$) were required to shoot lofted passes at a target. External-focus feedback resulted in greater accuracy than internal-focus feedback did. In addition, reduced feedback frequency was beneficial under internal-focus feedback conditions, whereas 100% and 33% feedback were equally effective under external-focus conditions. The results demonstrate the effectiveness of effect-related, as opposed to movement-related, feedback and also suggest that there is a need to revise current views regarding the role of feedback for motor learning.

Key words: feedback, focus of attention, motor learning, soccer, volleyball

In a number of studies conducted in the past few years, the effectiveness of instructions in motor skill learning has been found to depend largely on the focus of attention they induce (e.g., Wulf, Höß, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999; Wulf, McNevin, Fuchs, Ritter, & Toole, 2000; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001; for a review, see Wulf & Prinz, in press). Specifically, giving learners instructions that refer to the coordination of their body movements—as is typically done in teaching motor skills—has not been shown to be optimal for learning. When instructions that induced such an internal focus

of attention were compared with instructions that directed the learners’ attention to the effects of their movements on the environment (apparatus, implement), thereby inducing an external focus, the latter type of instructions were consistently shown to produce more effective learning.

It is interesting that learning differences occur even though the differences in the instructions given to learners are very small. For example, in the first demonstration of the phenomenon, Wulf et al. (1998, Experiment 1) used a ski-simulator task and found that instructing performers when to exert force on the wheels underlying the platform on which the performers were standing, and which were located directly under the feet, was more beneficial than instructing them to focus on when to exert force with their feet. Similarly, when participants were learning to balance on a stabilometer, directing their attention to markers located in front of their feet and attached to the stabilometer platform, rather than directing their attention to the feet themselves, facilitated learning (Wulf et al., 1998, Experiment 2; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). More recently, evidence for the learning advantages of instructions that induce an external focus of attention have also been found for sport skills. Wulf et al. (1999) showed that performance and learning in golf were enhanced by directing learners’ attention to the motion of the club rather than to the swinging motion of their arms.

Thus, the comparative learning benefits of an external over an internal focus of attention appear to hold for a variety of tasks. The advantages of an external focus have been

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attributed to performers' use of more automatic control processes when attending to the movement effect than when attending to the actual movements (Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). When concentrating on the movements themselves, performers appear to actively intervene in the control processes, resulting in degraded performance and learning.

The advantages of focusing on the outcome of one's movements might not only be important with respect to the instructions provided but might also have implications for the feedback given to the learner. In fact, the results of a recent study by Shea and Wulf (1999) suggested that feedback can be more effective if it directs the performer's attention away from his or her own movements and to the effects of those movements. Shea and Wulf used a stabilometer task and presented two groups of participants with the same concurrent feedback while they practiced balancing on the platform. The feedback consisted of two lines representing the deviations of the platform from the horizontal. Whereas one group of participants was informed that the lines represented their feet (internal focus), the other group was told that the feedback represented two lines attached to the platform and located in front of their feet (external focus). Even though the feedback was identical for the two groups and participants were given different information only about the interpretation of the feedback, external-focus feedback led to more effective balance performance than did internal-focus feedback in a retention test without feedback.

Thus, the results of Shea and Wulf's (1999) study provided preliminary evidence that the type of attentional focus induced by the feedback could differentially affect learning. In fact, those results are quite remarkable, because the feedback was actually identical for both groups of learners. In contrast to that experimental technique, in practical settings such as sports or clinical rehabilitation, coaches or instructors typically provide the learner with verbal feedback that refers to the aspect of performance that needs the most improvement. That is, on the basis of what the coach considers to be the critical mistake or flaw, the coach gives feedback that he or she hopes will help the performer make appropriate changes on subsequent attempts. As pointed out earlier, however, the feedback given by instructors often refers to the learner's body movements, which, based on the aforementioned findings, might not be optimal for learning. Our purpose in the present study was therefore to examine the relative benefits of feedback that avoids references to the performer's body movements and instead induces an external focus.

The answer to that question not only has practical importance but also is relevant for the theoretical understanding of the function of feedback in motor skill learning. The current predominant view of the role of feedback is that feedback manipulations are most effective if they enhance learners' awareness of their body movements (e.g., Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991; Schmidt & Lee,

1999). The findings of numerous recent studies have been interpreted as providing evidence that encouraging learners to attend to their movements or the intrinsic feedback associated with them—for example, giving feedback on only a portion of trials rather than on every trial—makes learning more effective (e.g., Lai & Shea, 1998; Nicholson & Schmidt, 1991; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989; Wulf, Schmidt, & Deubel, 1993). That is, focusing on one's own movements is seen as a precondition for the development of an effective movement representation. Thus, one would expect feedback that directs the learner's attention to his or her movements (internal-focus feedback) to be more effective than feedback that induces an external focus. If, however, more evidence for learning advantages of external-focus feedback was obtained, then new interpretations of the role of feedback might be necessary.

In the present study, we used two relatively complex motor skills, the volleyball "tennis" serve (Experiment 1) and a lofted soccer pass (Experiment 2), to compare the effects of internal- and external-focus feedback. For that purpose, we selected feedback statements that are typically used in training and that refer to the performer's body movements (internal-focus feedback). Those statements were translated into statements that contained basically the same information but referred less to the movements themselves. Rather, they directed the learners' attention more to the movement effects (external-focus feedback).

The procedure used in this study—that is, trying to match feedback statements that induce an internal focus of attention with statements that are equivalent in contents but induce more of an external attentional focus—is obviously different from that used in previous studies. In those studies, the learners' attention was directed to specific cues, such as their feet or the ski-simulator platform's wheels (Wulf et al., 1998, Experiment 1), their feet or markers on the stabilometer (Shea & Wulf, 1999; Wulf et al., 1998, Experiment 2), or their arms or a golf club (Wulf et al., 1999). In contrast, our goal in the present study was to examine the effectiveness of different types of feedback for actual sport skills under more realistic conditions that approximate those of athletic training situations. That objective required that more than one feedback statement be used and that the feedback be given as a function of the participant's performance; it also required that the feedback statements given to each group in the present study differ more from each other, in terms of the wording, than did the instructions or feedback used in previous studies. However, in light of our goal in this study—to determine the generalizability of feedback inducing different attentional foci to the learning of sport skills—and because in previous research even minor differences in attentional focus have been found to have significant effects on learning (e.g., Shea & Wulf, 1999; Wulf et al., 1998), that feedback manipulation was deemed appropriate.

Thus, our main purpose in the present study was to compare the relative effectiveness of feedback that induces an

external attentional focus and feedback that induces an internal attentional focus for the learning of sports skills. In Experiment 1, we used a volleyball serve and examined how those types of feedback affected performance and learning in novices as well as in advanced players. In Experiment 2, we went one step further and examined possible interactions of type of feedback and feedback frequency.

EXPERIMENT 1

Our main purpose in this experiment was to examine the generalizability of the benefits of external- as compared with internal-focus feedback found by Shea and Wulf (1999) to the learning of a sport skill. In addition, we wanted to determine whether the type of feedback (internal vs. external focus) would differentially affect learning as a function of the performer's expertise. Whereas participants in previous studies of the effects of learners' attentional focus, which was manipulated through instructions (e.g., Wulf et al., 1998; Wulf et al., 1999; Wulf, McNevin, et al., 2000; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001) or feedback (Shea & Wulf, 1999), were exclusively beginners without prior experience on the respective task, participants in the present study were novices as well as advanced volleyball players. On the one hand, it seemed possible, for example, that, as compared with external-focus feedback, internal-focus feedback would be less detrimental for advanced players than for beginners because advanced players' movements should be more automated and might be less affected by feedback that directs their attention to their movements. In that case, one would expect an interaction between type of feedback and expertise. On the other hand, there has been anecdotal (Gallwey, 1982; Schneider & Fisk, 1983) as well as some experimental evidence (Baumeister, 1984; Wulf & Weigelt, 1997) for performance decrements in experienced performers, who focus on their actions. If internal-focus feedback is indeed generally less effective than external-focus feedback, the type of feedback should similarly affect advanced players and novices.

Finally, in contrast to most previous studies in which the effects of attentional focus on the learning of sport skills have been examined (Wulf et al., 1999; Wulf, McNevin, et al., 2000), we assessed performance not only in terms of the movement outcome (i.e., accuracy in hitting a target) but also in terms of movement form. That is, we used expert ratings to determine how the type of feedback given to learners affects movement quality. It is conceivable, for example, that although internal-focus feedback that directs the performers' attention to their movement coordination has a negative effect on the movement outcome (accuracy), it produces better movement form than does external-focus feedback. Such a tradeoff between movement outcome and form would qualify any advantages of external-focus feedback. Yet, a finding that movement form does not suffer (or even benefits) under external-focus conditions would increase our confidence in the benefits of such feedback relative to internal-focus feedback.

In summary, we examined the effects of giving learners internal-focus or external-focus feedback by having four groups of participants practice the volleyball serve on 2 days, separated by 1 week. Two groups of novices and advanced players were provided either internal-focus or external-focus feedback. Learning was assessed in a retention test without feedback 1 week after the second practice session.

Method

Participants

Participants ($N = 48$) were high school and university students. The novices were between the ages of 16 and 23 years, and the advanced players were between 15 and 30 years of age. The high school students were tested during the time of their regular physical education classes. The university students played volleyball in intramural activity classes, and testing took place during their training hours. None of the novices had prior experience with the volleyball tennis serve, whereas all of the advanced players had some experience with that type of serve. All participants were naive as to our purpose in the experiment.

Apparatus and Task

The experiment took place on a regular indoor-volleyball court. A standard height (2.33 m) was used for all participants. In the center of the "opponents" side of the court, a 3- × 3-m target area was marked with 5-cm-wide colored tape, which was clearly visible from the participants' side of the court. A 4- × 4-m and a 5- × 5-m area were marked around the target area. If the center of the target area was hit, then 4 points were awarded. A score of 3, 2, or 1 was awarded if one of the three larger target areas or any other area on the opponents' side of the court, respectively, was hit. For balls that were out of bounds or hit the net, 0 points were recorded. The serves were always performed from the right side of the court. The video camera used to record some of the serves was positioned on the right of the participant. It was present throughout the entire practice or retention session but was turned on only for the first and the last blocks of three trials during each session. Before each session, we checked and adjusted the pressure of the balls, if needed, to ensure identical conditions for all participants.

Procedure

Before the beginning of each experimental session, participants were asked to warm up sufficiently. Each participant was tested individually. Before the beginning of the first session, the experimenter spent a few minutes with each participant to describe or review the basic technique of the tennis serve (e.g., Beutelstahl, 1979; Christmann, 1987; Hergenbahn, 1989). The instructions emphasized important aspects of the technique, such as maintaining a shoulder-wide stance, with the left foot placed in front of the right foot (right-handers) and pointing in the direction of the serve; tossing the ball with the left arm; and hitting the ball

with the open right hand. Those instructions, although very internal in nature, were not part of the important experimental manipulation (see the following). The experimenter demonstrated the serve once to each participant.

The novices and advanced participants were assigned to either internal- or external-focus feedback conditions (Nov-Int, Nov-Ext, Adv-Int, and Adv-Ext), which resulted in a 2 (expertise) × 2 (feedback type) design. In each of the two feedback-type conditions, one of four feedback statements was given after every 5th trial. The feedback given to the internal- and external-focus feedback groups was similar in content. Although the feedback statements given to the internal-focus groups referred to the performer's own movements, in the feedback statements given to the external-focus groups, references to the performer's body movements were avoided; those statements instead referred more to the movement effects. The feedback statements for the internal- and external-focus groups are listed in Table 1. As can be seen in that table, both types of feedback referred to the performer's coordination, or movement technique; thus, the external-focus feedback did not refer, for example, to the trajectory of the ball, which one might consider a more external focus. However, in order for the two feedback types (internal, external) to be comparable in contents, we had to use similar statements. On the basis of the previous 5 trials, the experimenter chose the feedback statement that referred to the aspect of the skill that needed the most improvement. Thus, even though the statements were worded as prescriptive information, instructing participants what to do on the subsequent trial or trials, they were considered feedback information (as opposed to instructions), because they were given as a function of performance (see also

Weeks & Kordus, 1998). The accuracy score for each trial was recorded. In addition, the first and last blocks of 3 trials in each session (practice and retention) were videotaped for later analysis. Each participant performed 25 practice trials in each of two practice sessions that were separated by a week. One week after the 2nd practice day, a retention test consisting of 15 trials was performed. No feedback was provided during retention.

Data Analysis

The accuracy scores were averaged across blocks of five trials. For the practice phase, those scores were analyzed in a 2 (expertise: novices vs. advanced players) × 2 (feedback type: internal focus vs. external focus) × 2 (day) × 5 (block) analysis of variance (ANOVA) with repeated measures on day and block. The retention scores were analyzed in a 2 (expertise: novices vs. advanced players) × 2 (feedback type: internal focus vs. external focus) × 3 (block) ANOVA with repeated measures on block.

Movement quality was assessed on the basis of a number of criteria (e.g., Beutelstahl, 1979; Christmann, 1987; Hergenhahn, 1989). Those criteria are listed in Table 2. Two independent raters¹ assessed the quality of the serves and awarded a score between 0 and 15, with the highest score indicating perfect performance. The correlation between the scores of the two raters was .988. Because even a high correlation does not necessarily show to what extent two raters are agreeing, however, we also calculated Cohen's kappa (e.g., Clark-Carter, 1997). Cohen's kappa was .7525, which is considered excellent (Robson, 1993). Therefore, the scores of both raters were averaged. The form scores for the practice phase were analyzed in a 2 (expertise: novices vs. advanced players) × 2 (feedback type: internal focus vs. external focus) × 2 (day) × 2 (block) ANOVA with repeated measures on the last two variables. For the retention test, the form scores were analyzed in a 2 (expertise: novices vs. advanced players) × 2 (feedback type: internal focus vs. external focus) × 2 (block) ANOVA with repeated measures on the last variable.

TABLE 1
Feedback Statements for the Internal- and External-Focus Feedback Groups in Experiment 1

Internal-focus feedback

- Toss the ball high enough in front of the hitting arm.
- Snap your wrist while hitting the ball to produce a forward rotation of the ball.
- Shortly before hitting the ball, shift your weight from the back leg to the front leg.
- Arch your back and accelerate first the shoulder, then the upper arm, the lower arm, and finally your hand.

External-focus feedback

- Toss the ball straight up.
- Imagine holding a bowl in your hand and cupping the ball with it to produce a forward rotation of the ball.
- Shortly before hitting the ball, shift your weight toward the target.
- Hit the ball as if using a whip, like a horseman driving horses.

TABLE 2
Criteria for Movement Form Evaluation

- Does the participant adopt the correct stance?
- Does the participant show a sufficient backswing with a high elbow?
- Does he or she begin the forward motion of the hitting arm by rotating the trunk forward?
- Does he or she accelerate the lower arm until hitting the ball?
- Is the weight shift recognizable?
- Is the arch of the back released quickly and forcefully?
- Is a hip flexion visible?
- Is the ball being hit with the open hand and with a wrist snap so that it receives a forward rotation?

Results

Practice

Accuracy Scores

The scores achieved by each of the four groups during the 2 days of practice can be seen in Figure 1.² All groups demonstrated a consistent increase in the accuracy of the serves. Not surprisingly, the advanced players generally scored higher than the novices did. More important, the groups with external-focus feedback were overall more accurate than the groups with internal-focus feedback— independent of the level of expertise. The main effects of expertise, $F(1, 41) = 29.16, p < .001$, feedback type, $F(1, 41) = 9.25, p < .01$, day, $F(1, 41) = 44.45, p < .001$, and block, $F(1, 41) = 13.55, p < .001$, were significant. None of the interactions was significant.

Form Scores

In terms of movement quality, there was a clear advantage for the advanced players as compared with the novices (see Figure 2). As well, the external-focus feedback groups (Nov-Ext and Adv-Ext) had higher form scores than the groups with internal-focus feedback (Nov-Int and Adv-Int). The main effects of expertise, $F(1, 41) = 90.34, p < .001$, feedback type, $F(1, 41) = 4.40, p < .05$, day, $F(1, 41) = 12.96, p < .001$, and block, $F(1, 41) = 46.52, p < .001$, were significant. Although there was a general improvement in movement form across practice, the Nov-Int group demonstrated a larger increase on Day 1 than on Day 2, whereas the reverse was true for the Nov-Ext group. That finding was confirmed by significant interactions of feedback type, day, and block, $F(1, 41) = 6.34, p < .05$, and expertise, feedback type, day, and block, $F(1, 41) = 6.34, p < .05$.

Retention

Accuracy Scores

On the retention test, there was a general trend for further improvements in the accuracy of the serves (see Figure 1). Again, the advanced players were more effective than the novices. More important, though, the two groups that had received external-focus feedback during practice (Nov-Ext and Adv-Ext) had clearly higher scores than the groups with internal-focus feedback did (Nov-Int and Adv-Int). That finding was confirmed by significant main effects of expertise, $F(1, 41) = 23.71, p < .001$, and feedback type, $F(1, 41) = 8.64, p < .01$. In addition, the block main effect was marginally significant, $F(1, 41) = 2.96, p = .057$. There were no significant interactions. Thus, the benefits of external- relative to internal-focus feedback were not merely temporary but were also seen after the 1-week retention interval under no-feedback conditions.

Form Scores

Although the advanced groups (Adv-Ext and Adv-Int) showed a better movement form than the novices (Nov-Ext and Nov-Int), there were no clear advantages for the external- as compared with the internal-focus feedback groups in retention (see Figure 2). In fact, with the withdrawal of feedback, the Nov-Int group showed a relatively large improvement in movement form, resulting in form scores similar to those of the Nov-Ext group. The main effects of expertise, $F(1, 41) = 47.95, p < .001$, and block, $F(1, 41) = 33.61, p < .001$, were significant. Moreover, the interaction of expertise, feedback type, and block was significant, $F(1, 41) = 6.10, p < .05$, indicating greater improvements for the Nov-Int group than for the Nov-Ext group, and for the Adv-

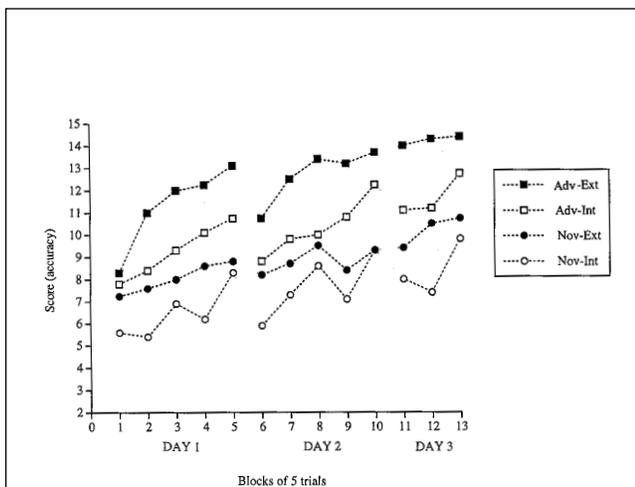


FIGURE 1. Accuracy scores of the Nov-Ext, Nov-Int, Adv-Ext, and Adv-Int groups during the 2 days of practice and in retention in Experiment 1. Nov, Adv, Ext, and Int = novices, advanced players, external focus, and internal focus, respectively.

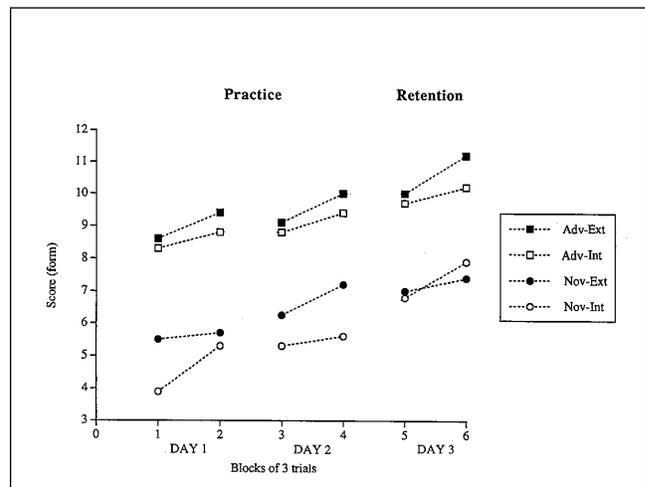


FIGURE 2. Form scores of the Nov-Ext, Nov-Int, Adv-Ext, and Adv-Int groups during the 2 days of practice and in retention in Experiment 1. Form was rated on the first and last three trials on each day. See Figure 1 for definitions of abbreviations.

Ext group than for the Adv-Int group. No other main or interaction effects were significant. Thus, even though the type of feedback differentially affected movement form during practice, those effects were not permanent; rather, with the withdrawal of feedback, the performance of the internal-focus feedback group seemed to catch up with that of the external-focus feedback group.

Discussion

Our main purpose in this experiment was to examine whether previous findings of learning advantages of external- compared with internal-focus feedback (Shea & Wulf, 1999) would generalize to more complex sport skills. In addition, we asked whether there would be differential effects of type of feedback depending on the performers' skill level. The results showed that external-focus feedback resulted in more effective performance than internal-focus feedback did in terms of the accuracy of the serves for both novice and advanced players. More important, the type of feedback not only affected performance temporarily, that is, when it was present during practice; it also had a relatively permanent, or learning, effect, as demonstrated by performances after a 1-week retention interval under no-feedback conditions. Those findings show that the attentional focus induced by the feedback can indeed have an effect on learning: Feedback that induced an external focus was clearly more beneficial than feedback that induced an internal focus. Moreover, the results demonstrated that those advantages are not restricted to early stages of learning (novices) but are also seen in experienced performers.

Most interesting, external-focus feedback also had a beneficial effect on movement form, at least when it was provided during practice. That finding demonstrates that performers do not need direct references to their body movements in order to acquire the correct technique. In contrast to practice, though, there were no clear group differences on the retention test without feedback. The withdrawal of the internal-focus feedback in retention appeared to result in performance improvements for the novices (more so than for the advanced players). The fact that the learners' attention was not constantly directed to their movements by the provision of internal-focus feedback during retention might have allowed the detrimental effects of that feedback to be offset, resulting in form scores similar to those of the external-focus feedback participants.

Admittedly, the external-focus feedback statements were not completely void of references to the body movements. The reason for that is twofold. First, in the acquisition of complex motor skills with many degrees of freedom, such as the ones used here, where the performer's major goal is the learning of the correct technique, it might be almost impossible to come up with statements that do not refer at all to the performer's own movements. Second, as mentioned earlier, to avoid confounding effects of differences in the statement contents, we had to use similar external- and internal-feedback statements. Yet, as the present results

showed, it does not seem to be necessary to completely avoid references to the performer's own movements, as long as the induced focus is predominantly external. If the external-focus feedback had been even more external in nature (e.g. referring to the ball trajectory), even greater learning advantages might have been found. McNevin, Shea, and Wulf (2001; see also Park, Shea, McNevin, & Wulf, 2000) recently demonstrated that an increased distance of the external focus (distance between markers on feet on the stabilometer platform) led to greater learning benefits, presumably because it facilitated discrimination between the movement effect and the body movements that produced it.

In the statements used for the external-focus conditions, metaphors or analogies were used. As Wulf et al. (1999) have pointed out, one advantage of metaphors might be that they detract the performer's attention from his or her body movements and at the same time provide a mental image of the movement goal—which presumably serves a function similar to instructions or feedback directing attention to the movement effects.

The finding that one can enhance the effectiveness of feedback by directing performers' attention away from their body movements not only has practical implications for the training of motor skills, it also has theoretical implications. The current predominant view with respect to the role of feedback in motor learning is that feedback manipulations are most effective if they enhance the learners' awareness of their body movements (e.g., Salmoni et al., 1984; Schmidt, 1991; Schmidt & Lee, 1999). That is, contrary to what our findings suggest, conscious control of movements is assumed to be essential for learning to be effective, especially early in the learning process (Adams, 1971; Fitts, 1964). Furthermore, the findings of numerous recent studies have been interpreted as evidence for the notion that giving learners a chance to attend to their movements—for example, by providing feedback only on a portion of trials as compared with every trial—makes learning more effective (e.g., Lai & Shea, 1998; Nicholson & Schmidt, 1991; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989; Wulf et al., 1993). Similarly, giving summary feedback—that is, providing feedback for a set of trials (e.g., 5) only after that set has been completed—has been found to enhance motor learning in comparison with giving feedback after every single trial (e.g., Schmidt, Lange, & Young, 1990; Schmidt, Young, Swinnen, & Shapiro, 1989). Furthermore, providing feedback about the average error on a set of trials (e.g., Wulf & Schmidt, 1996; Young & Schmidt, 1992) or bandwidth feedback (e.g., Lai & Shea, 1999; Sherwood, 1988) can facilitate learning in comparison with providing feedback in an every-trial format.

Those findings have been interpreted in terms of the guidance hypothesis (Salmoni et al., 1984; Schmidt, 1991), according to which feedback guides the learner to the correct response, thus reducing errors and facilitating performance. However, the negative effects of frequent (single-trial) feedback for learning are evidenced by the learner's

becoming too dependent on that informational support and neglecting the processing of intrinsic postresponse feedback. In other words, frequent feedback is assumed to prevent learners from focusing on their own movements, which is seen as a precondition for the development of an effective movement representation.

The present findings do not appear to be in line with the view that a focus on the body movements is essential for learning. On the basis of the present findings, we therefore suggest an alternative interpretation of the detrimental effects of frequent feedback found in previous studies. Rather than preventing learners from focusing on their own movements, frequent feedback might actually make them focus too much on their movements, leading to the typically observed learning decrements. In contrast, reducing the relative feedback frequency (or providing summary or average feedback) might give learners a chance, at least once in a while, to perform the movement without being too concerned about their performance. Even though not focusing on the movement itself does not necessarily induce an external focus, it still seems to be more effective than directing one's attention to one's own performance (Singer, Lidor, & Cauraugh, 1993; Wulf & Weigelt, 1997). Because of the theoretical and practical importance of understanding how the effectiveness of feedback is influenced by the attentional focus it induces, we decided to follow up on that issue in a further study. In Experiment 2, we therefore examined possible interactions of feedback frequency and attentional focus.

EXPERIMENT 2

If the feedback typically provided in experiments tends to induce an internal focus, then the benefits of reducing feedback could be the result of the relief that manipulation offers from the constant movement-related focus induced by every-trial feedback. Consider, for example, the results of a recent study by Weeks and Kordus (1998). In their study, different groups of participants practicing a soccer throw-in were given knowledge of performance (KP) similar to the internal-focus feedback given in Experiment 1. For example, statements such as "The feet, hips, knees, and shoulders should be aimed at the target, feet shoulder width apart"; "The back should be arched at the beginning of the throw"; or "The arms should go over the head during the throw and finish by being aimed at the target" were used. One of a total of eight feedback statements was given either after every trial (100%) or after every third trial (33%). The movement form of the 33%-KP group participants was superior to that of the 100%-KP group participants. More interesting, the benefits of the 33%-KP condition were seen not only in retention and transfer tests without KP but also during practice. Although the benefits of the reduced-feedback condition in retention and transfer could be explained by the guidance hypothesis (e.g., Salmoni et al., 1984), the finding that those advantages had already occurred during practice is contrary to the predictions of that view. Accord-

ing to the guidance hypothesis, frequent feedback exerts its strong guidance properties and leads to reduced errors while it is present during practice. However, such a finding makes sense from an attentional-focus point of view, in that the 100%-KP condition was detrimental both to practice and to retention and transfer performance because of the constant internal focus that it induced. The reduced feedback frequency might have alleviated the negative effects of the KP because information referring to participants' body movements was not constantly presented.

Although it is relatively easy to see that KP, which, by definition, refers to the "nature of the movement produced" (Schmidt & Lee, 1999, p. 415), would induce an internal focus, it is somewhat more difficult to make that argument for KR, which refers to the "result produced in terms of the environmental goal" (Schmidt & Lee, 1999). One might argue (a) that KR about movement time, final position, or score achieved, for example, should induce more of an external focus, and therefore—following our argument—(b) that no detrimental effects of frequent KR would be expected. When looking at the tasks that have been used in experiments examining KR frequency effects, however, one finds that the feedback was indeed very closely related to the movements that produced the outcome. For example, in several studies a movement patterning task was used in which a manipulandum had to be moved in a spatially and temporally defined way (e.g., Nicholson & Schmidt, 1991; Vander Linden, Cauraugh, & Greene, 1993; Winstein & Schmidt, 1990; Wrisberg & Wulf, 1997; Wulf et al., 1993). Obviously, the feedback in terms of the produced position–time curve presented on a screen was directly related not only to the movement of the manipulandum but also to the limb movement. Thus, participants might easily have interpreted the curve as representing their arm movement, that is, as internal-focus feedback (or KP). That argument also holds for positioning tasks (e.g., Winstein, Pohl, & Lewthwaite, 1994), in which a lever has to be moved to a certain target position in a specified movement time. In other studies, sequential key-press tasks in which a series of keys had to be depressed in specified movement times were used (e.g., Lai & Shea, 1998; Wulf, Lee, & Schmidt, 1994; Wulf & Schmidt, 1989). Because of the relatively minor spatial accuracy demands in those cases, feedback about the movement times between key presses was again directly related to the finger movements.

Thus, if the attentional focus induced by the feedback is indeed critical, then the often found detrimental effects of frequent feedback might be the result of the constant internal focus that such feedback typically induces, although those effects are attenuated under reduced feedback conditions. However, one would not expect to see detrimental effects of frequent feedback if it induces an external focus. In fact, one might even see advantages of frequent over less frequent external-focus feedback, because the frequent feedback might aid the performer in maintaining an external focus (see Shea & Wulf, 1999). Our main purpose in

Experiment 2 was therefore to test possible interactive effects of feedback frequency and feedback type on focus of attention.

In addition, we wanted to examine the generalizability of the advantages of external- as compared with internal-focus feedback seen in Experiment 1 to a different task. In Experiment 2, we used a lofted soccer pass. We also used only participants who had some experience in playing soccer, because we wanted to obtain more evidence for the benefits of an external focus in advanced players. A 2 (feedback frequency) × 2 (feedback type) design was used in which participants were provided either after every trial (100%) or after every third trial (33%) with feedback about movement quality that induced either an internal or external focus of attention. We predicted that external-focus feedback would generally lead to more effective performance and learning than would internal-focus feedback (as in Experiment 1). In addition, we expected to see an interaction between feedback frequency and type, such that 33% feedback would be more beneficial than 100% feedback under internal-focus conditions (as in Weeks & Kordus, 1998) but 100% feedback would be more effective than, or at least as effective as, 33% feedback under external-focus conditions.

Method

Participants

Participants were 52 right-foot-dominant university students who volunteered for the experiment. Participants included men and women whose ages ranged from 18 to 25 years. The criterion for inclusion in the study, even though rather loose, was that they have at least some experience in soccer. All participants gave their informed consent, and all were naïve as to our purpose in the study.

Apparatus and Task

The experiment took place on an Astroturf pitch. A clearly visible target was placed 15 m away from the participant. The square target was 1.4 m in length and height, and was hung 1 m above the ground. The central target area measured 80 × 80 cm, and two zones, each 15 cm wide, surrounded the central area. If the ball hit the center area, 3 points were awarded. A score of 2 or 1 point was awarded if one of the larger areas was hit, respectively. For balls that missed the target, 0 points were recorded. In instances in which the ball hit a line, points were awarded on the basis of the zone that was hit by the largest part of the ball. The position of the soccer ball to be struck was always 1 m to the left of the target so that the natural curl of the ball struck by a right-footed player using the instep could be accommodated.

Procedure

Participants were tested individually. Before the practice phase began, participants were asked to warm up, and the general technique for lofting the soccer ball was described to

the participant (Ford, 1982; Hargreaves, 1990). That is, participants were instructed to approach the ball from an angle of approximately 45°, perform a relatively long last step, and position the nonkicking foot to the side of the ball. After those general instructions, which were not part of the actual experimental manipulation, the experimenter gave one demonstration of the task by kicking the ball at the target.

Participants were randomly assigned to one of four groups that varied with regard to the feedback type (external vs. internal focus) and feedback frequency (100% vs. 33%). For the two groups receiving 100% feedback (Ext-100 and Int-100), one of five feedback statements was given after each practice trial. For the two groups receiving 33% feedback (Ext-33 and Int-33), one of five statements was provided after every third trial. The feedback statements given to the internal- and external-focus groups were similar in content. Although the internal-focus statements referred participants to their body movements, the external-focus statements were worded so that body-movement references were avoided as much as possible and attention was directed more toward the movement effects (see Table 3). The statement chosen by the experimenter reflected the aspect of the skill that needed the most improvement. The experimenter also recorded the scores. All participants performed 30 practice trials and returned 1 week later to perform a 10-trial retention test. No feedback was provided in retention.

TABLE 3
Feedback Statements for the Internal- and External-Focus Feedback Groups in Experiment 2

Internal-focus feedback

- Position your foot below the ball's midline to lift the ball.
- Position your bodyweight and the nonkicking foot behind the ball.
- Lock your ankle down and use the instep to strike the ball.
- Keep your knee bent as you swing your leg back, and straighten your knee before contact.
- To strike the ball, the swing of the leg should be as long as possible.

External-focus feedback

- Strike the ball below its midline to lift it; that is, kick underneath it.
- Be behind the ball, not over it, and lean back.
- Stroke the ball toward the target as if passing to another player.
- Use a long-lever action like the swing of a golf club before contact with the ball.
- To strike the ball, create a pendulum-like motion with as long a duration as possible.

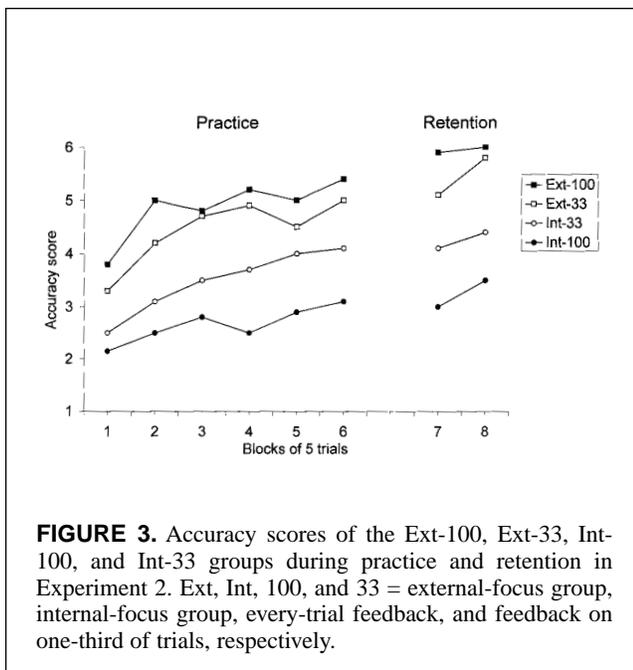
Data Analysis

The accuracy scores were averaged across five-trial blocks. The practice scores were analyzed in a 2 (feedback frequency: 100% vs. 33%) \times 2 (feedback type: internal focus vs. external focus) \times 5 (block) analysis of variance (ANOVA) with repeated measures on block. The retention scores were analyzed in a 2 (feedback frequency: 100% vs. 33%) \times 2 (feedback type: internal focus vs. external focus) \times 2 (block) ANOVA with repeated measures on block.

Results

Practice

As can be seen from Figure 3 (left panel), all groups showed an increase in the accuracy of the passes. Yet, the two groups that received external-focus feedback (Ext-100 and Ext-33) were generally more accurate than the two groups that received internal-focus feedback (Int-100 and Int-33), independent of feedback frequency. In addition, under internal-focus feedback conditions, the 33% group (Int-33) was more effective than the 100% group (Int-100), whereas the reverse was true for the external-focus feedback conditions. The main effects of feedback type, $F(1, 48) = 37.19, p < .01$, and block, $F(5, 240) = 12.18, p < .01$, were significant, but the main effect of feedback frequency was not, $F(1, 48) < 1$. Moreover, the interaction of feedback frequency and feedback type was significant, $F(1, 48) = 5.502, p < .05$, confirming the differential effects of feedback frequency as a function of attentional focus. Simple main effect analyses indicated that the difference between the Int-100 and Int-33 groups was significant, $p < .05$, whereas the difference between the Ext-100 and Ext-33 groups was not, $p > .05$. No other interactions were significant.



Retention

On the no-feedback retention test, there was a further general increase in the accuracy scores across trials (see Figure 3, right panel). Again, the external-focus feedback groups (Ext-100 and Ext-33) were overall more accurate than the internal-focus feedback groups (Int-100 and Int-33). Whereas the 100% group had lower accuracy scores than the 33% group under internal-focus conditions, the opposite was true for the external-feedback groups. The main effects of feedback type, $F(1, 48) = 32.80, p < .01$, and block, $F(1, 48) = 6.39, p < .05$, were significant. The main effect of feedback frequency was not significant, $F(1, 48) < 1$. Again, there was a significant Feedback Type \times Feedback Frequency interaction, $F(1, 48) = 4.89, p < .05$. Simple main effect analyses revealed that the Int-100 and Int-33 groups differed significantly from each other, $p < .05$, whereas the difference between the Ext-100 and Ext-33 groups did not reach significance, $p > .05$. None of the other interactions was significant. Thus, the results confirmed our prediction that reduced feedback would be more beneficial under internal-focus conditions but that frequent feedback would be at least as effective as reduced feedback under external-focus conditions.

Discussion

After the results of Experiment 1 had shown that external-focus feedback leads to more effective learning than internal-focus feedback does (see also Shea & Wulf, 1999), we wanted to examine whether and how the type of feedback interacts with feedback frequency. We predicted learning advantages for reduced feedback under internal-focus conditions but no difference, or even benefits, for frequent compared with reduced feedback under external-focus conditions. The results confirmed the predicted interaction of feedback frequency and attentional focus. Specifically, they are in line with previous findings (e.g., Weeks & Kordus, 1998) of more effective performance during both practice and retention when the frequency of feedback directed at the performer's movements (internal focus) is reduced. Although the benefits of reduced feedback seen in retention could be explained by the guidance hypothesis (e.g., Salmoni et al., 1984; Schmidt, 1991), the benefits observed during practice are contrary to that view. According to the guidance hypothesis, frequent feedback should lead to more effective performance during practice than less frequent feedback. From an attentional-focus point of view, however, one would expect reduced internal-focus feedback to be beneficial in both practice and retention because the negative effects of that type of feedback should be alleviated if it is provided on only a portion of trials.

Furthermore, the performances of the external-focus groups were in line with our prediction. Even though there was no significant difference between the two external-focus groups in practice or retention, 100% feedback tended to be more effective than 33% feedback, which is the reverse of what occurred in the internal-focus feedback

groups. The provision of feedback after every trial presumably served as a constant reminder to adopt an external focus, which benefited performance and learning (see also Shea & Wulf, 1999). Nevertheless, the advantages of that type of feedback were seen even when it was provided on only one third of the trials.

Most important, as in Experiment 1, external-focus feedback generally led to better performance and learning than internal-focus feedback did. In addition, those advantages were maintained after a 1-week retention interval in a no-feedback retention test. That finding provides additional support for the learning benefits of external-focus feedback.

It is not easy to see how the guidance theory can explain (a) the general benefits of external- relative to internal-focus feedback, (b) the advantages of reduced internal-focus feedback during practice, and (c) the interaction between feedback type and frequency. The present findings, together with those of Shea and Wulf (1999), suggest that attentional focus is indeed an important qualifying variable for the effectiveness of feedback. We may need to take a fresh look at and perhaps reinterpret previous findings in light of these new results in order to gain a better understanding of the functions of feedback.

GENERAL DISCUSSION

Although in a number of studies, the effectiveness of instructions has been shown to be enhanced if the learner's attention is directed to the movement effect instead of to the movements themselves (e.g., Wulf et al., 1998, Wulf et al., 1999, Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001), the present study is one of the first examinations of the influence of feedback as a function of the attentional focus that it induces. Shea and Wulf (1999) conducted the only previous study of that effect. In their study, however, the learning differences between groups with external- and internal-focus feedback were relatively small, presumably because the feedback was actually identical for the two groups and only their interpretation of the feedback was manipulated. Therefore, to assess the influence of feedback on the learning of sport skills, in the present experiment we actually manipulated the feedback itself and the attentional focus that it induced.

Both experiments were clear in showing that participants who received feedback that referred more to the movement effects than to their body movements learned more effectively than did participants who were provided with feedback regarding their movement patterns. Together with previous demonstrations of attentional-focus effects in laboratory tasks (e.g., Wulf et al., 1998) and in real-world skills (e.g., Wulf et al., 1999; present experiments), as well as for novices and advanced performers (present experiments), the present findings add to the growing evidence for the importance of that variable for motor performance and learning.

What are the reasons for the attentional-focus effects? Wulf and her colleagues (McNevin, Shea, & Wulf, 2000;

Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001; for a review, see Wulf & Prinz, in press) have argued, on the one hand, that focusing on the movements themselves and trying to consciously control one's movements interfere with automatic motor control processes that would normally regulate the movement. A focus on the movement effect, on the other hand, seems to allow the motor system to use those automatic processes, unconstrained by conscious control. A couple of recent studies have provided support for that assumption. In the study by Wulf, McNevin, and Shea, an analysis of the movement kinematics of the stabilometer platform, which participants were trying to keep horizontal, revealed that participants who focused on their feet showed comparatively low-frequency adjustments of their movements. Participants who focused on markers attached to the platform, however, demonstrated significantly higher response frequencies. Increases in response frequency have been interpreted as an indication of an increased number of active degrees of freedom (cf. Newell & Slifkin, 1996). In contrast, trying to consciously intervene in the motor control processes seems to result in a "freezing" of the degrees of freedom (Vereijken, van Emmerik, Whiting, & Newell, 1992) in a less automatic movement execution and, as a consequence, in degraded performance and learning.

Additional evidence for the notion that an external focus promotes the use of more automatic control processes than an internal focus does comes from a study by Wulf, McNevin, and Shea (2001). They took probe reaction times (RTs) from participants balancing on a stabilometer as a measure of the attention demands required under external- (markers) and internal- (feet) attentional-focus conditions. External-focus participants demonstrated lower probe RTs than internal-focus participants did, indicating a greater amount of spare attentional capacity or a higher degree of automaticity, respectively. Even though we did not measure the automaticity of the movements acquired with different types of feedback in the present study, it seems reasonable to conclude that, like external-focus instructions, external-focus feedback promotes the use of automatic control processes to a greater extent than feedback that directs attention to the movements. A fruitful endeavor for future researchers might be to use kinematic analyses in verifying those assumptions concerning feedback procedures.

One might ask whether an internal focus is detrimental to performance and learning or whether an external focus is actually beneficial. Obviously, one cannot answer that question without including control conditions. In the present study, control groups were not included because it appeared that they would almost necessarily have been at a disadvantage with respect to the other groups, who would have received considerably more information about the correct technique (independent of whether the information induced an external or internal focus). However, in other studies in which learners' attention was directed to one external or internal cue, respectively (wheels on ski-simulator vs. feet [Wulf et al., 1998, Experiment 1] or markers on stabilome-

ter platform vs. feet [Wulf & McNevin, 2001; Wulf, Weigelt, Poulter, & McNevin, 2001]), control groups without attentional-focus instructions were included. The results consistently demonstrated learning advantages for external-focus groups, as compared with internal-focus and control groups, which showed very similar performances. One cannot answer on the basis of the present results whether that finding would also hold for situations where (internal or external) feedback about various aspects of the technique is provided. Considering the (informational) disadvantage of a control condition without feedback, however, that question is almost irrelevant. At any rate, given that, in practical settings, instructions and feedback are often worded in a way that induces an internal focus, the finding that external-focus feedback yields relatively superior learning than internal-focus feedback does appear to be of greater importance. The present results shed new light on the role of feedback for motor learning. The finding that feedback was more effective when it was worded so that references to performers' movements were avoided as much as possible seems to be at odds with the current predominant guidance view of feedback. According to that view, the effectiveness of feedback is enhanced to the extent that it encourages learners, or at least gives learners a chance, to attend to their own movements (e.g., Salmoni et al., 1984; Schmidt, 1991). From a guidance theory point of view, one might therefore expect internal-focus feedback to be most effective. The present data, as well as those of Shea and Wulf (1999), clearly show that that was not the case, however.

We therefore suggest a new—although perhaps somewhat radical—interpretation of previous findings showing benefits of reduced feedback (e.g., Lai & Shea, 1998; Weeks & Kordus, 1998; Winstein et al., 1994; Winstein & Schmidt, 1990; Wulf & Schmidt, 1989; Wulf et al., 1993). According to that interpretation, reduced-feedback effects could result from the relief that reduction offers from the constant internal focus induced by every-trial feedback. The results of the present study—in particular, the general benefits of external- over internal-focus feedback (Experiments 1 and 2), the interactive effects of feedback frequency and attentional focus (Experiment 2), and the failure of frequent internal-focus feedback to produce a benefit during practice (Experiment 2)—seem to provide some support for that view. Those results would be difficult to explain from the guidance perspective.

We do not wish to discount the credibility of the guidance hypothesis. In fact, it is very likely that for typical laboratory tasks—where participants are often deprived of natural sources of feedback so that the effects of various manipulations of experimenter-provided feedback can be examined—they develop the dependency on augmented feedback postulated by the guidance hypothesis, if feedback is provided too frequently. That is, independent of whether the feedback induces an external or an internal focus, detrimental effects of frequent feedback might be observed under such artificial laboratory conditions. On the other hand, under more natural

conditions, where other sources of information are available and the development of a dependency on augmented feedback might be less likely (Wulf & Shea, in press), the focus of attention induced by the augmented feedback might have a greater impact. For example, in the Shea and Wulf (1999) study, concurrent feedback about the movements of the stabilometer platform—provided in addition to the performers' intrinsic feedback—led to differential effects, depending on the attentional focus induced by the instructions. Furthermore, no performance decrements were seen when concurrent feedback was withdrawn in retention—contrary to what would be expected from a guidance theory perspective. Shea and Wulf argued that, compared with no-feedback conditions, the feedback presented on the screen (independent of internal- or external-focus instructions) might have served to induce an external focus of attention, which therefore resulted in the observed learning benefits.

Clearly, one must conduct future studies to verify (or falsify) those assumptions. Nevertheless, to fully appreciate the different roles feedback can play in the learning process, one must look more at complex tasks under realistic conditions (Wulf & Shea, in press). Such studies could reveal new insights into the functions of feedback that cannot be obtained if we restrict our view to laboratory tasks with few degrees of freedom and limited sources of feedback (see also Swinnen, 1996). The present results suggest that a revision of researchers' views regarding the role of feedback, from both a practical and theoretical perspective, might be required.

NOTES

1. The raters (M. G. and A. S.) had extensive experience as both players and coaches. M. G. plays volleyball in the highest German league (*Bundesliga*) and is a member of the extended German national team. A. S. plays volleyball in the third-highest German league (*Regionalliga*). Also, both have at least 6 years of coaching experience.

2. Three participants in the novice-internal-focus group scored zero points, almost without exception, throughout the practice and retention phases. Those outliers were removed from the analysis.

REFERENCES

- Adams, J. A. (1971). A closed-loop theory of motor learning. *Journal of Motor Behavior*, 3, 111–150.
- Baumeister, R. F. (1984). Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology*, 46, 610–620.
- Beutelstahl, D. (1979). *Volleyball für Spieler und Trainer* [Volleyball for players and coaches]. München, Germany: BLV Verlagsgesellschaft.
- Clark-Carter, D. (1997). *Doing quantitative psychological research—From design to report*. East Sussex, England: Psychology Press.
- Christmann, E. (1987). *Volleyball Handbuch* [Volleyball manual]. Wien, Austria: Hg. DVV/Fago.
- Fitts, P. M. (1964). Perceptual-motor skills learning. In A. W. Melton (Ed.), *Categories of human learning* (pp. 243–285). New York: Academic Press.
- Ford, G. (1982). *Basic soccer: Strategies for successful player and program development*. Boston: Allyn & Bacon.

- Gallwey, W. T. (1982). *The inner game of tennis*. New York: Bantam Books.
- Hargreaves, A. (1990). *Skills and strategies for coaching soccer*. Champaign, IL: Leisure Press.
- Hergenhahn, K. H. (1989). *Volleyball Spielen—Üben—Trainieren* [Volleyball Playing—Practicing—Training]. Aachen, Germany: Merk.
- Lai, Q., & Shea, C. H. (1998). Generalized motor program (GMP) learning: Effects of reduced frequency of knowledge of results and practice variability. *Journal of Motor Behavior*, 30, 51–59.
- Lai, Q., & Shea, C. H. (1999). Bandwidth knowledge of results enhances generalized motor program learning. *Research Quarterly for Exercise and Sport*, 70, 79–83.
- McNevin, N. H., Shea, C. H., & Wulf, G. (2000). *Increasing the distance of an external focus of attention enhances learning*. Manuscript submitted for publication.
- Newell, K. M., & Slifkin, A. B. (1996). The nature of movement variability. In J. Piek (Ed.), *Motor control and human skill: A multidisciplinary perspective* (pp. 143–160). Champaign, IL: Human Kinetics.
- Nicholson, D. E., & Schmidt, R. A. (1991). Scheduling information feedback to enhance training effectiveness. *Proceedings of the Human Factors Society 35th annual meeting* (pp. 1400–1403). Santa Monica, CA: Human Factors Society.
- Park, J.-H., Shea, C. H., McNevin, N. H., & Wulf, G. (June 2000). *Attentional focus and the control of dynamic balance*. Paper presented at the annual meeting of the North American Society for the Psychology of Sport and Physical Activity (NASPSPA), Clearwater Beach, FL.
- Robson, C. (1993). *Real world research: A resource for social scientists and practitioner-researchers*. Oxford, England: Blackwell.
- Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical appraisal. *Psychological Bulletin*, 95, 355–386.
- Schmidt, R. A. (1991). Frequent augmented feedback can degrade learning: Evidence and interpretations. In J. Requin & G. E. Stelmach (Eds.), *Tutorials in motor neuroscience* (pp. 59–75). Dordrecht, The Netherlands: Kluwer Academic Publishers.
- Schmidt, R. A., Lange, C., & Young, D. E. (1990). Optimizing summary knowledge of results for skill learning. *Human Movement Science*, 9, 325–348.
- Schmidt, R. A., & Lee, T. D. (1999). *Motor control and learning: A behavioral emphasis* (3rd ed.). Champaign, IL: Human Kinetics.
- Schmidt, R. A., Young, D. E., Swinnen, S., & Shapiro, D. E. (1989). Summary knowledge of results for skill acquisition: Support for the guidance hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 352–359.
- Schneider, W., & Fisk, A. D. (1983). Attention theory and mechanisms for skilled performance. In R. A. Magill (Ed.), *Memory and control of action* (pp. 119–143). Amsterdam: North-Holland.
- Shea, C. H., & Wulf, G. (1999). Enhancing motor learning through external-focus instruction and feedback. *Human Movement Science*, 18, 553–571.
- Sherwood, D. E. (1988). Effects of bandwidth knowledge of results on movement consistency. *Perceptual and Motor Skills*, 66, 535–542.
- Singer, R. N., Lidor, R., & Cauraugh, J. H. (1993). To be aware or not aware? What to think about while learning and performing a motor skill. *The Sport Psychologist*, 7, 19–30.
- Swinnen, S. P. (1996). Information feedback for motor skill learning: A review. In H. N. Zelaznik (Ed.), *Advances in motor learning and control* (pp. 37–66). Champaign, IL: Human Kinetics.
- Vander Linden, D. W., Cauraugh, J. H., & Greene, T. A. (1993). The effect of frequency of kinetic feedback on learning an isometric force-production task in disabled subjects. *Physical Therapy*, 73, 79–87.
- Vereijken, B., van Emmerik, R. E. A., Whiting, H. T. A., & Newell, K. M. (1992). Free(z)ing degrees of freedom in skill acquisition. *Journal of Motor Behavior*, 24, 133–142.
- Weeks, D. L., & Kordus, R. N. (1998). Relative frequency of knowledge of performance and motor skill learning. *Research Quarterly for Exercise and Sport*, 69, 224–230.
- Winstein, C. J., Pohl, P. S., & Lewthwaite, R. (1994). Effects of physical guidance and knowledge of results on motor learning: Support for the guidance hypothesis. *Research Quarterly for Exercise and Sport*, 65, 316–323.
- Winstein, C. J., & Schmidt, R. A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 16, 677–691.
- Wrisberg, C. A., & Wulf, G. (1997). Diminishing the effects of reduced frequency of knowledge of results on generalized motor program learning. *Journal of Motor Behavior*, 29, 17–26.
- 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.
- Wulf, G., Lauterbach, B., & Toole, T. (1999). Learning advantages of an external focus of attention in golf. *Research Quarterly for Exercise and Sport*, 70, 120–126.
- Wulf, G., Lee, T. D., & Schmidt, R. A. (1994). Reducing knowledge of results about relative versus absolute timing: Differential effects on learning. *Journal of Motor Behavior*, 26, 362–369.
- Wulf, G., & McNevin, N. H. (2001). *Simply distracting learners is not enough: More evidence for the learning benefits of an external focus of attention*. Manuscript submitted for publication.
- Wulf, G., McNevin, N. H., Fuchs, T., Ritter, F., & Toole, T. (2000). Attentional focus in complex motor skill learning. *Research Quarterly for Exercise and Sport*, 71, 229–239.
- Wulf, G., McNevin, N. H., & Shea, C. H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *Quarterly Journal of Experimental Psychology*, 54A, 1141–1154.
- Wulf, G., & Prinz, W. (in press). Directing attention to movement effects enhances learning: A review. *Psychonomic Bulletin & Review*.
- Wulf, G., & Schmidt, R. A. (1989). The learning of generalized motor programs: Reducing the relative frequency of knowledge of results enhances memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 15, 748–757.
- Wulf, G., & Schmidt, R. A. (1996). Average KR degrades parameter learning. *Journal of Motor Behavior*, 28, 371–381.
- Wulf, G., Schmidt, R. A., & Deubel, H. (1993). Reduced feedback frequency enhances generalized motor program learning but not parameterization learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 19, 1134–1150.
- Wulf, G., & Shea, C. H. (in press). Principles derived from the study of simple motor skills do not generalize to complex skill learning. *Psychonomic Bulletin & Review*.
- Wulf, G., Shea, C. H., & Park, J.-H. (2001). Attention in motor learning: Preferences for and advantages of an external focus. *Research Quarterly for Exercise and Sport*, 72, 335–344.
- Wulf, G., & Weigelt, M. (1997). Instructions about physical principles in learning a complex motor skill: To tell or not to tell . . . *Research Quarterly for Exercise and Sport*, 68, 362–367.
- Wulf, G., Weigelt, M., Poulter, D. R., & McNevin, N. H. (2001). *Attentional focus on supra-postural tasks affects balance learning*. Manuscript submitted for publication.
- Young, D. E., & Schmidt, R. A. (1992). Augmented kinematic feedback for motor learning. *Journal of Motor Behavior*, 24, 261–273.

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