
**The Quarterly Journal of Experimental Psychology Section A**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713683590

# Attentional focus on suprapostural tasks affects balance learning

Gabriele Wulf [a]; Matthias Weigelt [b]; Damian Poulter [c]; Nancy McNevin [d]
[a] University of Nevada, Las Vegas, USA. [b] Max-Planck Institute for Psychological Research, Munich, Germany. [c] University of Reading, UK. [d] Wayne State University, Detroit, USA.

Online Publication Date: 01 October 2003

**To cite this Article** Wulf, Gabriele, Weigelt, Matthias, Poulter, Damian and McNevin, Nancy(2003)'Attentional focus on suprapostural tasks affects balance learning',The Quarterly Journal of Experimental Psychology Section A,56:7,1191 — 1211

**To link to this Article: DOI:** 10.1080/02724980343000062

**URL:** http://dx.doi.org/10.1080/02724980343000062

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY, 2003, *56A* (7), 1191–1211

# Attentional focus on suprapostural tasks affects balance learning

Gabriele Wulf
*University of Nevada, Las Vegas, USA*

Matthias Weigelt
*Max-Planck Institute for Psychological Research, Munich, Germany*

Damian Poulter
*University of Reading, UK*

Nancy McNevin
*Wayne State University, Detroit, USA*

We examined whether the attentional focus induced by a suprapostural task has an influence on the learning of a dynamic balance task. Participants balanced on a stabilometer and were required to hold a tube horizontal with both hands. In Experiment 1, the tube contained a table tennis ball, whereas it was empty in Experiment 2. Participants were instructed to focus on either their hands (internal focus) or the tube (external focus). We measured balance performance as a function of attentional focus on the suprapostural task. Participants practised for 2 days, and on Day 3 they performed a retention test (with tube) and a transfer test (without tube). In both experiments, the external focus groups demonstrated more effective retention and transfer than the internal focus groups (and than the control group in transfer in Experiment 2). In addition, in Experiment 1 the external group was superior in keeping the tube horizontal. This suggests that the performer's attentional focus regarding the suprapostural task affects performance and learning not only of the suprapostural task itself, but also of the postural task.

An interesting phenomenon can be observed when watching circus acrobats. Some of these performers show amazing balancing stunts, such as standing on several layers of cylinders with different orientations in the horizontal plane, so that minor deviations of the centre of

Requests for reprints should be sent to Dr Gabriele Wulf, Department of Kinesiology, University of Nevada, Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-3034, USA. Email: gabriele.wulf@ccmail.nevada.edu

The study was supported by a grant from the Economic and Social Research Council (UK) to Gabriele Wulf. It was conducted while Gabriele Wulf and Matthias Weigelt were with the Department of Psychology, University of Reading, UK.


http://www.tandf.co.uk/journals/pp/02724987.html DOI:10.1080/02724980343000062

mass in either direction could cause the whole "tower" (with the acrobat on top) to collapse. One is even more impressed when the performer proceeds to juggle on this highly unstable support surface. The addition of this second task makes the whole stunt even more dangerous and thrilling, as one intuitively expects the juggling to take away some of the attentional resources that can be directed towards balancing—which should have a detrimental effect on balance performance. However, as the (informed) observer will notice, the opposite is actually the case! When the acrobat proceeds to juggle, he or she actually becomes *more* stable. That is, the sway is reduced. It appears that the additional task, rather than having a detrimental effect on balance, in fact enhances it.

An experimental demonstration of postural stability being enhanced through the addition of a "suprapostural" task and an explanation for this interesting phenomenon were recently provided by Riley, Stoffregen, Grocki, and Turvey (1999). Riley et al. measured postural sway when participants, standing upright with their eyes closed, touched a curtain very lightly with their fingertips. A curtain, as opposed to a solid stationary object, was used because it did not provide any mechanical support for posture. They found that touching the curtain significantly reduced postural fluctuations, compared to not touching it. However, this was only the case if participants were asked to minimize movements of the curtain resulting from their touch ("touch-relevant" condition). If participants were told that touching the curtain was irrelevant for the experiment ("touch-irrelevant" condition), postural sway did not differ from that under no-touch conditions. Riley et al. interpreted these findings as indicating that it was not simply the sensory information derived from the touch (which was the same under touch-relevant and touch-irrelevant conditions) that reduced postural sway, but that the addition of a suprapostural goal (i.e., keeping the curtain still) resulted in spontaneous reductions in postural fluctuations to facilitate the achievement of the suprapostural goal.

This finding shows intriguing parallels to a series of recent studies demonstrating that directing performers' attention to the *effects* of their movements enhances motor performance and learning (e.g., Shea & Wulf, 1999; Wulf, Höß, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999; Wulf, McNevin, & Shea, 2001a; for a review, see Wulf & Prinz, 2001). Specifically, these studies compared the effectiveness of instructions directing attention to the movements themselves ("internal focus") or to the effects of these movements on an apparatus or implement ("external focus"). Some studies, for example, used a dynamic balance task that required participants to balance on a stabilometer platform and to minimize deviations of the platform from the horizontal (e.g., Wulf et al., 1998, Experiment 2, 2001a; Wulf, Shea, & Park, 2001b). The results consistently demonstrated that participants who focused on keeping markers attached to the platform horizontal produced more effective performance and learning than participants who focused on keeping their feet horizontal. Importantly, external focus advantages have not only been found relative to internal focus conditions, but also compared to control conditions with no attentional focus instructions (Wulf et al., 1998, Experiment 1; Wulf & McNevin, 2002; comparable to the "no-touch" condition in Riley et al., 1999). Thus, an external focus seems to *enhance* motor performance, whereas an internal focus neither enhances nor degrades performance compared to control conditions (Wulf et al., 1998; Wulf & McNevin, 2002).

The findings of Riley et al. (1999) and Wulf et al. (e.g., Shea & Wulf, 1999; Wulf et al., 1998, Experiment 2, 2001a) are similar in showing more effective balance, or reduced postural sway, when the participants' attention is directed away from the act of "standing still" and to an effect of this act on the environment. In the Riley et al. study, this effect was the movements of the curtain that were supposed to be minimized, while in the Wulf et al. studies the effect referred to the movements of the stabilometer platform (or the markers attached to it), which was supposed to be kept in a horizontal position. To explain the phenomenon of enhanced balance when focusing on an external effect, Riley et al. (1999; see also Stoffregen, Pagulayan, Bardy, & Hettinger, 2000) referred to the notion of suprapostural activity. According to this view, postural control is influenced by the suprapostural goal that the individual is trying to achieve. That is, the constraints imposed by the suprapostural task influence postural adjustments (e.g., reduce postural sway), so that goal achievement is facilitated.

Wulf and colleagues (e.g., McNevin, Shea, & Wulf, 2003; Wulf et al., 2001a; Wulf & Prinz, 2001) put forward a somewhat similar explanation for the benefits of an external focus of attention. They suggested that the advantage of focusing attention on the movement effect might be that it allows unconscious or automatic processes to control the movements required to achieve this effect. In contrast, when participants are asked to focus on their body movements—and perhaps also when they are not given any attentional focus instructions—they might be more likely to consciously intervene in these control processes and may inadvertently disrupt relatively automatic control processes. Support for the notion that the adoption of an external focus promotes the utilization of more automatic control processes than does an internal focus comes from a study (Wulf et al., 2001a) showing reduced attentional demands—that is, faster probe reaction times (RTs)—for participants balancing on the stabilometer with an external focus than for those with an internal focus. Furthermore, the frequency characteristics (Fast Fourier Transformation; FFT) of the platform movements demonstrated higher frequency adjustments for external than for internal focus participants. Higher frequency components seem to represent the incorporation and coordination of additional available degrees of freedom (see Thompson & Stewart, 1986)—a characteristic often associated with skilled performance. That is, higher frequency components in rhythmic activities represent the potential of the system to respond and are seen as a characteristic of a biological system with more active degrees of freedom (Newell & Slifkin, 1996).

The lines of research on suprapostural task effects (e.g., Riley et al., 1999; Stoffregen et al., 2000) and attentional focus effects on balance (e.g., Wulf et al., 1998, 2001a) differ in one important respect. In the former case, the performers' attention is directed to the suprapostural task—for example, touching a curtain without moving it (Riley et al., 1999) or searching for letters in a block of text (Stoffregen et al., 2000)—but the main variable of interest is postural control—that is, how postural adjustments are affected by the suprapostural task. In our attentional focus research, on the other hand, attention has typically been directed to an aspect of the postural or balance task itself (e.g., markers on balance platform or feet), and it is this performance that is also measured. While both lines of research have yielded intriguing findings that appear to have certain parallels, important questions for the concept of suprapostural tasks arise from findings related to attentional focus, and vice versa.

One question for suprapostural task research is whether the type of attentional focus induced by the suprapostural task is relevant. That is, do suprapostural task effects depend on whether the suprapostural task induces an external or internal attentional focus—that is, whether the performer directs attention to his or her movements or to the effects of these movements? Even though it is not entirely clear from the Riley et al. (1999) study whether participants' attention was more directed to keeping their finger still (internal focus) in order to minimize movements of the curtain, or more to keeping the curtain still (external focus), it seems likely that participants directed more attention to the curtain if instructed to "minimize movements of the curtain that might result from their touch" (Riley et al., 1999, p. 805). If indeed participants' attention was primarily directed to the movements of the curtain—that is, the *effects* of their (finger) movements—it is possible that the benefits of the touch-relevant condition, relative to the no-touch condition, on postural sway were due to the external focus that these instructions induced. The question is whether instructions inducing an internal focus—for example, specifically directed to the finger movements—would have the same (i.e., facilitatory), a different (i.e., detrimental), or no effect on postural control.

An interesting question for attentional focus research that is arising from the study of suprapostural task effects is whether the manipulation of the attentional focus directed at a suprapostural task would also affect performance of the postural task. In the attentional focus research by Wulf and colleagues (e.g., Shea & Wulf, 1999; Wulf et al., 1998, 1999), performers were typically instructed to focus on their movements (internal focus) or on the effects of their movements (external focus), but in either case attention is directed to the primary (e.g., postural control) task. It has not yet been examined whether instructions that induce an external versus internal focus with regard to a suprapostural task have an effect on the performance and learning of the postural task. One possibility is that because an external focus requires fewer attentional resources than an internal focus does (Wulf et al., 2001a), a less attention-demanding suprapostural task might leave more attentional resources available for the control of balance. One might therefore expect that an external focus on the suprapostural task enhances not only performance on this task, but also performance on the postural task.

Therefore, the purpose of the present study was to examine possible influences that the type of attentional focus promoted by the suprapostural task might have on the postural task. We used the dynamic balance task (stabilometer), which has been shown to be sensitive to attentional focus manipulations and, unlike the static balance task used in the Riley et al. (1999) study, is novel enough to identify learning effects over time (Wulf et al., 1998, Experiment 1; Wulf & McNevin, 2001; Wulf et al., 2001b). However, instead of manipulating the attentional focus related to the balance task itself, as we have done in these previous studies, we added a suprapostural task and gave internal or external focus instructions related to this task. Specifically, participants balancing on the stabilometer were required to hold a tube with both hands and to try to keep it horizontal. (In Experiment 1, there was a ball inside the tube that had to be kept in the centre of the tube.) While the internal focus group participants were instructed to focus on keeping their hands horizontal, the external focus group participants were instructed to focus on the tube. For both groups, however, the object was to keep the ball centred in the tube.

The task and design used in the present study also allowed us to address another issue that was not examined by Riley et al. (1999)—namely, how the *learning* of a novel balance (postural) task is affected by the suprapostural task. Whereas Riley et al. (1999) only examined the immediate, and presumably temporary, effects of a suprapostural task on a relatively simple postural task (i.e., standing still), in the present study participants had to learn a novel balance skill. In addition, in order to examine the relatively permanent, or learning, effects (e.g., Schmidt & Lee, 1999) of the suprapostural task on the postural (balance) task, we included a transfer test in which the suprapostural task was removed. This allowed us to assess the remaining effects, if any, of the attentional focus manipulation on balance learning. In both experiments, participants practised the balance task concurrently with the suprapostural task on two consecutive days. On Day 3, they performed a retention test with the suprapostural task (but without instructions or reminders) and a transfer test without the suprapostural task.

It should be pointed out that, in the present study, we view enhanced balance performance as indicated by reduced deviations of the balance platform from the horizontal. That is, less motion (around the horizontal plane) is equated with improved stability and thus better performance. This point is important, as Riley et al. (1999) and Stoffregen et al. (Stoffregen, Smart, Bardy, & Pagulayan, 1999; Stoffregen et al., 2000) have rightly emphasized that postural stability needs to be seen in the context of the suprapostural goal. In fact, in certain situations increased postural sway might be more adaptive than less sway in that it facilitates the achievement of the suprapostural goal (e.g., when tracking a visual target). In the present study, however, the suprapostural goal of holding the tube/hands horizontal should be facilitated by keeping the balance platform as stable as possible in a horizontal position. Therefore, reduced sway or smaller average deviations from the horizontal are equated with improved balance performance.

## EXPERIMENT 1

The purpose of this experiment was to determine whether the focus of attention adopted for a suprapostural task (e.g., Riley et al., 1999) can affect the performance and learning of the postural task. Based on previous findings showing advantages of an external relative to an internal focus (e.g., Wulf et al., 1998), we wanted to examine whether the adoption of an external focus on the suprapostural task would be more advantageous not only for performance of the suprapostural task, but also for performance of the balance task. Participants balancing on the stabilometer were required to hold a wooden tube in the horizontal plane with both hands. Inside the tube was a table tennis ball, and participants were instructed to keep the ball in the centre of the tube so that the ball did not contact the left or right side of the tube (suprapostural task). For different groups of participants, attention was directed either to the hands (internal focus) or to the tube (external focus). While Riley et al. (1999) did not measure performance on the suprapostural task (i.e., movements of the curtain), Riccio and Stoffregen (1991) suggested that both postural control and suprapostural task performance be measured. The reason for this is that performers may adopt different strategies regarding performance on either task. For example, in the case of poor performance on the suprapostural task, a performer might opt to focus on reducing postural instability in an attempt to enhance suprapostural task performance. Or, performers might invest more effort in performance on the suprapostural task at the expense of postural stability. To control for possible compensatory strategies, we measured performances on both postural and suprapostural tasks. The number of times the ball made contact with either side of the tube served as a measure of performance on the suprapostural task. Balance performance was measured by the average deviations of the platform from the horizontal during a 90-s trial.

# Method

## Participants

A total of 18 university students participated in this experiment. None of them had prior experience with the task, and all of them were naive as to the purpose of the experiment. All participants gave their informed consent. They received extra course credit for their participation.

## Apparatus and task

The postural task required participants to balance on a stabilometer platform and to try to keep it in a horizontal position for as long as possible during each 90-s trial. The stabilometer consists of a 65 × 105-cm wooden platform, with the maximum possible deviation of the platform to either side being 30 degrees. Two markers (2 × 2 cm) were placed on the platform, 9 cm from the front edge and 23 cm from the midline of the platform. Participants were instructed to place their feet behind these markers. The movements of the platform were monitored by a potentiometer (Novotechnik P4501, 5 kΩ resistance, and 0.1% linearity) that was linked to the platform. To analyse stabilometer performance, an analog signal from the potentiometer was recorded (40 Hz, 12-bit resolution) for the whole duration of each trial.

The suprapostural task required participants to hold a wooden 41.5 (length) × 5.7 (width) × 6.2 (height) cm tube with both hands at abdomen-height, with the elbows flexed at 90 degrees. The inside of the tube was 40 cm long and 4.2 cm wide—that is, slightly wider than the diameter of the table tennis ball (4.1 cm). When contacting the right or left side of the tube, a distinctive sound was heard allowing the experimenter to count the number of contacts during each 90-s trial.

## 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. In addition, all participants were asked to put their feet on the platform such that each foot was placed behind one of the markers in the middle of the platform, with the tips of the feet touching the markers. 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 experimenter gave the start signal. At the start signal, the participant attempted to move the platform, and data collection began as soon as the platform crossed the horizontal.

All participants were also asked to hold the wooden tube with the table tennis ball horizontally in front of their abdomens while balancing. Thus, participants were always able to see the tube. At the beginning of each trial, the ball was placed in the centre of the tube. Participants were instructed to try to keep the ball in the centre of the tube. However, the instructions regarding this suprapostural task differed slightly for participants in the external versus internal focus group. The internal focus participants were instructed to focus their attention on their hands and to try to keep them horizontal, whereas participants in the external focus group were instructed to focus on the tube. Before each trial, participants were briefly reminded to focus on their hands or the tube, respectively.

There were 2 days of practice, each consisting of seven 90-s trials. On Day 3, there were also seven trials. The first four trials were a retention test, during which participants were required to hold the tube (as during practice). However, no reminders with respect to attentional focus were given. The last three trials were transfer trials, where participants performed the balance task without the tube.

### Dependent variables and data analysis

The potentiometer data were transformed into degrees out of balance. Consistent with previous studies utilizing the stabilometer (e.g., Shea & Wulf, 1999; Wulf et al., 1998, 2001a), participants' proficiency in performing the balance task was measured by root-mean-square error (RMSE) calculated across approximately 3600 data points in each 90-s trial, with the 0-degree position (platform in horizontal) as the criterion. RMSE was then converted into degrees. Performance on the suprapostural task was measured by the number of errors—that is, the number of times the ball made contact with either end of the tube. RMSE (postural task performance) and number of errors (suprapostural task performance) during practice were each analysed in 2 (attentional focus) × 2 (days) × 7 (trials) analysis of variance (ANOVA) with repeated measures on days and trials. The retention data were analysed in 2 (attentional focus) x 4 (trials), and the transfer data were analysed in 2 (attentional focus) x 3 (trials) for RMSE (and number of errors in retention).

## Results

### Practice

*RMSE.* Both groups demonstrated a consistent improvement across the 2 days of practice, with the external group having lower RMSEs than the internal group throughout the whole practice session (see left and centre panel in Figure 1, solid lines). An Attentional Focus × Day × Trial ANOVA revealed significant main effects of attentional focus, $F(1, 16) = 28.31$, $p < .001$, $\omega^2 = .75$, day, $F(1, 16) = 57.16$, $p < .001$, $\omega^2 = .86$, trial, $F(6, 96) = 37.52$, $p < .001$, $\omega^2 = .80$. The Day × Trial interaction, $F(6, 96) = 3.42$, $p < .01$, $\omega^2 = .21$, was also significant, indicating relatively greater improvements on Day 1 than on Day 2. No other interaction effects were significant.

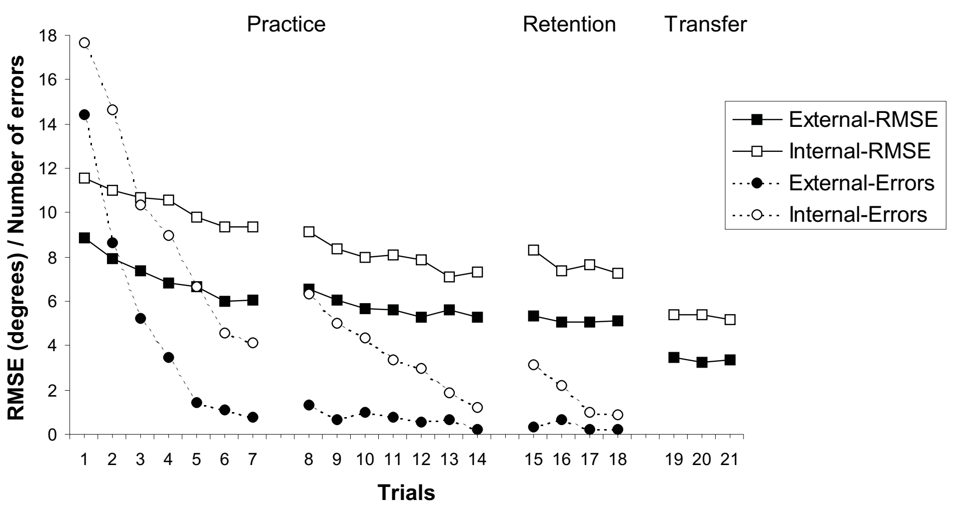


**Figure 1.** Root-mean-square errors (RMSE) on the balance task and errors on the suprapostural task for the external and internal focus groups in practice, retention, and transfer of Experiment 1.

*Errors*. As can be seen from Figure 1 (left and centre panel, dashed lines), both groups showed a clear improvement in the performance of the suprapostural task across practice. The external focus group, however, had fewer ball contacts than the internal focus group. The two groups demonstrated comparable reductions in errors on Day 1. On Day 2, the external focus group remained at the low error-rate level of less than 1 error per 90-s trial that they had reached by the end of Day 1 (average on Day 2: 0.74), whereas the internal focus group showed an increase in errors from the end of Day 1 to the beginning of Day 2 and gradually reduced their errors across the second day (average on Day 2: 4.05). The main effects of attentional focus, $F(1, 16) = 18.56$, $p < .001$, $\omega^2 = .66$, day, $F(1, 16) = 58.82$, $p < .001$, $\omega^2 = .87$, and trial, $F(6, 96) = 78.64$, $p < .001$, $\omega^2 = .90$, were significant. Also, the Day × Trial interaction, $F(6, 96) = 31.22$, $p < .001$, $\omega^2 = .77$, and the Trial × Attentional Focus interaction, $F(6, 96) = 2.63$, $p < .05$, $\omega^2 = .15$, were significant. None of the other interactions reached significance.

Thus, the instructions inducing an external focus of attention on the suprapostural task not only enhanced performance on this task, but also led to more effective performance on the postural (balance) task during practice.

### *Retention*

*RMSE*. Even when no attentional focus instructions or reminders were given on Day 3, the external focus participants continued to demonstrate superior balance performance compared to the internal focus participants (see right panel in Figure 1, solid lines). Also, there was a general, though modest, improvement across the four retention trials. The main effects of attentional focus, $F(1, 16) = 22.68$, $p < .001$, $\omega^2 = .71$, and trial, $F(3, 48) = 5.89$, $p < .01$, $\omega^2 = .35$, were significant. The interaction of attentional focus and trial, $F(3, 48) = 1.99$, $p > .05$, was not significant.

*Errors*. While the external focus group continued to demonstrate a very low error rate in retention (average: 0.36), the internal focus group had clearly more errors at the beginning of Day 3, but reduced their errors across the four retention trials (average: 1.81) (see Figure 1, right panel, dashed lines). The main effects of attentional focus, $F(1, 16) = 13.99$, $p < .01$, $\omega^2 = .59$, and trial, $F(3, 48) = 5.04$, $p < .01$, $\omega^2 = .31$, as well as the interaction of attentional focus and trial, $F(3, 48) = 3.44$, $p < .05$, $\omega^2 = .21$, were significant.

### *Transfer*

*RMSE*. When participants balanced without the tube on the final three trials of Day 3, performance generally improved compared to the retention test with the tube (see Figure 1, far right panel). A 2 (attentional focus) × 2 (test: retention vs. transfer) ANOVA using the average RMSEs on the retention and transfer tests revealed a highly significant effect of test, $F(1, 16) = 145.96$, $p < .001$, $\omega^2 = .94$. Importantly, the main effect of attentional focus in transfer was significant, $F(1, 16) = 15.23$, $p = .001$, $\omega^2 = .61$. Thus, even though the tube was taken away in transfer, the beneficial effects of practising the suprapostural task with an external focus seen in practice and retention were maintained in transfer. The trial main effect and the Attentional Focus × Trial interaction, $F\text{s}(2, 32) < 1$, were not significant.

## Discussion

The results of this experiment are interesting for various regards. First, in line with previous results (e.g., Shea & Wulf, 1999; Wulf et al., 1998, 1999, 2001a), performances on the suprapostural task demonstrated that instructions inducing an external focus of attention were more effective than instructions inducing an internal focus: Focusing on the ball in the tube resulted in superior performance compared to focusing on the movements of the hands. The external focus group had clearly smaller errors (ball contacts) throughout practice and retention, with errors of the internal focus group being, on average, 130% larger during practice and 400% larger during retention than those of the external focus group. Interestingly, the external focus advantages were already seen early in practice. This is also in line with previous studies (e.g., Wulf et al., 1999; Wulf, McConnel, Gärtner, & Schwarz, 2002) and can be seen as an indication of the immediate and powerful effects of the attentional focus manipulation.

Second, and more importantly, the present results confirm our hypothesis that the attentional focus adopted on a suprapostural task influences not only performance on the suprapostural task itself, but also performance on the postural task. The adoption of an external relative to an internal focus on the suprapostural task was not only beneficial for performance on this task, but also enhanced balance performance. Again, the differential effects of the type of attentional focus on balance were seen early on in practice and remained present throughout the two days of practice, as well as during retention and transfer. It is particularly interesting that the beneficial effects of an external focus were also seen in transfer—that is, when participants performed the balance task without the suprapostural task. Thus, even though both groups performed the balance task under exactly the same conditions in transfer (i.e., without the suprapostural task and the associated attentional foci), the attentional focus adopted during practice still had an effect on balance performance. That is, the suprapostural task effect was not only immediate while performed in concert with the suprapostural task; rather, it had a relatively permanent effect on the learning of the balance task. A possible explanation for how the attentional focus on the suprapostural task could affect performance on the postural task will be provided in the General Discussion.

In summary, the present findings extend those of previous studies (e.g., Riley et al., 1999) in two regards. First, they show that the type of attentional focus induced by the suprapostural task has a powerful effect on the performance and learning of the postural task. Therefore, when examining the effects of suprapostural tasks on postural performance, the attentional focus induced by the task/instructions should be taken into consideration, as it apparently plays a significant role. Second, our results demonstrate that the effects of a suprapostural task on the postural task are not necessarily restricted to temporary influences on performance, such as those examined by Riley et al. (1999) and Stoffregen et al. (2000), but that they can also affect the *learning* of a novel postural task. In the light of these results, another interpretation of the Riley et al. (1999) findings appears plausible. Their touch-relevant condition might have resulted in greater postural stability than the baseline ("no-touch") condition because it induced an external focus of attention (focus on keeping the curtain still). Of course, it is not known what, if anything, participants focused on under no-touch or touch-irrelevant conditions in the Riley et al. study—that is, whether they adopted an internal focus or no particular focus of attention. However, some of our previous studies have shown that an external focus is superior not only to an internal focus, but also to that of control conditions with no attentional focus instructions, while internal focus and control groups showed similar performances (Wulf et al., 1998, Experiment 2; Wulf & McNevin, 2002). These results would be in line with the interpretation that the touch-relevant condition in the Riley et al. study induced an external focus and was therefore more effective than the baseline (control) condition, whereas the touch-irrelevant condition did not differ from the baseline condition.

However, as mentioned above, in all of our previous studies (e.g., Shea & Wulf, 1999; Wulf et al., 1998, 1999, 2001) the attentional focus instructions referred to the primary (e.g., balance) task to be learned, whereas in the present context we are concerned with the influence of the attentional focus adopted on a suprapostural task and its effect on postural control. Thus, the addition of a control group without attentional focus instructions regarding the suprapostural task would seem to be necessary to substantiate our claim that an external focus is *beneficial*, as opposed to an internal focus being detrimental relative to a control or baseline condition. Therefore, we included a control group in the second experiment.

Another motive for Experiment 2 was our concern that the relatively poor performance on the suprapostural task under internal focus conditions—rather than the internal focus per se—might have been responsible for the detrimental effects seen on the balance task. Even though participants were not given any indication of what "good performance" on the suprapostural task was like, the relatively frequent ball contacts with ends of the tube under internal focus conditions might have caused participants to direct relatively more attention to their performance on this task—to the detriment of balance performance. While this would be a direct consequence of the type of attentional focus adopted on the suprapostural task, and would therefore not necessarily weaken our interpretation of the results, we wanted to examine the "pure" effects of attentional focus. Therefore, we eliminated this source of feedback about suprapostural task performance in Experiment 2.

## EXPERIMENT 2

Experiment 1 demonstrated that the focus of attention that the performer adopts on a suprapostural task has an influence on the performance and learning not only of the suprapostural task, but also of the postural task: An external focus was clearly more effective than an internal focus for both tasks. Experiment 2 followed up on these results in two ways. First, we asked whether an external focus *enhanced* performance and learning, or whether an internal focus *degraded* performance and learning, relative to a control condition without attentional focus instructions. Therefore, a control condition was added in the present experiment to examine the relative effectiveness of internal and external foci on the suprapostural task for the performance and learning of the postural task.

Second, in contrast to Experiment 1, the ball was removed from the tube in the present experiment, and the attentional focus instructions referred to keeping either the hands (internal focus) or the tube (external focus) horizontal. Thus, there was no "knowledge to results" in terms of the number of ball contacts that informed participants about their success on the tube task. If the attentional focus per se was responsible for the differential effects on balance performance in Experiment 1, similar differences between the internal and external focus groups should be seen when the ball was removed. Thus, if the adoption of an external focus is beneficial for the performance and learning of the postural (balance) task, the external group should show more effective balance than both the internal and control groups. Group differences in retention and transfer would provide the most convincing evidence for any relatively permanent effects of attentional focus, as no instructions or reminders were given during these tests. In particular, if group differences were observed in transfer, where the tube was removed, additional strong evidence for learning effects of attentional focus instructions on balance would be provided.

A third and final change, compared to Experiment 1, was the fact that no attentional focus instructions were provided on the very first practice trial in the present experiment. In Experiment 1, group differences were already observed on the first trial. While effects of attentional focus have been demonstrated to occur very early in practice in previous studies (e.g., Wulf et al., 1999, 2002), theoretically, the early group differences in Experiment 1 could have been due to sampling error. Therefore, in the present experiment all groups performed the very first trial under identical conditions, and thus no group differences would be expected on Trial 1. Otherwise, the design was identical to that of Experiment 1, with practice being provided on Days 1 and 2, and retention and transfer testing taking place on Day 3.

## Method

### *Participants*

A total of 29 university students participated in this experiment, none of whom had prior experience with the task or was familiar with the purpose of the experiment. All participants gave their informed consent and either received extra course credit or were paid £9 for their participation.

### *Apparatus and task*

The apparatus and task used in the present experiment were the same as those used in Experiment 1. The only difference was that the tube used for the suprapostural task did not contain the table tennis ball.

### *Procedure*

The procedures were also similar to those of Experiment 1. However, a control group was added to the internal and external focus conditions. Control group participants ($N = 9$) were asked to hold the tube with both hands in front of their abdomen, but were not given any attentional focus instructions.[1] The external ($N = 10$) and internal focus ($N = 10$) participants were instructed to focus their attention on the tube or on their hands, respectively, and to keep them horizontal. On the first practice trial, however, all participants were only asked to hold the tube with both hands. The attentional focus instructions were given to the external and internal focus groups before the second trial, and brief reminders were given before each of the following practice trials.

As in Experiment 1, the practice phase consisted of 2 days of seven 90-s trials each. On Day 3, there were again four retention trials with the tube (but without reminders regarding attentional focus) and

[1]Control group participants were also required to hold the tube, because otherwise they would have been able to use their arms for balance control, which presumably would have facilitated the maintenance of balance on the stabilometer platform. (Indeed, control group participants in a study by Wulf & McNevin, 2002, who could freely move their arms, showed RMSEs that were considerably lower than those of control participants in the present study.)

three transfer trials without the tube. The dependent variables and analyses were the same as those in Experiment 1.

## Results

### *Practice*

*RMSE.* As expected, all groups demonstrated very similar performances on the first practice trial—that is, before attentional focus instructions were provided to the external and internal focus groups (see Figure 2, left). Performances started to diverge when attentional focus instructions were given, however, with the external focus group showing clearly greater improvements across the two days of practice than the internal focus group did. The control group demonstrated intermediate performance. While the main effect of attentional focus failed to reach significance, $F(2, 26) = 2.18$, $p = .13$, the main effects of day, $F(1, 26) = 276.80$, $p < .001$, $\omega^2 = .97$, and trial, $F(6, 156) = 130.29$, $p < .001$, $\omega^2 = .93$, as well as the interactions of day and trial, $F(6, 156) = 32.24$, $p < .001$, $\omega^2 = .76$, trial and attentional focus, $F(12, 156) = 1.89$, $p < .05$, $\omega^2 = .08$, and day, trial, and attentional focus, $F(12, 156) = 2.37$ $p < .01$, $\omega^2 = .12$, were significant. The other interactions were not significant.

### *Retention*

*RMSE.* On the retention test without attentional focus instructions, the external focus group had again the smallest RMSEs (mean: 4.2), while the internal focus group had the largest errors (mean: 5.9), and the control group showed intermediate errors (mean: 5.1; see

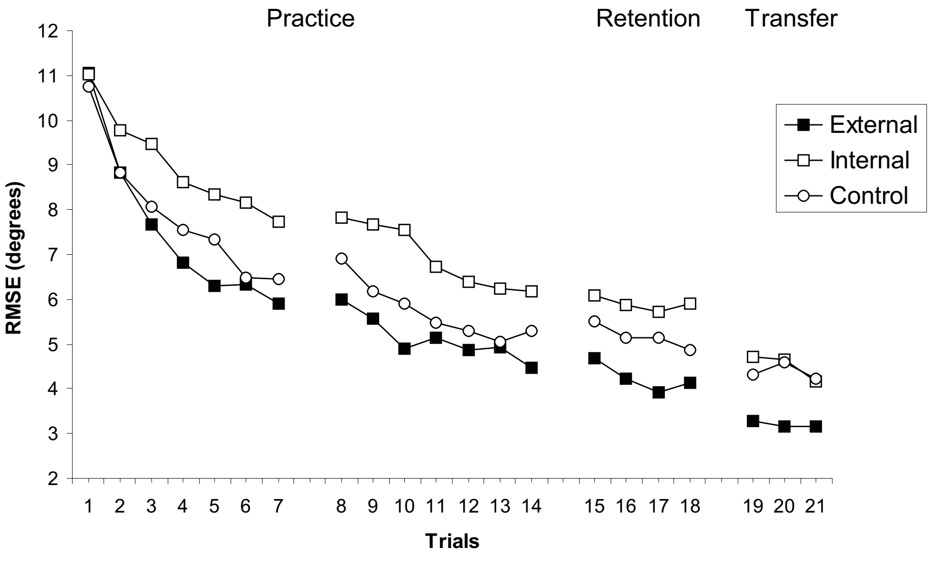


**Figure 2.** Root-mean-square errors (RMSE) on the balance task for the external focus, internal focus, and control groups in practice, retention, and transfer of Experiment 2.

Figure 2). The attentional focus main effect was significant, $F(2, 26) = 3.45$, $p < .05$, $\omega^2 = .20$. Post hoc tests (LSD) indicated that the external focus group was significantly more effective than the internal focus group ($p < .05$), while the control group did not differ from either group. There was a further general reduction in RMSEs across retention trials, as indicated by a significant main effect of trial, $F(3, 78) = 5.89$, $p < .001$, $\omega^2 = .33$. The Attentional Focus × Trial interaction, $F(6, 78) < 1$, was not significant.

### *Transfer*

*RMSE.* The removal of the tube in transfer appeared to result in generally enhanced balance performance compared to retention (see Figure 2, far right). A 2 (attentional focus) × 2 (test: retention vs. transfer) ANOVA on the average RMSEs in retention and transfer yielded a significant effect of test, $F(1, 26) = 79.09$, $p < .001$, $\omega^2 = .89$. In contrast to retention, the internal focus (mean: 4.5) and control groups (mean: 4.4) demonstrated very similar RMSEs, whereas the external focus group (mean: 3.2) was clearly more effective than either group. This was confirmed by a significant main effect of attentional focus, $F(2, 26) = 3.45$, $p < .05$, $\omega^2 = .20$. Post hoc tests (LSD) revealed that the external focus group was significantly superior to both the internal focus and the control groups ($p$s < .05). Even though all groups tended to show a further improvement across trials, the main effect of trial failed to reach significance, $F(1, 26) = 3.07$, $p = .07$. The interaction of attentional focus and trial was not significant, $F(2, 26) < 1$. Thus, importantly, the adoption of an external focus on the suprapostural task during practice was beneficial for balance learning, relative to no focus instructions or internal focus instructions, as demonstrated by transfer performance without the suprapostural task.

## Discussion

The results of this experiment confirmed and extended those of Experiment 1. First, they confirmed the differential effects of external versus internal foci adopted on the suprapostural task on the performance and learning of the postural (balance) task. While performances were similar on the first practice trial with no attentional focus instructions, group differences emerged when focus instructions were provided after Trial 1. Importantly, as in the first experiment, the external focus advantages remained present when no instructions/reminders were given on Day 3 (retention), and even when the balance task was performed without the suprapostural task (transfer). Thus, again, the focus adopted on the suprapostural task affected the learning of the dynamic balance task.

Second, the differences between the external and internal focus groups occurred, even though no form of knowledge of results about suprapostural task performance (number of ball contacts with the ends of the tube) was available, which in turn might have differentially affected the amount of attentional resources dedicated to the suprapostural task. Assuming that movements of the tube were so small that they did not provide any meaningful (visible) feedback, we conclude from this that the differences between the external and internal focus groups must be due to the influence of the attentional focus per se.

Third, and extending the results of Experiment 1, the relative performances of the external and internal focus groups compared to the control group indicate that an external focus on the suprapostural task was, in fact, *beneficial* for balance learning. Even though the external focus group did not differ significantly from the control group in retention, the external focus group was clearly superior to both the control and the internal focus groups in transfer. The lack of difference between the external and control groups in retention might be due to the fact that the external (and internal) group participants still remembered the attentional focus instructions given during practice and therefore maintained their focus on the suprapostural task. The control group participants, on the other hand, who were not given any focus instruction regarding this task, could basically dedicate all of their attentional resources to the balance task. This might not only have led to the control group's relatively good performance during the practice phase, but presumably also affected their performance during retention. However, when the suprapostural task was withdrawn in transfer—resulting in *identical* conditions for all groups—the learning advantages of the external focus condition, compared to both the internal and control conditions, were clearly visible.

Overall, the results of this experiment again demonstrate that postural stability is a function of the focus of attention adopted on the suprapostural task. Theoretical and practical implications of these findings are discussed in the General Discussion.

## GENERAL DISCUSSION

The present study was motivated by findings from two independent lines of research—that is, those showing suprapostural task effects on postural stability (e.g., Riley et al., 1999; Stoffregen et al., 2000) and those demonstrating attentional focus effects on motor performance and learning (e.g., Wulf et al., 1998, 1999, 2001a). We combined both areas of research by manipulating the performer's attentional focus on suprapostural tasks and measuring the effects on balance performance. Both experiments were clear in showing that an external focus of attention—that is, a focus on the effects of one's movements (tube)—resulted in more effective balance performance than an internal focus—that is, a focus on the movements themselves (hands). In addition, the relative performances of the external and internal focus groups in comparison to the control condition in Experiment 2 demonstrated that the adoption of an external focus constitutes a performance benefit, as opposed to an internal focus resulting in a performance detriment.

These present results extend previous findings regarding suprapostural task effects as well as those regarding attentional focus effects. Specifically, they extend suprapostural task research in two ways: First, they demonstrate that the attentional focus on a suprapostural task that is induced by the instructions given to participants has a significant influence on postural control (see also McNevin & Wulf, 2002). Second, they show that this influence is not only temporary, but can also be more permanent—that is, affect the learning of the postural control task (provided the task is novel enough to warrant learning). The present results also extend previous attentional focus research by demonstrating that motor skill learning not only can be influenced directly by manipulating the learner's attentional focus with regard to a certain (postural) task, but also can be influenced *indirectly* by manipulating the attentional focus with regard to a suprapostural task.

Before we discuss in more detail how different attentional foci might act to influence motor performance and learning, we would like to consider the possibility that the instruction effects found in the present study were not (only) due to the different foci of attention induced by the instructions, but were the result of other, nonmental differences in the task constraints.[2] In Experiment 1, for example, the goal of the suprapostural task was to keep the ball centred in the tube. In addition, participants' attention was directed to keeping either their hands (internal) or the tube (external) horizontal. One might argue that this manipulation could have resulted in two different suprapostural tasks, and that this task was more difficult for the internal relative to the external focus group. Whereas external focus participants had to direct their attention only to the ball relative to the tube, internal focus participants additionally had to direct their attention to their hands. In addition to the greater attentional requirements imposed by the directing attention to the hands (and the hands relative to the tube and ball), the task might also have resulted in different visual strategies. In this case, it would be difficult to argue that the difference between the two suprapostural tasks was purely mental in nature. In Experiment 2, where the ball was removed from the tube, the differences between the two suprapostural task conditions were reduced, and this would be expected to result in smaller performance differences between internal and external groups. In fact, a comparison across experiments reveals that stabilometer performance of the internal focus group in Experiment 1 was degraded more, relative to the external focus condition, than it was in Experiment 2.[3] This was confirmed by 2 (Experiment) × 2 (Attentional Focus: internal vs. external) ANOVAs for the practice, retention, and transfer phases. In each case, there was a significant interaction between experiment and attentional focus: practice, $F(1, 34) = 32.1$; retention, $F(1, 34) = 34.7$; transfer, $F(1, 34) = 23.9$, $p\text{s} < .001$. While the two external focus groups performed relatively similarly in the two experiments, the internal focus condition was relatively less effective in Experiment 1 than it was in Experiment 2. Thus, the suprapostural task was apparently more difficult for the internal focus group when the task required them to keep the ball centred *and* to focus on their hands (Experiment 1) relative to just focusing on their hands (Experiment 2). This might be seen as support for the view that, at least in Experiment 1, factors other than just the attentional focus could have been responsible for the observed group differences. However, a case for nonmental task constraints would be harder to make for Experiment 2, where attention was directed either to the tube (external) or to the hands (internal). Our interpretation is, therefore, that external versus internal focus differences are (primarily) due to the utilization of different motor control processes promoted by them. In the following sections, we first review influences of different attentional foci on motor control and then discuss in more detail possible reasons for the benefits that an external focus adopted on a suprapostural task has for the postural task.

## Attentional focus effects on motor control

The learning benefits of an external relative to an internal focus of attention have been explained by a greater automaticity of movement control afforded by attention directed to the movement effects (Wulf et al., 2001a; Wulf & Prinz, 2001). Conversely, when performers

---

[2]We would like to thank an anonymous reviewer for raising this point.

[3]Comparisons across experiments are always somewhat problematic, because there are potentially a host of factors that could differentially affect the results (e.g., the time of testing). Therefore, the results of this analysis should be viewed with caution. Nevertheless, we report these results as they might reveal insights into the effects of the different suprapostural task manipulations.

direct attention to the actual movements (internal focus), they tend to consciously intervene in the motor control processes underlying these movements. This is assumed to interfere with a smooth and efficient movement execution and to be responsible for the observed performance and learning decrements (e.g., "constrained action hypothesis"; Wulf et al., 2001a).

Support for the view that an external focus promotes the utilization of more automatic control processes than an internal focus does comes primarily from two lines of evidence: FFT analyses of balance movements (McNevin et al., 2003; Wulf et al., 2001a, 2001b) and probe RTs (Wulf et al., 2001a) while balancing under external versus internal focus conditions. For example, Wulf et al. (2001a) performed FFT analyses on the movements of the balance platform when learners were instructed to focus on markers attached to the platform in front of their feet (external focus) or their feet (internal focus), respectively. Higher frequency and lower amplitude movements under external relative to internal focus conditions were interpreted as an indication of a higher degree of automatic control. Even though no kinematic data were available for the suprapostural task (tube/hand movements) in the present study, the number of errors on the suprapostural task (Experiment 1) demonstrated that the external attentional focus led to considerably fewer errors than the internal focus did. It is conceivable that the more effective performance in the former condition was a result of higher frequency and lower amplitude adjustments of the tube, and that these fast corrective movements resulted in smaller excursions of the ball and therefore fewer ball contacts with the ends of the tube.

## Why is an external attentional focus on a suprapostural task beneficial for postural control?

The more important question in the present context, however, is how the superior balance performance of participants who adopted an external focus, as opposed to an internal or no particular focus (control), on the suprapostural task in the present study can be explained. One possible explanation could be related to reduced attentional demands under external focus conditions. A greater degree of automaticity in movement control, such as that postulated for an external focus, is generally associated with reduced attention demands (e.g., Schmidt & Lee, 1999). That is, with fewer of the limited attentional resources being required for the control of the primary task, more attentional resources are available for other tasks performed simultaneously. The automaticity of a skill is therefore often measured by probe RTs, the rationale being that the less attention is required for the primary task, the faster the probe RTs (e.g., Abernethy, 1988). Wulf et al. (2001a) indeed found shorter probe RTs for external focus relative to internal focus participants, providing additional evidence for the view that an external focus promotes more automatic control processes. Assuming that the performance of the suprapostural task was less attention demanding under external relative to internal focus conditions, more attentional resources would have been available for the balance task under the former conditions. Indeed, balance has been shown to require attentional capacity, with increasing attentional demands as the balance task becomes more difficult (e.g., from sitting to standing or walking, from single-support phase to double-support phase in walking; Lajoie, Teasdale, Bard, & Fleury, 1993). Also, recovering upright stance after perturbations has been demonstrated to be attention demanding, particularly for older adults (Brown, Shumway-Cook, & Woollacott, 1999). The stabilometer task, which basically requires constant postural recovery, can therefore be assumed to be relatively attention demanding. Thus, if fewer attentional resources are required by a secondary task, such as the suprapostural task, more resources should be available for the balance task, and performance should be improved. This could explain the more effective performance of the external focus compared to the internal focus group.

However, lower attentional demands cannot explain the advantage of the external focus relative to the control condition in Experiment 2. Even though it is unclear what control group participants focused on, they were not given any instructions regarding the suprapostural task other than to hold the tube in front of their abdomens. Therefore, the attentional demands, if any, required for this task under the control condition can be assumed to be considerably lower than those required under external (or internal) focus conditions. Thus, if control group participants were able to direct most or all of their attention to the balance task, why did they not show the most effective performance (practice) and learning (retention, transfer) on the balance task? Clearly, the external focus condition must have provided a *benefit* over and above a reduced demand of attentional resources. Otherwise, no advantages for the external focus relative to the control group—particularly in transfer, where all participants performed under identical conditions (i.e., without the suprapostural task)—would have been seen.

One possibility is that an external focus on the suprapostural task might have directly benefited the learning of this dynamic postural activity by augmenting the relationship between peripheral feedback and motor unit recruitment. The rationale for this view is derived from findings that suggest motor control is a product of coherency between sensory feedback and physiological tremor—with skilled control perhaps reflecting a greater degree of coherence. Tremor is defined as an involuntary, rhythmic, and mechanical oscillation of a body part that possesses a regular amplitude and frequency (Habib-ur-Rehman, 2000; McAuley & Marsden, 2000; Morrison & Newell, 2000). Although used to describe the oscillations of body segments, the postural sway associated with static balance (and by extension, dynamic balance) has also been described in terms of an oscillator (Pagnacco, Sorbello, Oggero, Morr, & Berme, 1998). Tremor appears to be specific to the goals of the task in that different frequency/amplitude characteristics emerge as a function of task constraints. During quiet standing, for example, postural tremor in healthy, young adults is around 5 Hz (Pagnacco et al., 1998), while intentional tremor (associated with voluntary movements) has been found to range between 7 and 12 Hz (Habib-ur-Rehman, 2000). Because tremor is believed to play an important role in both sensory information processing and in the synchronization of motor unit recruitment (McAuley & Marsden, 2000), it is possible that different task constraints (minimize hand movements vs. minimize tube movements vs. no specific instructions) lead to different coherencies between sensorimotor feedback and motor unit recruitment—the result of which would be different effector outputs. Evidence for this relationship comes from a study by Marsden, Ashby, Limousin-Dowsey, Rothwell, and Brown (2000), who found a linear relationship between the oscillatory activity recorded in the cerebellar system and areas of the sensorimotor areas of the cortex and muscles. Their findings indicated a common mechanism for the temporal sampling of movement-related activities within the sensorimotor cortex and cerebellar systems and suggested that the coherency between these systems entrained motor unit recruitment (Marsden et al., 2000).

The addition of a suprapostural task, as for example in Riley et al.'s (1999) "touch-relevant" condition, would impose a greater constraint on the system as a whole and may facilitate or augment the coupling between sensory input and motor output. Removal of the suprapostural task during transfer in the present study would not be expected to disrupt this well-established relationship. In fact, the increase in performance of the external focus group observed during transfer, relative to retention, suggests that removal of the suprapostural task reduced the control demands on the system. When reflexive mechanisms are not elicited, as would be expected to occur if the performer attempted to control the movement (internal focus and perhaps control conditions), disruptions in the feedback loop would result in less than optimal motor unit recruitment (e.g., Teasdale, Stelmach, & Breunig, 1991). The finding that performance actually improved for both internal focus and control groups from retention to transfer suggests that once the disrupting influence of the suprapostural task was removed, greater coherence between sensory input and motor output emerged.

While it is not possible to determine the impact that different attentional focus strategies have on the coherence between feedback and effector systems, it is possible to examine differences in the frequency characteristics found in previous studies (McNevin et al., 2003; Wulf et al., 2001a, 2001b) and extrapolate from these findings. In those studies, the frequency characteristics of platform movements under external focus conditions were higher than those produced under internal focus conditions. Because a higher frequency of responding reflects the potential of the system to adapt to perturbations (i.e., Newell & Slifkin, 1996), the implication is that there was a higher degree of coherence in motor unit recruitment under external focus conditions. If this is the case, it could be argued that the learning advantages of an external focus reflect a coherency between afferent input and effector output—facilitated presumably as a result of exploiting the intrinsic dynamics of corticospinal pathways and cerebellar functions. To examine this issue, FFT analyses of balance platform movements and suprapostural kinematics could be used in future studies.[4] If an external focus does indeed facilitate coherence between the sensory input and effector output for both suprapostural and postural tasks, higher frequency/lower amplitude adjustments should be seen on both tasks, relative to the internal focus and control conditions.

## Summary and conclusions

Previous studies have nicely demonstrated the influence of suprapostural goals on postural control. The focus in these studies has been on how different types of task, such as those requiring touch (Riley et al., 1999), aiming (Balasubramaniam & Turvey, 2000), or vision (Stoffregen et al., 1999, 2000), affect postural performance. The results are typically interpreted from an ecological perspective, which emphasizes the importance of considering postural control in the context of other behavioural goals. Clearly, these studies have made an interesting and important contribution to our understanding of postural control. However,

[4]FFT analyses could not be performed in the present study, because participants—even in retention and transfer—often "slammed" the platform onto the base. The problem is that very rapid movements from one side to the other introduce a relatively high frequency/power component into the spectrum. Furthermore, the reverberation that occurs when the platform hits the bottom relatively hard introduces an artefact into the FFT analysis that is not characteristic of the actual performance. Attempts to rectify this problem by using smoothing techniques or by sampling meaningful windows of data resulted in either unrepresentative power spectra for "good" balancers or yielded an insufficient number of data points for performing the FFT analysis of "poor" balancers.

one limitation of these studies is that little effort has been directed at understanding the mechanisms underlying postural control as a function of different suprapostural goals. Furthermore, the postural tasks used in these studies were limited to upright stance. Questions as to how novel, more complex balance skills are learned, and how postural control changes over practice, have not been addressed. Finally, participants' interpretations of the experimenter-defined suprapostural tasks have not been considered.

Research on how the performer's focus of attention affects motor performance and learning has addressed some of these issues (e.g., McNevin et al., 2003; Shea & Wulf, 1999; Wulf et al., 1998, 2001a). The present study was an attempt to bridge the gap and to bring us closer to an understanding of how the performer's attentional focus adopted on a supra-postural task affects postural control in the learning of a novel balancing task. The results showed that attentional focus plays an important qualifying role in the effectiveness of suprapostural goals, and that this influence goes beyond temporary effects on performance and affects the learning of new skills. How exactly the focus of attention acts to influence motor control, and how changes across practice are brought about, remain to be challenging questions for future research. For example, while we did not measure the attentional resource demands under external and internal focus conditions as well as the control condition, it would be interesting to examine whether, or to what extent, this factor plays a role for the differential effectiveness of these conditions. Future studies examining the effects of attentional focus on suprapostural tasks should also control for other factors that might differ between tasks, such as the processing of visual information. This could be accomplished by preventing vision of the apparatus or device used for the suprapostural task.[5]

The present results also have practical implications. Many tasks involve the manipulation of objects while maintaining (dynamic) balance—ranging from walking with a bowl of soup to throwing a discus, putting a shot, shifting the sail on a windsurfer, lifting a partner in ice-skating, or juggling on an unstable surface. Often such skills require several years of practice—and considerable amounts of monetary and personal resources—to achieve "perfection". Typically, the instructions given to learners refer to the coordination of their body movements, such as the throwing arm and upper body in discus or the timing of changes in hand position on the boom in windsurfing. Based on the present results, instructions such as these that induce an internal attentional focus would not be expected to be very effective. That is, they would not only be relatively ineffective for the (suprapostural) aspect of the skill that the attention is directed to, but also for the maintenance of balance. In contrast, instructions that induce an external focus, for example, by directing attention to the object to be thrown, would be expected to be more beneficial for both suprapostural and postural (balance) aspects of the skill. Thus, wording instructions given to learners in a way that they induce an external focus should increase the effectiveness and efficiency of training, with the result that higher performance levels are reached in a shorter period of time. In fact, skilled

[5]Differences in the processing of visual feedback cannot explain attentional focus effects found in studies, for example, where performers directed their attention to either keeping their feet (internal) or markers on the stabilometer platform (external) horizontal but, at the same time, were required to look straight ahead (e.g., Wulf, Höß, & Prinz, 1998, Experiment 2; Wulf, McNevin, & Shea, 2001a). Nevertheless, the control of this factor in future studies would be desirable.

performers typically seem to focus on the anticipated outcome or effect of their actions, rather than on the details of their movements. The present findings should not lessen the well-deserved admiration of acrobats performing juggling stunts on highly unstable surfaces, but rather increase our admiration of the automatic control capabilities of the motor system.

## REFERENCES


Abernethy, B. (1988). Dual-task methodology and motor skills research: some methodological constraints. *Journal of Human Movement Studies*, *14*, 101–132.

Balasubramaniam, R., & Turvey, M. T. (2000). The handedness of postural fluctuations. *Human Movement Science*, *19*, 667–684.

Brown, L. A., Shumway-Cook, A., & Woollacott, M. H. (1999). Attentional demands and postural recovery: The effects of aging. *Journal of Gerontology A: Biological Sciences and Medical Sciences*, *54*, M165–M171.

Habib-ur-Rehman (2000). Diagnosis and management of tremor. *Archives of Internal Medicine*, *60*, 2438–2444.

Lajoie, Y., Teasdale, N., Bard, C., & Fleury, M. (1993). Attentional demands for static and dynamic equilibrium. *Experimental Brain Research*, *97*, 139–144.

Marsden, J., Ashby, P., Limousin-Dowsey, P., Rothwell, J., & Brown, P. (2000). Coherence between cerebellar thalamus, cortex and muscles in man. *Brain*, *123*, 1459–1470.

McAuley, J., & Marsden, C. (2000). Physiological and pathological tremors and rhythmic central motor control. *Brain*, *123*, 1545–1567.

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research*, *67*, 22–29.

McNevin, N. H., & Wulf, G. (2002). Attentional focus on suprapostural tasks affects postural control. *Human Movement Science*, *21*, 187–202.

Morrison, S., & Newell, K. M. (2000). Limb stiffness and postural tremor in the arm. *Motor Control*, *4*, 293–315.

Newell, K. M., & Slifkin, A. B. (1996). The nature of movement variability. In J. Piek (Ed.), *Motor control and human skill: A multidisciplinary perspective*. Champaign, IL: Human Kinetics.

Pagnacco, G., Sorbello, D., Oggero, E., Morr, D. R., & Berme, N. (1998). *Tremor in normal subjects: Spectral characteristics*. Proceedings of the North American Congress on Biomechanics, Waterloo, Ontario, Canada.

Riccio, G. E., & Stoffregen, T. A. (1991). An ecological theory of motion sickness and postural stability. *Ecological Psychology*, *3*, 195–240.

Riley, M. A., Stoffregen, T. A., Grocki, M. J., & Turvey, M. T. (1999). Postural stabilization for the control of touching. *Human Movement Science*, *18*, 795–817.

Schmidt, R. A., & Lee, T. D. (1999). *Motor control and learning* (3rd ed.). Champaign, IL: Human Kinetics.

Shea, C. H., & Wulf, G. (1999). Enhancing motor learning through external-focus instructions and feedback. *Human Movement Science*, *18*, 553–571.

Stoffregen, T. A., Smart, L. J., Bardy, B. G., & Pagulayan, R. J. (1999). Postural stabilization of looking. *Journal of Experimental Psychology: Human Perception and Performance*, *25,* 1641–1658.

Stoffregen, T. A., Pagulayan, R. J., Bardy, B. G., & Hettinger, L. J. (2000). Modulating postural control to facilitate visual performance. *Human Movement Science*, *19*, 203–220.

Teasdale, N., Stelmach, G. E., & Breunig A. (1991). Postural sway characteristics of the elderly under normal and altered visual and support surface conditions. *Journal of Gerontology*, *46*, 238–244.

Thompson, J. M. T., & Stewart, H. B. (1986). *Nonlinear dynamics and chaos*. New York: Wiley.

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., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Feedback and attentional focus: Enhancing the learning of sport skills through external-focus feedback. *Journal of Motor Behavior*, *34*, 171–182.

Wulf, G., & McNevin, N. H. (2002). *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., & Shea, C. H. (2001a). The automaticity of complex motor skill learning as a function of attentional focus. *Quarterly Journal of Experimental Psychology*, *54A*, 1143–1154.

Wulf, G., & Prinz, W. (2001). Directing attention to movement effects enhances learning: A review. *Psychonomic Bulletin & Review*, *8*, 648–660.

Wulf, G., Shea, C. H., & Park, J.-H. (2001b). Attention in motor learning: Preferences for and advantages of an external focus. *Research Quarterly for Exercise and Sport*, *72*, 335–344.

*Original manuscript received 14 March 2002*
*Accepted revision received 29 August 2002*