Research Quarterly for Exercise and Sport

Vol. 79, No. 3, pp. 319–325

Attentional Focus Effects in Balance Acrobats

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Performing and learning motor skills has been shown to be enhanced if the performer adopts an external relative to internal focus (or no focus) of attention (Wulf, 2007). The present study examined the generalizability of this effect to top-level performers (balance acrobats). Participants performed a balance task (standing on an inflated rubber disk) under each of three attentional focus conditions: (a) external focus (i.e., minimize movements of the disk), (b) internal focus (i.e., minimize movements of the feet), and (c) control conditions (no focus instructions). While there were no differences between conditions in the amount of postural sway, the frequency of movement adjustments was higher in the control condition, relative to both external and internal focus conditions. This suggests that movement automaticity and postural stability were greatest when the balance experts were free to adopt their "normal" focus of attention. The finding implies that there may be a limit to the performance-enhancing effects of external focus instructions for top-level performers. The findings are discussed in terms of action control levels and possible changes in the optimal attentional focus with the performer's level of expertise.

Key words: attention, expertise, motor control, posture

Studies have shown that the performer's focus of attention has an important influence on performing and learning motor skills (see Wulf, 2007). Specifically, instructions that direct a performer's attention to the effects her or his movements have on the environment (external focus) have been shown to lead to more effective performance or learning than directing attention to the movements themselves (internal focus). For example, studies using a variety of balance tasks (e.g., stabilometer, Pedalo, disk) have shown that directing participants' attention to movements of the support surface (external focus) is more beneficial for learning than directing attention to movements of the feet (internal focus; e.g., Landers, Wulf, Wallmann, & Guadagnoli, 2005; McNevin, Shea, & Wulf, 2003; Totsika & Wulf, 2003; Wulf, Höß, & Prinz, 1998; Wulf, McNevin, & Shea, 2001). Other studies have found advantages of focusing on the movement effect for sport skills such as basketball (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002), golf (Wulf, Lauterbach, & Toole, 1999), tennis (Wulf, McNevin, Fuchs, Ritter, & Toole, 2000), or volleyball and soccer (Wulf, McConnel, Gärtner, & Schwarz, 2002). In addition, instructions inducing an external focus have been demonstrated to be effective for individuals with Parkinson's disease (Landers et al., 2005) or stroke (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002). An important aspect of these findings is that external focus benefits have been found relative not only to internal focus conditions but also to control conditions (e.g., Landers et al., 2005; McNevin & Wulf, 2002; Wulf & McNevin, 2003; Wulf, Töllner, & Shea, 2007; Wulf, Weigelt, Poulter, & McNevin, 2003). That is, inducing an external focus generally resulted in performance advantages, while internal focus conditions and control conditions with no specific focus instructions produced similar and less effective performance.

The benefits of adopting an external focus of attention relative to internal focus have been explained with the "constrained action hypothesis" (e.g., McNevin et al., 2003; Wulf, McNevin, & Shea, 2001). According to this view, individuals who are instructed to focus on their movements—which they might also do sponta-

Submitted: September 16, 2006
Accepted: October 29, 2007

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neously without specific attentional focus instructions (control conditions)—control their actions in a relatively conscious manner. This, in turn, tends to constrain the motor system and disrupts automatic control processes. In contrast, focusing on the movement effect allows automatic processes to control the movement, resulting in more effective performance and learning. Support for this notion comes from findings showing shorter probe reaction times for participants performing balance tasks with an external relative to internal focus, indicating reduced attentional demands or greater automaticity (Wulf, McNevin, & Shea, 2001). In addition, analyses of the movement frequency characteristics (mean power frequency; MPF) in balancing have shown higher frequency adjustments for external compared to internal focus participants (McNevin et al., 2003; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001). A high frequency of movement adjustments indicates a more automatic, reflex-type control mode based on faster and more finely tuned integrated movement responses (e.g., Thompson & Stewart, 1986). Specifically, in the studies mentioned above (McNevin et al., 2003; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001), participants learning to balance on a stabilometer showed consistently higher MPF values when instructed to adopt an external focus (i.e., movement of markers attached to the platform) compared to an internal one (i.e., movement of their feet), indicating greater automaticity and greater stability due to faster compensatory reactions to perturbations.

Most studies examining attentional focus effects have used novices as participants, while only few have examined the effectiveness of different attentional foci in advanced or expert performers. For example, Wulf et al. (2002) found external focus advantages for experienced volleyball and soccer players. Similarly, skilled golfers have been shown to benefit from external relative to internal focus instructions (Perkins-Ceccato, Passmore, & Lee, 2003; Wulf & Su, 2007). The only study including a control condition without focus instructions—essentially allowing expert performers to adopt their "normal" focus of attention—appears to be the one by Wulf and Su (2007). In that study, zero-handicap golfers hit golf balls with greater accuracy when instructed to focus on the club motion (external focus), compared to the control condition. Assuming that the golf swing is already automated in performers at that skill level, one would not necessarily have expected to see an advantage of external focus instructions. If the relative task difficulty already affords an automatic mode of control, no additional benefit of inducing an external focus would be expected. This finding suggests that external focus instructions can still improve performance, even at that level of expertise.

In the present study, I went one step further and examined how different attentional foci would affect performance at the *highest* skill level, such as that demonstrated by world-class athletes. If performance is already at, or very near, the optimum level (i.e., controlled with a high degree of automaticity), one might not necessarily expect external focus instructions to provide additional performance benefits. While world-class performers are rarely studied in fundamental research on motor control and learning, examining how variables such as the type of attentional focus affect their performance is important from both theoretical and practical perspectives.

Specifically, the purpose of the present study was to examine the effects of internal and external attentional focus instructions relative to no instructions (control condition) in world-class balance performers. Participants were required to balance on an unstable surface (inflated rubber disk). They were instructed to focus on reducing movements of either their feet (internal focus) or the disk (external focus), or they were not given attentional focus instructions (control). In previous studies using the same task, young healthy adults without special balance skills showed enhanced performance with external focus instructions (Wulf, Mercer, McNevin, & Guadagnoli, 2004; Wulf et al., 2007). In the present study, we asked whether highly balance-trained individuals would also benefit from external focus instructions. Dependent measures included the amount of postural sway (root-mean-square error; RMSE) and the frequency of postural adjustments (mean power frequency; MPF). RMSE is an overall performance measure that indicates the average deviations from a goal—in this case, the fluctuations of the center of pressure around its own mean. MPF can reveal subtle frequency performance differences under different focus conditions. It can indicate the control mechanisms used to perform a task, with higher MPF values viewed as reflecting a greater degree of automaticity. While RMSE and MPF have often been associated in previous studies (e.g., McNevin et al., 2003; Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001), in which an external focus resulted in small RMSEs and high MPFs, MPF analyses in other studies detected performance differences as a function of attentional focus, although no differences in RMSE were observed (e.g., McNevin & Wulf, 2002). Thus, MPF was my main variable of interest in the present study.

Method

Participants

Twelve world-class acrobats (10 men, 2 women) participated in the present study. All were performers of the Cirque du Soleil show "Mystère" in Las Vegas, NV. All regularly performed balance stunts in the show (e.g., walking on balls, landing on top of a three-person pyramid after jumping off a teeter-totter, and performing several twists and somersaults; see Figure 1), and their balance capabilities can be assumed to be at or near the highest possible level. All participants gave their informed consent, and all were naïve as to the purpose of this study.

Apparatus, Task, and Procedure

The task required participants to balance on an inflated rubber disk (Disc 'O' Sit™, Perform Better, Cranston, RI) with a 13-inch [33 cm] diameter. Before data collection, participants were allowed to familiarize themselves with the task and to stand on the disk for about 10 s. The disk was placed on a force platform (Model #9286AA, Kistler, Winterthur, Switzerland) to record the center of pressure (COP) data, which were recorded at 500 Hz. Participants were instructed to look straight ahead while balancing on the disk (see Figure 2). Each participant performed four 15-s trials under each of three attentional focus conditions. Specifically, participants were instructed to "stand still" (control), "focus on minimizing movements of your feet" (internal focus), or "focus on minimizing movements of the disk" (external focus). The order of attentional focus conditions was counterbalanced across participants. Data collection for each trial began after the participant stepped onto the disk and attained a "quiet" stand.

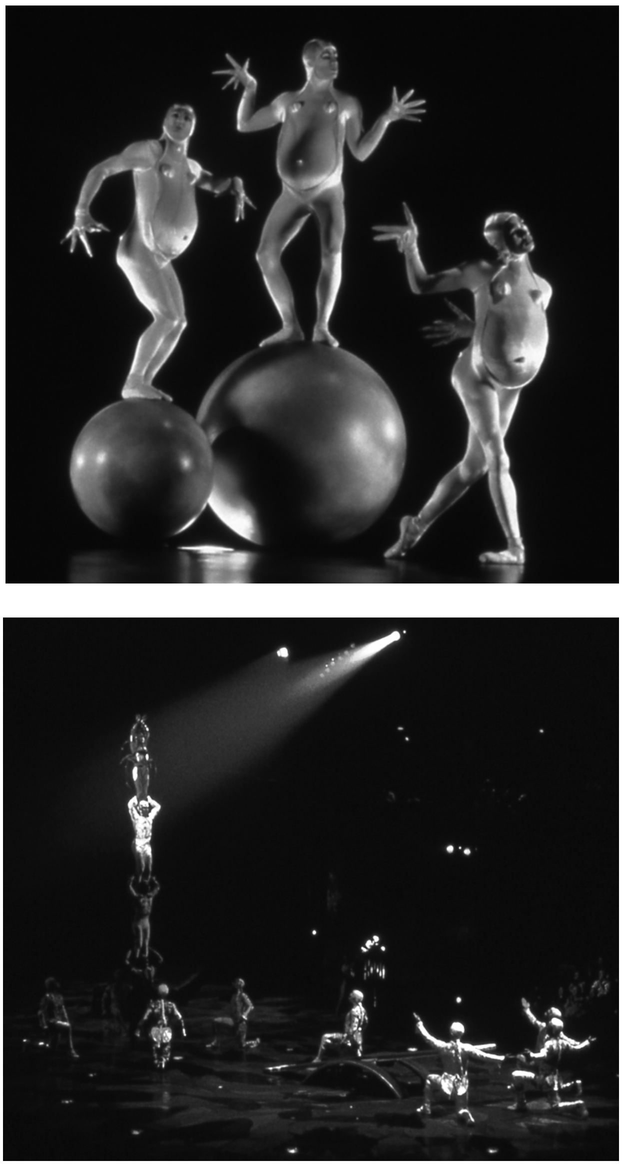


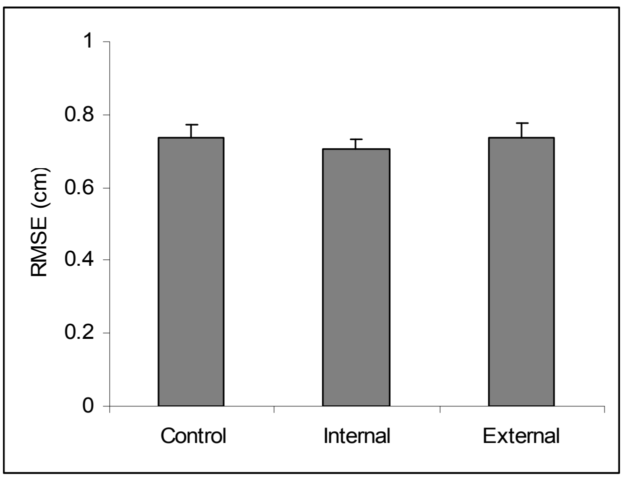
Figure 1. Acrobats from the *Cirque du Soleil* show *"Mystère"* in Las Vegas, who served as participants in the present study. Photos: Al Seib; costumes: Dominique Lemieux; © 1999, 2003, Cirque du Soleil, Inc.

Dependent Variables and Data Analysis

The data were converted to ASCII format and processed using custom laboratory software. COP data were adjusted so that the central coordinates were (0, 0). Data were then converted from Cartesian to Polar coordinates, with the magnitude vector analyzed by calculating the RMSE and MPF of the signal. MPF was calculated by first transforming the vector magnitude signal to the frequency domain by calculating the Power Spectral Density (PSD) of the signal, using a box car window. The PSD was calculated with the mean and linear trends

Figure 2. Person (nonparticipant) standing on the inflated disk and force platform.

removed from the signal. The 7,500 data points (15 s of data recorded at 500 Hz) were padded with zeros to result in 8,192 points used in calculating the PSD, because the length of the data set must be a power of 2. This resulted in frequency bin sizes 0.061 Hz. MPF was calculated as $\Sigma(PSD_i*Freq_i)/\Sigma(PSD)$, where PSD_i represents power spectral density at frequency bin 'i', $Freq_i$ represents the frequency (in Hz) and Σ(PSD) represents the sum of powers across all frequency bins analyzed (Winter & Patla, 1997). The 0–0 Hz frequency range was used, because it was calculated that 97–99% of the power was contained within this range. RMSE of the COP vector magnitude was a measure of postural sway, whereas MPF indicated the frequency of postural adjustments, with higher MPF values indicating higher frequencies. The dependent variables were analyzed in 3 (attentional focus: internal, external, control) x 4 (trial) analyses of variance, with repeated measures on both factors.



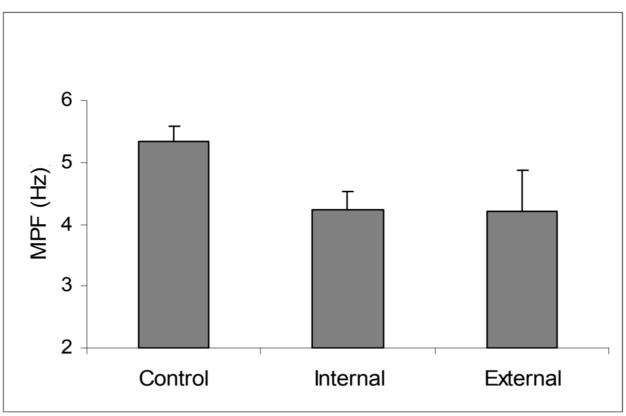


Figure 3. Magnitude of sway (top; root mean square error; RMSE) and frequency of responding (bottom; mean power frequency; MPF) as a function of the type of attentional focus (control, internal, or external).

Results

Postural Sway (RMSE)

Figure 3 (top) shows the amount of postural sway under the three attentional focus conditions. Participants showed similar RMSEs in all conditions. The main effect of attentional focus, $F(2, 22) < 1$, was not significant. Also, the main effect of trial, $F(3, 33) = 1.86$, $p > .05$, and the interaction of attentional focus and trial, $F(6, 66) = 1.06$, $p > .05$, were not significant.

Frequency of Responding (MPF)

The frequency of responding showed clear differences between conditions (see Figure 3, bottom). MPFs were higher in the control condition than in both the internal and external focus conditions, which did not differ from each other. The main effect of attentional focus was significant, with $F(2, 22) = 5.44$, $p < .05$, $\eta^2 = .33$. Post hoc tests (LSD) confirmed that MPFs in the control condition were significantly higher than those under internal and external focus conditions, $p < .05$, with no difference between the latter two. There was no main effect of trial, $F(3, 33) < 1$, or interaction of attentional focus and trial, $F(6, 66) < 1$. Thus, the experts showed the highest degree of automaticity in movement control under "normal" (i.e., control) conditions, while either internal or external focus instructions apparently hampered this automaticity.

Discussion

The present study is unique in that it examined attentional focus effects in top-level acrobats. While previous studies have shown that not only novices but even highly skilled individuals (golfers) can benefit from external focus instructions (Perkins-Ceccato et al., 2002; Wulf & Su, 2007), only one study included a no-instruction control condition in which the experts were free to adopt their "normal" attentional focus (Wulf & Su, 2007). Also, the participants in those studies could not be considered world-class athletes, such as the ones in the present study. Therefore, the purpose of the present study was to examine whether the benefits of external focus instructions would generalize to top-level performers.

The task and design used in the present study was also used in two previous studies that involved young healthy individuals without special balance skills (Wulf et al., 2004, 2007). Those individuals showed enhanced performance with external focus instructions (disk), compared to internal focus (feet) or no instructions.

The expert balancers in the present study produced less postural sway than the nonexperts in those previous studies, with RMSEs about half the size of those seen in the nonexperts. The effects of attentional focus, however, were different for the experts than for the nonexperts in previous studies. Although the amount of postural sway (RMSE) was not affected in experts, there were clear differences in MPFs, which were significantly higher in the control condition than in the external or internal focus conditions.

MPF is arguably a more sensitive measure than RMSE and is capable of detecting subtle differences in performance that might not show up in the amount of sway. A higher response frequency has been characterized as an increase in the number of active degrees of freedom (e.g., Gurfinkel, Ivanenko, Levin, & Barbakova, 1995; for a discussion of this issue, see Newell & Slifkin, 1996) and as reflecting a greater degree of automaticity (e.g., McNevin & Wulf, 2002; McNevin et al., 2003; Wulf, McNevin, & Shea, 2001; Wulf et al., 2004). For example, relative to "normal" motor systems, in which there are fast and low amplitude adjustments, motor systems that are constrained or compromised by disease or aging have exhibited lower frequency components. Analyses of finger or hand tremor in compromised systems (e.g., Gantert, Honerkamp, & Timmer, 1992; Newell, Gao, & Sprague, 1995) or of balance, in which inputs (e.g., vision) into the vestibular-occular system were perturbed (e.g., Gurfinkel et al., 1995), yielded tremor and balance records characterized by larger amplitudes and lower frequencies. Higher frequency components, in contrast, indicate the incorporation and coordination of additional degrees of freedom (see Thompson & Stewart, 1986) and are generally associated with skilled performance.

The important point is that human posture is inherently unstable and must be maintained via small, rapid (reflexive) patterns of muscle activation. Asking balance experts to focus on disk movements (or their feet) was not beneficial; rather, it apparently resulted in a more active postural control, which, in turn, led to a degradation of the more natural movement dynamics and hampered stability. The result was poorer performance as indexed by a general "damping" in the response frequency. In contrast, when the experts were free to concentrate on their typical focus on under normal conditions, they could compensate for perturbations or deviations of the COP rapidly and effectively by using reflex-type control mechanisms. Thus, the high MPF values under control conditions demonstrated that the expert performers' balance was most effective under "normal" conditions.

How can the experts' superior performance under control conditions be explained? It has long been known that expert performers typically do not focus on the details of their actions. In fact, if they do—as often happens under increased pressure to perform well—their performance tends to suffer (e.g., Baumeister, 1984; Baumeister & Steinhilber, 1984; Beilock, Carr, MacMahon, & Starkes, 2002; Bliss, 1892–1893; Boder, 1935; Gray, 2004). It is generally assumed that directing attention to the movement details disrupts the automatic control processes experts have developed. With increasing expertise, movement control becomes more fine tuned, and errors are corrected immediately and effectively via various reflex loops. As a consequence, "control over the act moves towards higher levels of representation as the lower level features of the action become coordinated and thus capable of discharge without conscious monitoring" (Vallacher, 1993, p. 455). Such a hierarchy of goals might be to "win a tennis match," "hit an ace," "give the ball a topspin," and "flip the wrist." Hitting an ace, for example, would be a relatively high-level goal, while the steps required to achieve it would be represented at a lower level, with muscle control at the lowest level. As an action becomes more automated, it is assumed to be monitored at progressively higher levels. Yet, under certain conditions, such as social pressure to do well, individuals tend to focus on lower-than-optimal hierarchical levels of action control (e.g., Vallacher, 1993; Vallacher & Wegner, 1987). "Choking" under pressure, for example, is seen as the result of individuals becoming self-conscious and too concerned with the step-by-step task execution (e.g., Baumeister, 1984, 1985; Lewis & Linder, 1997). This is assumed to disrupt the automaticity in movement control that typically characterizes skilled performance. Masters (2000) termed this idea the "conscious processing hypothesis."

The use of conscious control processes reflects a temporary regression to earlier learning stages. Action control at a lower-than-optimal level would also be expected to occur when performers are instructed to pay attention to the details of their actions. The result is that movements that are typically performed effectively and efficiently are disrupted. Attempts to consciously control an action that is normally controlled automatically essentially disintegrate it and take away its fluidity (Vallacher, 1993). For the balance experts in the present study, "standing still" on a compliant surface was presumably represented at the highest control level. Because of their extensive experience with similar skills (e.g., standing on balls), this type of focus presumably triggered the muscular activities necessary to achieve this effect. Asking participants to focus on moving the disk (external focus) or their feet (internal focus) as little as possible directed their attention to a lower control level and disrupted the finely tuned, reflexive control mechanisms that normally control their balance.

The present results suggest there may be a limit to the performance-enhancing effects of external focus instructions. Although these have been effective for a wide range of skill levels, the top-level performers in the present study did not exhibit the same benefits. Clearly, the external focus instructions in the present experiment were not effective at that level. While there might be no way to enhance their performance further (through attentional focus instructions or otherwise), this finding raises the interesting question of whether the optimal (external) focus might change across practice. Given that, with increasing proficiency, individuals tend to control actions at higher levels (e.g., Vallacher, 1993; Vallacher & Wegner, 1987), it makes sense to assume performers should also be encouraged to focus on movement effects at different hierarchical levels. Of course, for novices who have not yet developed the necessary motor programs, it might not be feasible to focus on high-level effects. Indeed, for beginning golfers, focusing on a "low-level" effect (e.g., golf club motion) has been more effective than focusing on a "high-level" effect (e.g., golf ball trajectory; Wulf et al., 2000). The problem for a novice golfer is that he or she first needs to develop a motor program for the correct swing. Focusing on the ball trajectory would not be an effective strategy in this case, because different coordination patterns could produce the same trajectory (i.e., there is no direct relationship between a given trajectory and a particular movement pattern). Therefore, learning the correct technique/motor pattern, would be relatively difficult. In contrast, directing attention to a lower-level effect, such as golf club movement, should be more effective, because it is more directly related to body movements and more easily associated with the motor commands that produced the motion (see also Wulf & Prinz, 2001). Thus, it seems reasonable to suggest that the optimal attentional focus should depend on the level of expertise.

A direction for future research might be to examine these issues more closely. The results might not only contribute to a better understanding of a possible interaction between attentional effects and level of expertise, but they may also have implications for the training of top-level performers. Those individuals often perform in high-pressure situations (e.g., when the risk of injury is high or when a championship is at stake); thus, future investigations should also look into how attentional focus strategies might reduce incidents of choking under pressure.

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Author's Notes

Special thanks to Arthur, Dima, Jeremy, Ludmilla, Marco, Marek, Micheline, Oscar, Rustam, Sebastian, Slava, and Vladimir for participating in this study; to Janet Pundick and Nancy Mallette at Cirque du Soleil's *Mystère* for their organizational help; and to Bhaarath Kumar and Rohith Ramnath for technical assistance. Please address all correspondence concerning this article to Gabriele Wulf, Department of Kinesiology, University of Nevada–Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-3034.

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