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Performance of gymnastics skill benefits from an external focus of attention

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Abstract
The present study was designed to fill a gap in the literature on attentional focus and sports performance. Specifically, in contrast to most previous studies in which an external focus was directed at an implement, we used a gymnastics skill that did not involve the use of an implement. Furthermore, while most studies used only outcome measures of performance, we also assessed movement quality. Twelve-year-old gymnasts performed a maximum vertical jump with a 180-degree turn while airborne, with their hands crossing in front of their chest during the turn under three different focus conditions. Under the external focus condition, participants were asked to focus on the direction in which a tape marker, which was attached to their chest, was pointing after the turn. Under the internal focus condition, they were asked to focus on the direction in which their hands were pointing after the turn. Under the control condition, no focus instructions were given. The external focus condition resulted in both superior movement form and greater jump height than did the other two conditions, which produced comparable results. The present findings show that, similar to other tasks, the performance of form-based skills can be enhanced relatively easily by appropriate external focus instructions.

Keywords: *focus of attention, sports, movement form, jump height*

Introduction

Aside from practice per se, the instructions and feedback athletes receive from their coaches are perhaps the most important variables in the process of sport skill learning. Importantly, it is not just the information content of instructions or feedback that determines their effectiveness, but also the way in which athletes' attention is directed through them. Specifically, if attention is directed to body movements (i.e., promoting an internal focus of attention) – arguably the predominant type of instruction in movement-related contexts (e.g., Durham, Van Vliet, Badger, & Sackley, 2009; Porter, Wu, & Partridge, 2010) – skill learning is impeded relative to instructions that direct attention to the intended movement effect (i.e., promoting an external focus) (for a review, see Wulf, 2013). Since the first demonstration of learning advantages resulting from external focus instructions relative to internal focus or no instructions (control conditions) for balance tasks (Wulf, Höß, & Prinz, 1998), numerous studies have followed and shown for various motor skills that directing attention to the planned movement effect results in more effective and efficient performance than does directing attention to body movements per se.

Wulf, McNevin, and Shea (2001) proposed the "constrained action hypothesis" (CAH) to explain the attentional focus effect. According to this notion, when attending to body movements, the performer constrains his or her motor system by using conscious control processes that interfere with automatic control mechanisms. In contrast, when attention is directed at the intended movement effect, automatic – that is, unconscious, fast and reflexive – processes are utilised, with the result that motor performance is enhanced. Support for the CAH has been provided in several studies using a variety of measures. These include demonstrations that, with an external relative to an internal focus, attentional demands are generally reduced as indicated by improved dual-task performance (e.g., Kal, Van Der Kamp, & Houdijk, 2013; Lohse, 2012; Wulf et al., 2001); the frequency of movement corrections is high suggesting an

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increased use of reflexes (e.g., McNevin, Shea, & Wulf, 2003); pre-movement times are reduced representing more efficient motor planning (Lohse, 2012); and functional variability is increased, reflecting compensatory corrections among effectors, with the results that variability in the movement outcome is decreased (Lohse, Jones, Healy, & Sherwood, 2014; Wulf & Prinz, 2001). The utilisation of automatic control mechanisms that is fostered by the adoption of an external focus can enhance performance almost immediately and speed the learning process (Land, Frank, & Schack, 2014; Wulf, 2007).

A wide range of motor tasks and performance measures have been used in studies that examined attentional focus effects (see Wulf, 2013). Perhaps not surprisingly, the majority of studies used tasks that involved an implement such as a golf club (e.g., Bell & Hardy, 2009), ball to be thrown, served or kicked (e.g., Pascua, Wulf, & Lewthwaite, 2014; Wulf, McConnel, Gärtner, & Schwarz, 2002, Experiments 1 and 2), dart (e.g., Lohse, Sherwood, & Healy, 2010), bar bell (Marchant, Greig, Bullough, & Hitchen, 2011) or moveable balance platform (e.g., Wulf et al., 1998). Attention was typically directed to the intended movement of the implement (or sometimes a target, or an object striking a target) in external focus conditions versus to movements of the respective limbs in internal focus conditions. Only in relatively few studies did the task involve no implement. In those cases, attention was directed, for instance, to pushing the water back in swimming (e.g., Freudenheim, Wulf, Madureira, Pasetto, & Corrêa, 2010), lines on the floor in long jump (Porter, Ostrowski, Nolan, & Wu, 2010) or a cyclical leg extension-flexion task (Kal et al., 2013), imaginary lines between joints in a wall-sit task (Lohse & Sherwood, 2011), the "approaching" environment in running (e.g., Schücker, Hagemann, Strauss, & Völker, 2009), or to images such as producing smooth movements (without referring to specific body movements) while performing sit-ups (Neumann & Brown, 2013).

Examinations of attentional focus effects for complex tasks without implements – in particular those for which movement form is the primary evaluation criterion (e.g., gymnastics, diving, figure skating) – are largely lacking. Moreover, some authors have suggested that the performance of those types of skills might, in fact, benefit from a concentration on body movements: "It is plausible that … an internal focus of attention could actually be more effective when the goal of the task is to (re)produce a specific movement pattern or routine" (Peh, Chow, & Davids, 2011, p. 75; see also; Künzell, 2007; Wrisberg, 2007). In one recent study, Lawrence, Gottwald, Hardy, and Khan (2011) attempted to address this issue. They used a complex five-part gymnastics floor routine and assessed movement form based on the Féderation Internationale de Gymnastique Code of Points (FIG-COP, 2009). However, no attentional focus effects were found in that study. Methodological issues might be responsible for the lack of effects, though (see Wulf, 2013). For instance, in the external focus condition participants were asked to focus on the movement pathway and on exerting an "even pressure on the support surface," whereas in the internal focus condition, they were instructed to "focus on exerting an equal force on their feet, keeping their arms out straight, level with their shoulders" (Lawrence et al., 2011, p. 434). Thus, confounds existed between the induced attentional focus and the information provided by the instructions. In addition, the instructions were irrelevant to many aspects of the routine (e.g., a full turn).

Thus, there is clearly a need to further examine effects of attentional focus in skills that do not involve implements (see above) and that are judged on the basis of movement quality. While a few previous studies have assessed movement kinematics as a function of attentional focus for skills such as a jump-and-reach task (Wulf & Dufek, 2009), dart throwing (Lohse et al., 2010) or golf (An, Wulf, & Kim, 2013), they typically involved an apparatus or implement. In the present study, we therefore asked participants to perform a gymnastics skill (i.e., vertical jump with a 180-degree turn while airborne), and we assessed their performance as a function of attentional focus. We intentionally kept the task and instructions simple and straightforward to avoid possible confounds or confusion (cf. Lawrence et al., 2011). In contrast to the majority of studies, we used both qualitative and quantitative measures. It is perhaps not surprising that most researchers have used quantitative measures to assess attentional focus effects, such as the accuracy in hitting a target (e.g., Lohse, 2012; Pascua et al., 2014), deviations from a balanced position (e.g., Jackson & Holmes, 2011), jump height (e.g., Wulf & Dufek, 2009) or distance (e.g., Porter, Ostrowski, et al., 2010), or movement speed (e.g., Freudenheim et al., 2010; Totsika & Wulf, 2003), given the ease of use and experimental efficiency. In the present study, we used expert ratings based on the FIG-COP (2009) to evaluate movement quality. In addition, jump height was used as a quantitative performance measure. Participants were young gymnasts, and they performed the task under 3 different attentional focus conditions (external, internal and control) in a within-participant design.

Method

Participants

Twenty-four gymnasts (22 females, 2 males) with an average age of 12.0 years (s = 2.1) participated in the present study. All participants were experienced gymnasts, with an average length of gymnastics training of 5.3 years (s = 2.6). Their current training involved three 2-h sessions per week. Most of them had experience competing at the Czech national level. Participants were not aware of the specific purpose of the study. The study was approved by the university's institutional review board. Informed consent was obtained from the children's parents or legal guardians, and participants gave their oral assent to participate in the study.

Apparatus and task

Participants were asked to perform a vertical maximum jump with a 180-degree turn while airborne, with the hands crossing in front of the chest during the turn (see Figure 1). The skill required not only maximum force production but also high precision (e.g., alignment, feet position and landing) as any imperfection resulted in a deduction (see below). At the beginning of the jump, participants stood with their feet together and their arms extended downward. Participants were barefoot. The experiment was conducted in a gymnastics hall on a standard surface (Conipur KF protect+, Conica, Schaffhausen, Switzerland). All jumps were recorded by a video camera that was mounted onto a tripod. The camera was set up in front of participants at a distance of 3 m and at a 45-degree angle. The recordings were used for later ratings of movement form. An Optojump Next instrument (Optojump Next, Version 1.3.20.0, Microgate, Bolzano, Italy) was used to record jump height. The Optojump consisted of 2 transmitting and 2 receiving bars (100 × 8 cm) that were joined together. Each bar contained 96 light-emitting or light-receiving diodes (approximately one every centimetre) that were located 3 mm above the floor level. The series of transmitting and receiving bars were placed on the floor opposite to each other. Participants jumped between the bars. Data were sampled at 1000 Hz and were processed into 1D footfall patterns using dedicated software. A piece of yellow tape (2 × 5 cm) was attached to the participant's chest and served as the attentional cue in the external focus condition. It was in approximately the same location in which the hands, to which attention was directed in the internal focus condition, crossed during the turn.

Figure 1. Schematic of the jump with a 180-degree turn (from right to left).

Procedure

At the beginning of the experiment, participants watched a short video (5 times) of an expert gymnast performing the turn. The video included a verbal description of the task by experimenter. Four aspects of the task were highlighted: 1) standing between the Optojump bars with both feet together, arms extended and pointing downward; 2) two-foot take off with the body vertical and fully extended, jumping as high as possible; 3) turning 180° while airborne, arms crossing in front of the chest; 4) landing with feet together, perfect alignment. Participants practised the task two or three times before data collection commenced. All participants then performed 5 trials under each of 3 conditions: external focus (E), internal focus (I) and control (C). The order of focus conditions was counterbalanced (CIE, ECI and IEC). Thus, one-third of the participants (8) performed the 15 trials in the order CIECIECIECIECIE, ECIECI …, or IECIEC …. There was a 20-s break between trials during which participants watched the video demonstration again and received one of the instructions, depending on the upcoming condition. In the external focus condition, participants were given the following instructions: "While airborne, focus on the direction in which the tape marker is pointing after the half turn." In the internal focus condition, they were asked: "While airborne, focus on the direction in which your hands are pointing after the half turn." No focus instructions were given in the control condition. Participants were not provided feedback about their performance.

Dependent variables

Jump height and movement form served as quantitative and qualitative measures, respectively. Maximum vertical jump height (cm) for each trial was provided by the Optojump software. Two experienced gymnastics judges assessed movement form. Both were Czech Gymnastic Federation judges with 15 and 10 years of experience, respectively. The raters were blind with respect to the purpose of the study and different focus conditions. Each rater judged each jump execution according to the general and specific regulations of the FIG-COP

Table I. General and specific execution deductions from the Fédération Internationale de Gymnastique code of points for aerobic gymnastics (2009).

Execution faults	Judging criteria	Performance phases	Small	Medium	Large	Unacceptable
			0.1	0.2	0.3	0.5
Incorrect body alignment	Position of the upper body, carriage of the neck, shoulders and head relative to the spine	Before jumping, airborne phase, and landing	1 part	2 parts	3 parts	
Legs/feet apart	In each phase of the movement feet have to be together	Before jumping, airborne phase and landing	<5 cm	5–10 cm	10–15 cm	>15 cm
Uncontrolled feet position	Positioning of the feet relative to the ankles	Airborne phase	Each time			
Legs/feet bend	Positioning of the feet relative to the knees and hip joint	Airborne phase	<5 cm	5–10 cm	10–15 cm	>15 cm
Incomplete rotation	Positioning of a clear start and landing position	Landing	<45°	45°–90°	>90°	
Uncontrolled arms	Positioning of perfect control of arms to avoiding extra arm movements	Landing	Each extra arm movement			
Incorrect landing	Feet should be together in landing to demonstrate perfect control and proper balance without extra steps	Landing	Extra step <5 cm	Extra step between 5–10 cm	Extra step between 10–15 cm	

(2009) for aerobic gymnastics. The kappa coefficient for inter-rater agreement was $k = 0.868$. The judges subsequently compared their ratings of performance faults (execution deductions) and, if there was a discrepancy, reached consensus. Deductions were given for incorrect body alignment, uncontrolled feet position, legs/feet bent or apart, incomplete rotation, uncontrolled arm movements and incorrect landing. Deductions were given for each error as follows: small error 0.1, medium error 0.2, large error 0.3 and or fall/unacceptable error 0.5 (for more details, see Table I).

Data analysis

The raters' (jointly agreed upon) deductions for each trial were used as a measure of movement quality or form. Both jump height and movement form were analysed in 3 (attentional focus: external, internal and control) × 5 (trial) × 3 (focus order) analysis of variance (ANOVAs) with repeated-measures on the first two factors. Mauchly's test was performed to evaluate the sphericity assumption. It showed that the assumption was not violated. Bonferroni adjustments were made for all post hoc comparisons. Data analyses were performed with SPSS 21.

Results

Jump height

Jump height was higher when participants adopted an external focus (M = 23.88 cm, s = 5.56) compared with an internal focus (M = 22.54 cm, s = 5.56), or were not given focus instructions (control condition) (M = 22.73 cm, s = 5.34) (see Figure 2). The main effect of attentional focus was significant, $F(2, 42) = 9.959$, $P < .001$, $\eta_p^2 = .322$.

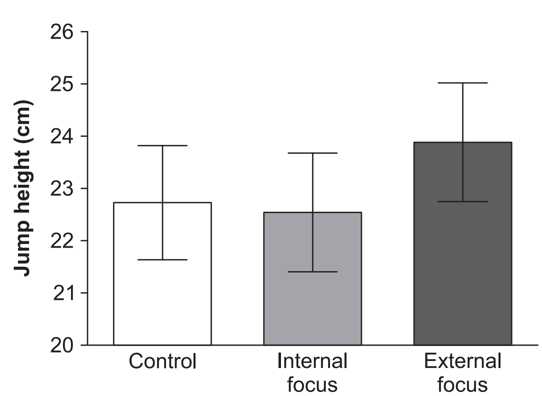

Figure 2. Jump height for the control, internal focus and external focus conditions.

Note: Error bars represent standard errors.

Post hoc tests showed that the external focus condition was significantly different from both the internal focus, P = .001, and control conditions, P = .002. The latter two conditions did not differ from each other, P > .05. The main effects of trial, $F(4, 84) = 1.098$, $P = .363$, $\eta_p^2 = .050$, and focus order, $F(2, 21) = .662$, $P = .526$, $\eta_p^2 = .059$, and the interactions of attentional focus and focus order, $F(4, 42) = 1.042$, $P = .397$, $\eta_p^2 = .090$, trial and focus order, $F(8, 84) = 1.351$, $P = .230$, $\eta_p^2 = .114$, attentional focus and trial, $F(8, 168) = 0.989$, $P = .447$, $\eta_p^2 = .045$, attentional focus, trial and focus order, $F(16, 168) = 0.915$, $P = .553$, $\eta_p^2 = .080$, were not significant.

Movement form

Execution deductions were smallest when participants adopted an external focus (M = 0.019, s = 0.02) relative to an internal focus (M = 0.042, s = 0.04), or no particular focus (control condition) (M = 0.054, s = 0.04) (see Figure 3). The main effect of attentional focus was significant, $F(2, 42) = 10.196$, $P < .001$, $\eta_p^2 = .327$. Post hoc tests showed that the external focus condition was significantly different from both the internal focus, P = .014, and control conditions, P = .001, while the latter two did not differ from each other, P > .05. The main effects of trial, $F(4, 84) = .469$, $P = .758$, $\eta_p^2 = .022$, and focus order $F(2, 21) = .054$, $P = .947$, $\eta_p^2 = .005$, and the interactions of attentional focus and focus order, $F(4, 42) = 1.238$, $P = .310$, $\eta_p^2 = .105$, trial and focus order, $F(8, 84) = 1.275$, $P = .268$, $\eta_p^2 = .108$, attentional focus and trial, $F(8, 168) = 0.337$, $P = .951$, $\eta_p^2 = .016$, attentional focus, trial, and focus order, $F(16, 168) = 1.009$, $P = .450$, $\eta_p^2 = .088$, were not significant.

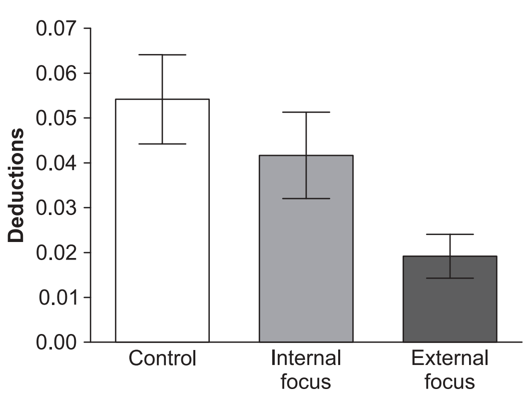

Figure 3. Execution deductions for the control, internal focus, and external focus conditions.

Note: Error bars represent standard errors.

Discussion

The present study fills a gap in the literature on attentional focus. A lack of studies using skills that do not involve an implement (to which attention could be directed) and that are evaluated based on movement quality, or form, led some authors to speculate that skills performed in gymnastics, dance, diving, etc. might benefit from an internal focus (e.g., Künzell, 2007; Peh et al., 2011; Wrisberg, 2007). Our findings show that the performance of those skills – like the performance of other skills (Wulf, 2013) – is enhanced by an external attentional focus. Moreover, the results provide evidence that one relatively simple instruction can positively affect *both* movement outcome (increased jump height) and movement quality (fewer deductions) (see also An et al., 2013). It is also interesting to note that participants were experienced gymnasts. Despite their relatively high level of expertise, providing them with an external focus cue yielded significant benefits relative to both control and internal focus conditions.

Thus, form-based skills are no exception to the rule. Similar to other skills, their performance can be enhanced by adopting an external focus of attention. In fact, our results are in line with previous findings in various respects. As in earlier studies, a *1 or 2-word difference* in the instruction (i.e., the marker versus your hands) was sufficient to elicit the effect (e.g., Wulf et al., 1998). Furthermore, similar to other studies (e.g., Marchant, Clough, & Crawshaw, 2007; Wu, Porter, & Brown, 2012), external focus conditions produced superior performance or learning relative to both internal focus *and* control condition, which in turn did not differ from each other. This pattern of results has also seen in *experienced* performers (e.g., Wulf & Su, 2007, Experiment 2). Furthermore, as in the present study, external focus advantages often occur *immediately* (e.g., Porter, Ostrowski, et al., 2010; Wulf & Dufek, 2009; Wulf & Su, 2007, Experiment 1), that is, do not require long acquisition periods. Attentional focus effects have previously been shown using a variety of outcome measures, including jump height (e.g., Wulf, Zachry, Granados, & Dufek, 2007) or movement form measures (An et al., 2013; Parr & Button, 2009; Southard, 2011; Wulf, Chiviacowsky, Schiller, & Ávila, 2010). However, the present study appears to be the first one to demonstrate an external focus advantage for a form-based sport skill without the use of an implement. Moreover, it shows a "double" advantage in that both movement quality (form) and quantity (jump height) benefited from a single external focus cue.

The present findings add a critical piece to the overall picture related to attentional focus. It is now clear that the attentional focus effect is independent of the type of task, in addition to its generalisability across level of expertise, age, dis/ability, etc. (see Wulf, 2013). Given that external focus advantages have also been demonstrated for a wide variety of performance measures – ranging from neurophysiological measures (e.g., brain activity, muscular activity, heart rate, oxygen consumption) (e.g., Neumann & Brown, 2013; Schücker et al., 2009; Zentgraf, Lorey, Bischoff, & Munzert, 2009) to qualitative performance measures (e.g., present study; Wulf et al., 2010) – the overall body of evidence suggests that the performer's attentional focus fundamentally impacts motor control. Interestingly, an internal focus on even a single body part, such as a finger (e.g., Wulf & Dufek, 2009), wrist (Zachry, Wulf, Mercer, & Bezodis, 2005), hand (Zarghami, Saemi, & Fathi, 2012), or leg (An et al., 2013), can increase muscular activation in other body parts (see also Lohse, Sherwood, & Healy, 2011). The consequence is less-than-optimal coordination and overall performance. A potential limitation of the present study is that the internal focus instructions were directed at the hands crossing in front of the chest rather than the chest itself. That is, a comparison between a focus on the chest (internal) versus a marker on the chest (external) might have been somewhat more compelling.

Control conditions without attentional focus instructions typically show similar effects as internal focus conditions (see Wulf, 2013, for a review). This was also the case in the present study, where both resulted in reduced jump height as well as poorer movement form relative to an external focus. There is some evidence that performers tend to spontaneously focus on their body movements, unless they are instructed otherwise (Land, Tenenbaum, Ward, & Marquardt, 2013; Pascua et al., 2014, but see Porter, Nolan, Ostrowski, & Wulf, 2010). Although children's reports of their strategies are not always reliable (Bjorklund & Douglas, 1997; Winsler, Naglieri, & Manfra, 2006), in future studies, it would be interesting to assess through post-experimental interviews what experienced performers focus on in control conditions (e.g., Stoate & Wulf, 2011), in addition to determining the extent to which they adhered to the focus instructions. In any case, adopting an external focus on the intended movement effect (and away from body movements) seems to be requisite for optimal performance and learning.

From a practical perspective, finding appropriate external foci for form-based skills that do not involve implements might appear challenging. However, as Wulf, Lauterbach, and Toole (1999) pointed out, in those situations metaphors can serve the same purpose as they provide a mental image of the movement goal that the performer can try to produce without directing attention to body movements per se. The external attentional focus created by those images is presumably responsible for their effectiveness. Indeed, professional ballet dancers often report the use of images for positions or moves, such as "stretching like a star in all directions" when performing an arabesque, "climbing up a corkscrew" during a pirouette, or "jumping over a lake" while performing a grand jeté (Guss-West & Wulf, 2015). Thus, for sequences of ballet or gymnastics moves, series of external focus cues, or metaphors, might be an effective way to enhance overall performance.

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