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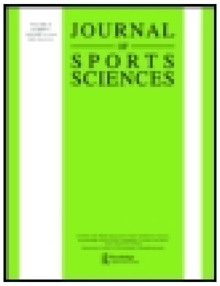

Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rjsp20

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Published online: 28 May 2013.

To cite this article: Anne Ille , Ingrid Selin , Manh-Cuong Do & Bernard Thon (2013): Attentional focus effects on sprint start performance as a function of skill level, Journal of Sports Sciences, DOI:10.1080/02640414.2013.797097

To link to this article: http://dx.doi.org/10.1080/02640414.2013.797097

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Journal of Sports Sciences, 2013
http://dx.doi.org/10.1080/02640414.2013.797097

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Attentional focus effects on sprint start performance as a function of skill level

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(*Accepted 15 April 2013*)

Abstract
Several researchers have demonstrated that an external focus of attention (about movement's effects) during movement execution allowed better performances and learning of various motor tasks than an internal focus of attention (about movement itself). However, attentional focus effects have not been studied in tasks requiring explosive actions preceded by fast reaction time to a signal, such as a sprint start. We hypothesised that the beneficial effect of external focus of attention would be observed in the different stages of the sprint start (i.e. reaction time, block clearance and running) for both expert and novice sprinters. Novice and expert sprinters performed sprint starts followed by a 10 m sprint under three conditions: external focus instructions; internal focus instructions; and neutral instructions. The reaction time and the running time were significantly shorter in the external focus condition than in the internal focus condition, for both expert and novice participants. These results confirm the beneficial effect of an external focus of attention on the speed of movement execution. Moreover, they revealed that attentional focus influences movement preparation. Several hypotheses are proposed to account for these results, with reference to the processes that could be responsible for the observed effects.

Keywords: *focus of attention, reaction time, motor control, expertise*

Introduction

In track sprints, the start is a crucial skill, and its efficiency is an important determinant of the final performance (Majumdar & Robergs, 2011). During this phase, the athlete has to react quickly to the 'go' signal, coordinate arms and legs movements, and generate forces in the shortest time period to leave the starting blocks and reach, as soon as possible, the highest running speed (Fortier, Basset, Mbourou, Faverial, & Teasdale, 2005). Thus, the search of the optimal conditions to perform this task is of great importance. Besides biomechanical and physiological factors determining sprint start performance, the efficacy of information processes involved in movement preparation and execution could influence the success of such a complex task that requires a quick response to a signal and the coordination of several effectors. One factor that has been proved to have a great influence on motor learning and performance is related to the focusing of attention of the athlete towards different sources of information (Ferrel-Chapus & Tahej, 2010; Lohse, Wulf, & Lewthwaite, 2012; Wulf, 2007, 2012; Wulf & Prinz, 2001). To our knowledge, no researchers have previously analysed the influence of attentional focus on sprint start performance despite the importance of the potential gains that an efficient mental preparation strategy would provide.

Two categories of attentional focus have been distinguished: an external focus concerns 'the effects of the performer's actions on the environment' whereas an internal focus refers to the performer's 'own body movements' (Wulf, Höß, & Prinz, 1998, p. 170). Several experiments revealed that directing attention to movement effects leads to better performance and learning compared with an internal focus condition. For example, Wulf, Höß, & Prinz (1998) asked participants involved in the learning of slalom-like movements on a ski simulator either to direct attention to their feet (internal focus) or to the wheels of the platform located just under their feet (external focus). The external focus condition enhanced learning, compared with the internal focus or control conditions. The beneficial effects of an external focus on motor learning and performance have been replicated for dynamic balance tasks (McNevin, Shea, & Wulf, 2003; Shea & Wulf, 1999; Wulf & McNevin, 2003; Wulf, Weigelt, Poulter, & McNevin, 2003), ball throwing tasks (Wulf, McNevin, Fuchs, Ritter, & Toole, 2000), volleyball

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serve (Wulf, Gartner, McConnel, & Schwarz, 2002), golf shots (Bell & Hardy, 2009; Perkins-Ceccato, Passmore, & Lee, 2003; Poolton, Maxwell, Masters, & Raab, 2006; Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007), basketball free throw (Zachry, Wulf, Mercer, & Bezodis, 2005), baseball batting (Castaneda & Gray, 2007; Gray, 2004), dart throwing (Lohse, Sherwood, & Healy, 2010), displacement on a Pedalo (Totsika & Wulf, 2003), bimanual coordination task (Hodges & Franks, 2000), accurate force production task (Lohse, 2012; Lohse, Sherwood, & Healy, 2011), swimming (Stoate & Wulf, 2011) or vertical jumping (Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010).

These results are interpreted within the framework of the constrained-action hypothesis (Wulf & Prinz, 2001) which states that movements emerge from automatic self-organised processes constrained by the goal of the task. An external focus of attention would facilitate this mode of functioning, whereas an internal focus would engage the participant in a conscious 'unnatural' mode of movement control that is likely to disturb automatic processes. This interpretation is supported by the demonstration that an external focus promotes automatic movement control as revealed by shorter probe reaction times to auditory stimuli during a balancing task under external compared with internal focus condition (Wulf, McNevin, & Shea, 2001).

Thus, the beneficial effect of an external focus of attention on learning and performance seems to be widely encountered in a great variety of motor tasks (Lohse, Wulf & Lewthwaite, 2012; Wulf & Prinz, 2001; Wulf, 2007, 2012) but it is evident that most researchers assessed performance using accuracy scores. Few experimental tasks required participants to maximise movement speed or frequency (Stoate & Wulf, 2011; Totsika & Wulf, 2003; Wulf & Dufek, 2009; Wulf et al., 1998, 2010). Most of them were self-paced (i.e. participants start moving when they are ready) or continuous tasks that did not require short reaction time. However, several researchers have shown that reaction time can be influenced by the instructions given to the participants concerning the direction of attention either to the execution of the response (motor set) or to the stimulus (sensory set) (Buckolz, 1980; Buckolz & Vigars, 1987; Christina, 1973; Henry, 1960; Sidaway, 1994). Nevertheless, until recently, these effects were not studied with respect to the internal/external attentional focus distinction. Only one study demonstrated a beneficial effect of an external focus of attention on pre-movement time (Lohse, 2012) but this advantage was restricted to the very first practice trials of a force reproduction task, and was not revealed in retention and transfer tests.

Thus, the first aim of the present work was to further analyse the effects of external and internal foci of attention on performance in a reaction time task. Since the great majority of previous studies have been centred on movement execution, we wanted to gain an insight into the effects of attentional foci on movement preparation processes occurring during reaction time. Lohse (2012) has proposed that some movement parameters, such as force of contraction, are selected consciously under an internal focus of attention, in addition to the task goal, whereas only the task goal is consciously monitored under an external focus. This greater involvement of conscious processes would result in a longer pre-movement time.

In addition, the sprint start is a complex whole body movement that can be broken down into three subcomponents: preparation before the start signal; block clearance; and running. Block clearance is an explosive action that aims at producing a maximum acceleration and an efficient coordination of the four members (Slawinski, Bonnefoy, Ontanon et al., 2010). Some experimental results suggest that the block clearance and the running stages would be influenced by the type of attentional focus adopted by the athlete. First, Wulf, Dufek and her colleagues (Wulf & Dufek, 2009; Wulf et al., 2010) showed that an external focus of attention resulted in a greater impulse and a higher height reached in a vertical jump task. Second, performances in cyclical speeded tasks such as swimming (Stoate & Wulf, 2011) or displacement on a Pedalo (Totsika & Wulf, 2003) are enhanced under an external compared with an internal focus of attention.

The second aim of our work was to analyse the influence of attentional focus as a function of skill level. Theories of motor learning state that the cognitive and attentional demands of task execution decrease as practice increases (Adams, 1971; Fitts, 1964; Schmidt & Lee, 2005). Although the advantage of external focus over the internal focus of attention has been shown for both expert and novice participants, a few studies obtained the opposite result for novices (Castaneda & Gray, 2007; Gray, 2004; Perkins-Ceccato, Passmore, & Lee, 2003). Various explanations have been suggested for these conflicting results; however, this issue remains unclear. In particular, Castaneda and Gray (2007) showed that novice participants performed better in a baseball batting task under an internal focus of attention (hands movement) than under an external focus (bat movement), unlike expert batters. These authors argued that the use of a dual-task methodology to induce different attentional foci may lead to an additional task demand exceeding novices' capabilities. They suggested that the effects of the focus of attention could depend on the level of time constraints imposed by the task. In the present experiment, we compared the effects of internal versus external attentional focus (prompted by verbal instructions) on performance of the sprint start in expert and novice sprinters. As expert

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sprinters have acquired highly automatised skills for the sprint start, we hypothesised that they would perform faster under an external focus of instruction because an internal focus would disrupt their automatic motor control. Following Wulf's conclusions (Wulf, 2012), we hypothesised that novice participants would perform the sprint start faster under an external focus than under an internal focus of attention. Moreover, we supposed that expert sprinters have acquired efficient attentional strategies (i.e. they concentrate on intended movement effects) that they would use when they have no instructions about attentional focus. Hence, a neutral condition with no instructions about attentional focus was performed first, and post-session interviews were conducted in order to determine the type of attentional focus that participants would spontaneously adopt during the performance of the sprint start. Thus, this study should lead to interesting suggestions for training, such as the type of attentional focus that sprinters should adopt before a race, and the type of instructions that should be used.

Methods

Participants

Sixteen men (20 to 30 years old) volunteered to participate in this experiment. Eight of them were skilled sprinters involved in regional to international level competitions. They all trained in the regional training centre that included only a small number of skilled sprinters. The other participants were involved in football and basketball at a similar level of competition, but had no experience in the sprint start.

All participants knew the task to perform but were naïve as to the precise purpose of the experiment. Participants' informed consent was obtained before they began to participate in the experiment. The experiment was run according to the ethical guidelines for behavioural sciences defined by the French Society of Psychology (Societe Française de Psychologie).

Task and apparatus

Participants had to perform short runs starting with official orders: they had to adopt the previously learnt starting position in the blocks, and at the starter signal, run as fast as possible to the finish line, 10 m further.

The experiment was performed indoor on a 30 m synthetic track. Standard starting blocks were used for all participants. In order to time contact-off of each foot and each hand, FSR pressure sensors (21.2 mm diameter Force Sensing Resistor, Interlink Electronics) were used. The sensors were fixed on the ground, under each block and under each hand. The accuracy of the timing was within 0.002 s. The four signals were recorded via an A/D converter card (10 bits, ± 5 V) and saved in a computer file for offline analysis. The sampling frequency was 1000 Hz. For each trial, the four curves of force as a function of time were displayed by means of homemade software that allowed getting the times at which the pressure was minimal under each limb. This criterion was chosen because it was clearly identifiable for every trial of all participants. If the participant anticipated the start-signal (reaction time shorter than 100 ms), the trial was cancelled and another one was performed.

A photoelectric cell was placed at the 10-m line and was connected to a time-counter to measure the running time (accuracy within 0.01 s).

Data acquisition started between 1 and 2 s after the experimenter gave the 'ready' signal. The start signal was a loud sound that triggered synchronously the A/D converter card and the time-counter.

Procedure

Blocks positions were adjusted to the participant body type, so that the body positioning was similar for all participants. It was the position usually taught by the French track and field coaches and it corresponded to the optimal biomechanical criterions reported in the literature (Harland & Steele, 1997). Participants practised some warm-up trials at the beginning of each session.

The experiment took place in three sessions corresponding to three different instructions concerning the focusing of attention: external focus instructions; internal focus instructions; and neutral instructions. Participants performed five trials in each condition. The number of trials was chosen in order to avoid fatigue effects.

For all participants, the first session corresponded to the neutral instructions condition in which no other instruction than those concerning the starting position and task goal was given to them. At the end of this session, the experimenter questioned the participant about his thoughts at different moments ('on your marks', 'set' and running). This interview was aimed at determining the type of attentional focus that participants adopted when they had no attentional focus instructions.

During the two attentional focus conditions, specific instructions were repeated before every sprint start. In the external focus condition, participants were told: 'Get off the starting blocks as quickly as possible, head towards the finish line rapidly and cross it as soon as possible'. Thus, these instructions referred only to the movement effects. In the internal focus condition, participants were told: 'Push quickly on your legs and keep going as fast as possible while swinging both arms back and forth and raising rapidly your knees'. In that case, instructions contain explicit references to the effectors involved in task execution.

These two conditions took place during the second and the third session; their order was counterbalanced across participants. The sessions were interspaced by a two-day interval. At the end of each session, the experimenter interviewed the participant to verify if he had followed the specific focus instructions. Participants had to answer orally three standardised questions: 'during these five starts, did you comply with the instructions?', 'did you experience any difficulty in focusing your attention according to the instructions?', 'did you think to anything else?' Their answers were recorded with a handheld recorder and transcribed verbatim.

Dependent variables and statistical analysis

Participants' global performance, called total time, was the time between the start signal and the crossing of the finish line.

For each trial, the times collected via the pressure sensors were used to compute the durations of the three stages of the sprint start. The first stage (reaction time) was the time from the start signal to the first hand take-off. The onset of the front foot movement ended the second stage (block clearance). It was followed by the running stage.

All dependent variables were averaged over the five trials and were analysed using a 2 (group) × 2 (condition) analysis of variance (ANOVA), with repeated measures on the last factor. As the neutral instructions condition was always performed first, it was not included in the analysis to avoid possible confounding order effects.

Results

Attentional focus under the neutral instructions condition

Two of the authors coded participants' answers to the interview following the first session (neutral instructions condition) into three categories. Items relating to 'going quickly', or to spatial cues (i.e. forward, ground, blocks) were coded as 'external focus of attention'. Items related to body parts or to the movement were coded as 'internal focus of attention'. The 'other' category comprises items related to both focus or to an attentional focus that was neither external nor internal (e.g. attending to the start signal or thinking to nothing).

Attentional focus during the three stages of the sprint start in the neutral instructions condition is presented in Table I.

Owing to the small size of the groups, it was not possible to run statistical comparisons between experts and novices. However, most participants adopted an internal focus of attention when positioning in the starting blocks and when running. At the 'set' order, participants, especially in the expert group, reported various attentional focus strategies, if any. We can deduce from the individual reports for the three stages, that half of the participants used the same type of focus during the entire sprint start, and half of the participants shifted from one type of focus to another.

Table I. Number of subjects reporting an external focus, internal focus or another type of focus for each stage of the sprint start in the neutral instructions condition.

	External focus	Internal focus	Other
'On your marks'			
Novices	1	6	1
Experts	2	5	1
'Set'			
Novices	4	2	2
Experts	0	1	7
Running			
Novices	0	6	2
Experts	2	5	1

Manipulation check for the experimental conditions

For the two experimental conditions, participants stated that they had succeeded in following the attentional focus instructions. However, in each of the external and internal focus conditions, three subjects in each group reported they had not focused their attention on all the points during one or two of the trials. During the external focus condition, only one expert and two novice participants reported one difficulty in following the instructions in one particular stage, or due to the number of points on which attention had to be focused. During the internal focus condition, one novice participant reported this type of difficulty, and four participants had trouble with the execution (and not with the focusing of attention) of the 'push quickly on your legs' instruction (one expert sprinter and three novice participants). During the external focus condition, one expert sprinter and three novice participants used an additional internal focus, whereas during the internal focus condition, only one novice participant used an additional external focus.

Attentional focus effect on performance indicators

For each dependent variable, means and standard deviations for each group and each condition are summed up in Table II.

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Table II. Mean times (s) in each condition of attentional focus (*SD* in parentheses).

	External focus	Internal focus	Control
Total time			
Novices	2.33 (0.10)	2.44 (0.10)	2.24 (0.08)
Experts	2.18 (0.08)	2.25 (0.06)	2.27 (0.06)
Reaction time			
Novices	0.24 (0.06)	0.27 (0.07)	0.26 (0.04)
Experts	0.21 (0.03)	0.22 (0.04)	0.24 (0.04)
Block clearance time			
Novices	0.33 (0.04)	0.33 (0.04)	0.35 (0.04)
Experts	0.30 (0.03)	0.31 (0.03)	0.30 (0.04)
Running time			
Novices	1.77 (0.08)	1.83 (0.07)	1.81 (0.06)
Experts	1.68 (0.06)	1.72 (0.05)	1.72 (0.04)

Total time

Statistical analysis revealed a significant effect of group, F (1,14) = 16.61, P < 0.01, η_p^2 = 0.54. Experts (M = 2.22 s, SD = 0.08) had shorter total times than novices (M = 2.39 s, SD = 0.11). The effect of condition was also significant, F (1,14) = 33.80, P < 0.0001, η_p^2 = 0.69. Total time was shorter in the external focus condition (M = 2.26 s, SD = 0.12) than in the internal focus condition (M = 2.35 s, SD = 0.12). The group by condition interaction was not significant, F (1,14) = 1.10, P > 0.05.

Reaction time

The effect of group was not significant, F (1,14) = 2.27, P > 0.05. Condition had a significant effect, F (1,14) = 21.89, P < 0.0001, η_p^2 = 0.55. Reaction time was significantly shorter in the external focus condition (M = 0.22 s, SD = 0.05) than in the internal focus condition (M = 0.25 s, SD = 0.06). The group by condition interaction was not significant, F (1,14) = 2.08, P > 0.05.

Block clearance time

The effect of group was not significant, F (1,14) = 2.96, P > 0.05. The effects of condition, F (1,14) = 2.74, P > 0.05, and interaction, F(1,14) <1, were not significant.

Running time

Statistical analyses revealed a significant effect of group, F (1,14) = 10.63, P < 0.01, η_p^2 = 0.43, and of condition, F (1,14) = 23.46, P <0.001, η_p^2 = 0.62, whereas the interaction between group and condition was not significant, F (1,14) < 1. The running time was shorter in the external focus condition (M = 1.72 s, SD = 0.08) than in the internal focus condition (M = 1.78 s, SD = 0.08).

Discussion

The aims of the present study were to analyse the effects of different attentional focus conditions on sprint start performance and to determine if these effects were the same in novice and expert sprinters. The results indicated a beneficial effect of an external focus, compared with an internal focus, on the total time from the go signal to the 10-m line. The time saved in the first part of the race in the external focus condition was important (a total of 0.09 s, with 0.03 s saved on reaction time and 0.06 s on running time) and could be a factor of success in competition. However, this effect was not the same according to the stage of the sprint start. The benefit of the external focus of attention was revealed for reaction time and running time, not for block clearance time. Finally, the effects of attentional focus were not different in novices and expert sprinters.

We will discuss the effects of attentional focus on the performance of the three stages, before discussing their relationship with skill level.

Reaction time

In accordance with our hypothesis, during the sprint start, expert sprinters, as well as novices, had significantly shorter reaction times under an external focus than under an internal focus condition. The present experiment corroborates the results of Lohse's (2012) study that reported an effect of attentional focus on pre-movement time during the first stage of learning of a force production task. These results demonstrate that attentional focus influences not only movement execution but also its preparation.

Several factors are known to influence reaction time and may thus explain this attentional focus effect. First, uncertainty about the response increases reaction time because it develops the informational processing of the response-selection stage (Hick, 1952; Hyman, 1953). However, during the sprint start, there is no uncertainty about the action to be done at the signal. This factor cannot explain the observed effects. Second, reaction time increases with response complexity (Christina, 1992; Klapp, 1996; i.e. with the number of sub-components that must be prepared and initiated). We suggest that attentional focus could influence this factor. In the nodal-point hypothesis, Hossner and Ehrlenspiel (2010) have proposed that an internal focus of attention results in the splitting of the sensorimotor chain in subparts. Although their experiments tested this hypothesis during movement execution, we can suppose that this splitting would result in the preparation of two sub-parts of the action, instead of one forming a functional unit. Klapp and Jagacinsky (2011) named this kind of movement unit a motor

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chunk. They reviewed experimental results showing that a simple reaction time to perform a sequence of movements increases with the number of chunks comprising the sequence. Thus, a longer reaction time under an internal focus could result from the splitting of the movement sequence in several motor chunks, increasing the number of chunks to be prepared before the signal, and thus the time required. Third, as suggested by Lohse (2012), we propose that under an internal focus of attention, participants attempt to plan their movement consciously. Under an external focus, these planning processes would be run automatically, without awareness. As controlled processes are more resource demanding and slower than automatic ones (Shiffrin & Schneider, 1977), the internal focus would result in longer reaction time.

Lastly, Henry (1960) and Christina (1973) proposed that reaction time would be longer when attention was oriented to the execution of the response (motor set) than when it was oriented to the stimulus (sensory set). Similarly, Buckolz (1980) suggested that encouraging the performer to focus attention upon the details of response execution, slows down the response preparation, thereby prolonging reaction time. Thus, we can suppose that an internal focus of attention encouraged the participants to pay attention to the execution of the forthcoming movements, resulting in a weakening of their disposition to react to the go signal.

Running time

As was hypothesised, the duration of the running stage was shorter in the external focus condition than in the internal focus condition. This result demonstrates that the beneficial effect of an external focus of attention, already known for various motor tasks (see Wulf, 2007, 2012 for reviews), extends to speed tasks. In the present experiment, during the internal focus condition, participants received instructions on their arms and knees movements. In line with the constrained action hypothesis (Wulf & Prinz, 2001), we can suppose that these instructions engaged them in a conscious control of their movements, thus disrupting the automatic control mode normally used for running, which is a well-automated skill for all the participants. On the contrary, the external focus instructions, by orienting the participants' attention on the desired outcomes of their action, promoted this automatic, goal-driven control, leading to a better performance.

Block clearance

Unlike the reaction time and the running time, the block clearance time was not influenced by the attentional focus instructions. With reference to Wulf and Dufek's (2009) results about the impulse in a vertical jump task, we hypothesised that block clearance would be faster under an external focus than under an internal focus of attention because of a greater impulse. However, it is possible that under external focus, participants have exerted higher forces on the starting blocks than under internal focus, with the same duration of application. This would result in greater impulse but not in shorter block clearance time (Slawinski, Bonnefoy, Leveque et al., 2010). Thus, future studies will have to compare the effects of different attentional foci on kinematic and kinetic variables in similar tasks.

Influence of expertise level on attentional focus effects

The external focus condition led to shorter reaction times and running times than the internal focus condition for both novice and expert groups. This result confirms that an external attentional focus is beneficial for novice subjects in a task with high time constraints, contrary to the results obtained by Castaneda and Gray (2007) in a baseball-batting task.

Analysis of the verbal reports following the neutral instructions condition revealed that most of the participants, either experts or novices, adopted an internal focus of attention when positioning in the starting blocks and when running. In this condition, participants received no instructions about attentional focus. This neutral condition was performed first for all participants so that they were not influenced by the attentional focus instructions given in the experimental conditions. It is surprising that experienced high-skilled sprinters have spontaneously adopted a focus of attention that is not optimal. The instructions that their coaches usually give to them during training may have influenced their spontaneous focus of attention in this experiment (Porter, Wu, & Partridge, 2010). This hypothesis highlights the negative effects of some types of instructions given during training on subsequent performance, which have been shown by various authors (Masters, 1992; Wulf et al., 1998).

In summary, in this experiment we revealed a beneficial effect of an external focus of attention on performance of the sprint start in both expert sprinters and novice participants. The time saved in the external focus condition compared to the internal focus is not negligible, even for expert sprinters, and this could make the difference in a race. This attentional focus effect was not different in expert and novice sprinters.

The analysis of the performance in the three stages of the sprint start allowed us to study the effects of attentional focus on different motor processes. First,

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the beneficial effect of attentional focus on movement execution was confirmed in the running stage. Second, the shorter reaction time under an external than under an internal focus of attention reveals that the preparation stage of complex movements can be influenced by the focus of attention. From a theoretical point of view, the mechanisms by which attention influences motor preparing and motor execution require further developments.

A limitation of this study lays in the instructions used to induce an external versus an internal focus of attention. The internal focus instructions were based on typical instructions that French track and field coaches give to their athletes during training; the external focus instructions where created by transcribing these 'technical instructions' into movement effects, without reference to the body segments involved in task execution. However, these internal focus instructions may be more complex than the external focus instructions. We cannot exclude that the longer times in the internal focus condition may have been due to a higher load on working memory. Although only one participant in each condition reported a difficulty with focusing on several points, this may have influenced the results.

These present results have important issues on training methods for performance enhancement in novice and expert sprinters. Whatever their skill level, sprinters should use the external focus of attention as a more efficient attentional strategy during a race. Coaches should help the athletes with carefully worded instructions orienting their attention toward the desired movement effects.

Acknowledgement

Manh-Cuong Do is now at the Unité de Recherche Complexité, Innovation et Activités Motrices et Sportives (CIAMS), Université Paris-Sud 11, F-91405 Orsay cedex, France

Note

The authors declare no competing financial interest.

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