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Doctoral Dissertation

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THE EFFECTS OF ATTENTIONAL FOCUS INSTRUCTIONS ON PERFORMANCE AND LEARNING OF MOTOR SKILLS

Doctoral Dissertation

Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Kinanthropology (Motor Control and Learning)

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Abstrakt:

Prvním cílem této disertační práce bylo ověření vlivu pozornostního zaměření instrukcí na motorický výkon v různých typech koordinačních úloh u dětí. Druhý cíl dizertační práce vycházel z předpokladu, že vidění a pozornost spolu úzce souvisí. Proto se práce zaměřila na ověření zrakových informací jako možného mechanismu účinků pozornostního zaměření na dovednostní výkon. S tímto cílem byly provedeny čtyři studie, které zahrnovaly soubory dětí a dospělých a byly založeny na intraindividuálním nebo interindividuálním srovnání. Výsledky ukázaly, že vnější zaměření pozornosti ve srovnání s vnitřním zaměřením pozornosti vede ke zvýšení pohybového výkonu v interceptivních motorických úlohách (např. chytání) u dětí, které se nacházejí v počátečních fázích učení (studie I). Děti, které mají zkušenosti s gymnastikou, by mohly mít prospěch z vnějšího zaměření pozornosti ve srovnání s vnitřním zaměřením pozornosti v úlohách, které vyžadují projekci těla v prostoru a které nezahrnují náčiní pro provedení úlohy (studie II). Současný výzkum ukázal, že mechanismy, které podmiňují výhodu vnějšího zaměření pozornosti, jsou nezávislé na zrakových informacích v diskrétních úlohách, které vyžadují projekci těla v prostoru (např. skoky) (studie IV). Současný výzkum také ukázal, že ačkoli jsou zrakové informace důležité pro úspěšný výkon v průběhu osvojování pohybových úloh spojených s projekcí předmětu (např. házení na cíl), vnější zaměření pozornosti bylo výhodnější než vnitřní zaměření v úlohách, zvláště když úloha užitá v transferovém testu je náročnější (studie III). Výsledky studií v této dizertaci poskytují empirické důkazy o odlišných účincích instrukcí s vnějším a vnitřním zaměření pozornosti.

Klíčová slova: zaměření pozornosti, zrak, instrukce, výkon, učení.

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Abstract:

The first aim of this dissertation was to examine the possibility of the influence of attentional focus instructions on motor performance in different types of coordinative motor tasks in children. Also, as vision and attention are closely related, the second aim of this dissertation was to investigate the role of vision as a possible mechanism underlying attentional focus effects. For these purposes, four studies were carried out on children and adults, using either within subject or between-within subject designs. The results showed that external focus is better than internal focus for enhancing motor performance in an interceptive motor task (e.g., catching) in children who were in the early stages of learning motor skills (study I). In addition, children who had experience of gymnastics could benefit from external focus compared to internal focus of attention in body projection tasks that do not involve an implement for the execution of a task (study II). Furthermore, the current research demonstrated that the mechanisms underlying the advantages of external focus of attention are independent of vision in discrete body projection tasks (e.g., jumping) (study IV). Moreover, the current research showed that although vision is important for successful performance during acquisition of an object projection motor task (e.g., throwing at a target), external focus of attention was more beneficial than internal focus especially when the task was more challenging in the transfer test (study III). The findings of the studies within this dissertation provided empirical evidence on the different effects of external and internal focus of attention.

Keywords: focus of attention, vision, instructions, performance, learning.

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I declare that I have prepared this dissertation independently under the supervision of prof. PaedDr. Rudolf Psotta, Ph.D. I have listed all the literature and professional resources used, and I have adhered to the principles of scientific ethics.

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I would like to express my sincere gratitude to my supervisor prof. PaedDr. Rudolf Psotta, Ph.D. for his continuous support of my Ph.D. study, his immense knowledge and valuable advice during the preparation of the dissertation. My sincere thanks also go to prof. Gabriele Wulf and Dr. William Land for providing me with thoughtful discussions on my research works during my Ph.D. study. In addition, I thank my fellow lab mates and the staff of the Faculty of Physical Culture at Palacký University Olomouc for all their kind support. Last but not least, I would like to thank my family: my parents, my brothers, my sisters-in-law, my nephew and my nieces, for supporting me spiritually throughout my Ph.D. study and my life in general.

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Chapter 1

1.1 Introduction

1.1.1 Optimization of performance and learning of motor skills

Researchers and practitioners who are faced with teaching movement skills have focused on understanding the potential variables that optimize the performance and learning of movement skills. Generally, movement skills can be learned and enhanced by practicing that particular movement skill (Schmidt & Lee, 2011). Besides practice, researchers have shown that intervention programs which manipulate the conditions of learning such as conditions of practice or nature of augmented feedback, i.e. feedback provided by an external source in addition to the individual's inherent feedback, may also facilitate and optimize the performance and learning of various types of movement skills (Mass et al., 2008; Swinnen, 1996; Wulf & Shea, 2004).

In particular, studies have shown that manipulation of the conditions of practice, including the amount thereof such as large versus small (e.g., Park & Shea, 2003, 2005; Shea & Kohl, 1991), distribution of practice consisting of distributed versus massed practice (e.g., Baddeley & Longman, 1978; Shea, Lai, Black, & Park, 2000), practice variability involving variable versus constant practice (e.g., Lee, Magill, & Weeks, 1985; Van Rossum, 1990; Wulf & Schmidt, 1997), and practice schedule consisting of random versus blocked practice (e.g., Lee & Magill, 1983; Shea, Kohl, & Indermill, 1990; Shea & Morgan, 1979; Wulf & Lee, 1993), would also significantly affect performance and learning processes of movement skills.

Furthermore, the nature of the feedback has been shown to be an important factor that impacts on performance and learning processes. In general, two sources of feedback could potentially impact on the performance and learning of a movement skill: inherent (sensory) and augmented feedback (Schmidt & Lee, 2011). Inherent feedback is sensory information that comes from vision, audition, proprioception (e.g., muscle force, length) and kinesthesia (e.g., joint or body positions). This sensory information can impact on the action planning/programming and execution of an ongoing motor action. Augmented feedback is based on information about the performance outcome, which is provided by an external source of information from the environment (e.g., coach, teacher). This information concerns knowledge of results (KR) or knowledge of performance (KP), which influences the forthcoming trials (Schmidt & Wrisberg, 2000; Figure 1).

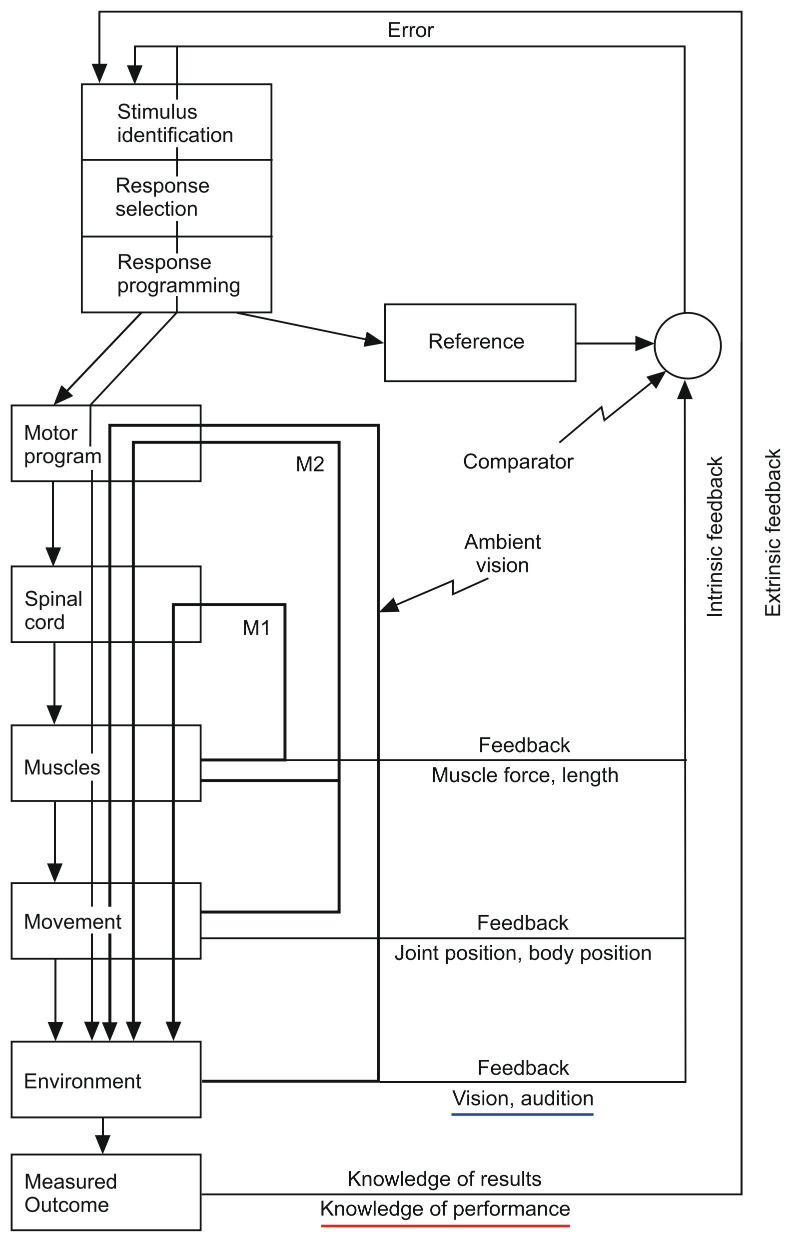

Figure 1. The completed conceptual model of human performance. Reprinted with permission, from R.A. Schmidt and C.R. Wrisberg, 2000, *Motor learning and performance*, 2nd ed. (Champaign, IL: Human Kinetics), p. 291.

All these variables that have an impact on performance and learning processes may manifest different effects during motor skill execution and acquisition. It should be pointed out that motor performance is different from motor learning. Motor performance, i.e., skill execution without a sufficient amount of practice, refers to the level or ability of the performer to execute a particular motor skill which leads to immediate changes in the performance of a movement. Motor learning refers to a process of changing movement performance through adequate instructions, practice or experience, which leads to relatively permanent changes in the performance of a movement (Schmidt & Lee, 2011).

It should be noted that permanent changes in performance which reflect the learning of a new skill should also be observed over time in retention or transfer tests, because other factors (e.g., fatigue, mental distraction, or mind wandering) that are not related to learning may affect the performance outcome during practice (Schmidt & Lee, 2011; Soderstrom & Bjork, 2015). It is also important to know that even though performance changes during practice do not reflect motor learning, they may provide insights into the underlying mechanisms of motor learning processes. Also, some other factors such as age, gender, individual differences and others may affect the performance and learning of different motor skills.

Aside from the effects of conditions of practice or the nature of feedback on motor performance and learning, the individual's focus of attention has been shown to play a critical role on the performance and learning of motor skills. Specifically success in learning motor skills is highly dependent on the performer's concentration on relevant cues or key elements of a motor skill (Singer, Lidor, & Cauraugh, 1994; Wulf, 2007).

1.1.2 Attention and its role on motor performance and learning

Attention has been defined as "the focusing of the mind" (James, 1890). As James characterized "attention is taking possession by the mind, in clear and vivid form, of one out of what seem to be several simultaneously possible objects or trains of thought. Focalization, concentration of consciousness are of its essence. It implies withdrawal from some things in order to deal effectively with others" (James, 1890, p. 403). Eric Kandel (2007) highlights the importance of attention for memory storage and encoding information that results in learning.

The core of attention is concentration. In fact, attention is an umbrella term for concentration. Concentration is the focusing of attention on one particular aspect of the task at hand, which is not interrupted by other distractors (Lavallee, Kremer, Moran, & Williams, 2012). It refers to the ability to control attention, which takes place within the attentional field. The attentional field involves information that originates from both the internal domain, such as internal thoughts, emotions, or physical responses, and the external domain, involving sensory information from the environment such as visual, auditory, and tactile stimuli (cues). Concentration or focus of attention is the ability to direct attention selectively toward internal and/or external cues in the attentional field.

Various motor tasks have different attentional fields. Performers should learn how to focus attention on the cues that are relevant to the execution of a motor task. In other words, performers should be instructed in the way that they are able to ignore or block out potential distractors and concentrate on the task in hand. Nideffer (1976) suggested that appropriate attentional focus would be beneficial for enhancing performance outcome. It has also been suggested that keeping people's attention on the task-goal, which is one type of task-related information, is a fundamental prerequisite for encoding information in memory for the learning of motor skills (Nideffer, 1993).

1.1.3 Attentional focus instructions

Studies have suggested that verbal instructions have a great impact on directing the attentional focus of performers, and influence the performance and learning of motor skills (Landin, 1994; Wulf, 2007, 2013). These verbal instructions are typically provided before practice trials, when performers need to receive information about motor skills. In the next part, the role of attentional focus instructions on motor performance and learning is presented. During the past two decades, numerous experimental studies have shown that attentional focus instructions could have a different influence on the performance and learning of various types of motor skills (for a review see Wulf, 2007; 2013).

In particular, research has shown that verbal instructions and augmented feedback typically given by instructors or practitioners to learners can direct performers' focus of attention to either internal (e.g., concentration on body movements) or external (e.g., concentration on movement effects such as environmental object, feature, location, implement) aspects of a movement task, which can affect the rate of movement *effectiveness* and *efficiency* (Wulf, 2013; Wulf, & Lewthwaite, 2016). On one hand, for example, internal focus is defined when the performer's focus of attention is directed to the manner of execution of body movements and the coordination (technique) of hand movements in a golf putting task or tennis serve, or focusing on the feet while balancing on a stabilometer. On the other hand, external focus is defined when the performer's focus of attention is directed to the motion of the club in a golf putting task or the racquet in a tennis serve, or to the board while balancing on a stabilometer.

The superiority of external focus in comparison with internal focus of attention has been examined and shown in different types of motor skills that involved an object. For instance, external focus has been shown to result in superior performance or learning compared to internal focus in targeting motor skills such as dart throwing (Lohse, Sherwood, & Healy, 2010; Marchant, Clough, Crawshaw, & Levy, 2009), golf putting (Bell & Hardy, 2009; Wulf & Su, 2007); basketball free throw (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002), soccer kick (Wulf, McConnel, Gartner, & Schwarz, 2002, Exp. 2) and throwing tennis balls at a target (Pascua, Wulf, & Lewthwaite, 2015). Additionally, external focus has been found to facilitate performance or learning of a variety of balance tasks that involve an implement, such as maintaining balance on a stabilometer (McNevin, Shea, & Wulf, 2003; Wulf, Höß, & Prinz, 1998, Exp. 2), ski simulator (Wulf et al., 1998, Exp. 1), and riding a pedalo (Totsika & Wulf, 2003). Therefore, it has been repeatedly confirmed that external focus instructions are more beneficial than internal focus instructions for enhancement of object projection motor tasks, such as targeting and balance motor skills that involve an implement (see Wulf, 2013).

As such, research has shown the advantages of external focus over internal focus in body projection motor tasks that do not involve an implement. For instance, external focus was better than internal focus for enhancing performance in long jump (Porter, Ostrowski, Nolan, & Wu, 2010), swimming (e.g., Freudenheim, Wulf, Madureira, Correa, & Corrêa, 2010) and running (e.g., Schücker, Hagemann, Strauss, & Völker, 2009).

Numerous studies on attentional focus instructions have supported the superiority of external over internal focus of attention for the performance and learning of a variety of motor tasks in adults (for a review see Wulf, 2013). However, few studies have examined the effects of attentional focus instructions on typical children (Hadler, Chiviacowsky, Wulf, & Schild, 2014; Perreault & French, 2015, Wulf, Chiviacowsky, Schiller, & Ávila 2010). In children, for example, learning advantages of external focus relative to internal focus were reported for accuracy of a basketball free throwing task in both the acquisition and retention stages (Perreault & French, 2015), as well as forehand tennis strokes in both retention and transfer tests (Hadler et al., 2014) and movement form of soccer throw-in task in retention (Wulf et al., 2010).

Conversely, Emanuel, Jarus, and Bart (2008), have reported that typical children (mean age = 9.04 ± 0.35 years) who were not familiar with the task were more successful in throwing darts at a target under internal focus compared to external focus instructions in transfer tests. Since these controversial results may be due to methodological issues (see Wulf, 2013), it is necessary to carry out more experimental studies on children, using different types of motor skills in order to examine the possibility of generalizing regarding attentional focus instructions to children. Therefore, two experiments in this dissertation (studies I & II) were carried out in order to examine the influence of attentional focus instructions on the motor performance of two different types of motor skills in children.

1.1.4 Hypotheses concerning mechanisms that underlie the effects of attentional focus on motor performance

A few studies have been conducted on understanding the possible mechanisms that underlie the beneficial effects of external compared to internal focus of attention. These potential mechanisms are explained below.

1.1.4.1 *Constrained action hypothesis (CAH)*

One of the possible reasons for the advantages of external over internal focus of attention has been explained by the constrained action hypothesis (Wulf, McNevin, & Shea, 2001). The constrained action hypothesis states that when attentional focus is allocated to body movements, the possibility of disruption in automatic control processes increases, which results in a demotion of performance outcome, whereas directing attentional focus to movement effects within the environment results in a promotion of performance outcome. In other words, internal focus instructions increase the chance for accessing self-evaluation and self-regulatory processing (Wulf & Lewthwaite, 2010). This may produce micro-choking episodes, reducing the fluency of movement that potentially affects automatic control of the movement, with the consequence of degrading performance outcome. On the other hand, external focus instructions promote concentration on the task-goal, whilst excluding self-evaluation processing, resulting in an enhancement of performance outcome (Wulf & Lewthwaite, 2010; Figure 2).

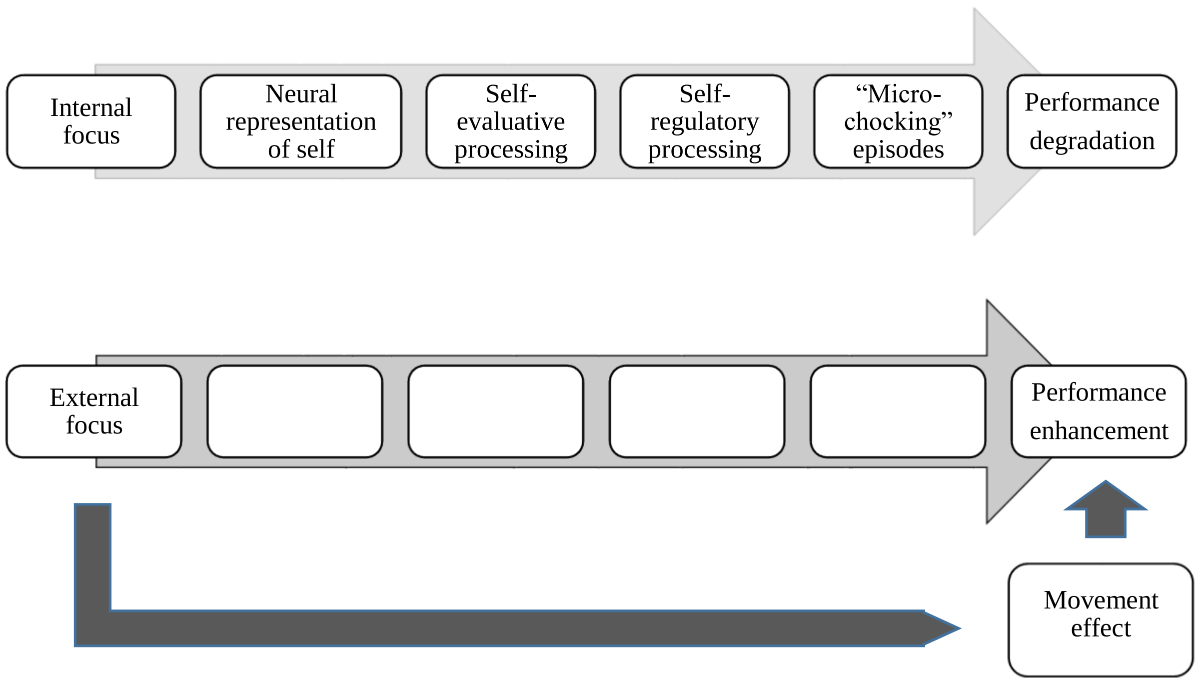

Figure 2. Constrained action hypothesis

Support for the constrained action hypothesis is provided by various studies, which have shown that external focus has increased movement fluency as an indicator of movement automaticity (Kal, van der Kamp, & Houdijk, 2013). Also, individuals in the external focus condition have shown a higher frequency of movement regulation, indicating a higher contribution of reflexes (e.g., McNevin et al., 2003), and higher correlations among dimensions of body movements, resulting in reduced variability in the performance outcome (Lohse, Jones, Healy, & Sherwood, 2014). In addition, adopting external focus instructions produced optimal force production using less muscular activities (e.g., Lohse & Sherwood, 2012; Marchant, Greig, & Scott, 2009), and affected instant modulation of intracortical inhibition within the primary motor cortex, resulting in enhanced movement efficiency (Kuhn, Keller, Ruffieux, & Taube, 2017). The evidence shows that an external focus accelerates the rate of achieving movement coordination, which influences the optimization of performance outcome, whereas an internal focus prevents the progress of achieving movement coordination, thus limiting achievement of the optimal performance outcome. It has also been proposed that in situations where there is no implement or external cues, 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 (Wulf, Lauterbach, & Toole, 1999).

The constrained action hypothesis emerged from "*the common-coding theory"* (Prinz, 1990, 1997). According to this theory, a commensurate coding procedure for action planning in relation to perception occurs when afferent and efferent codes are generated and maintained at a distal level of representation of an action. Specifically, directing attention to the intended movement outcome produces a more optimal connection between motor representation of an action and representation of the action goal.

The constrained action hypothesis could also be interpreted from the dynamic system approach, i.e., when precision of the task performance increases, external focus is less disruptive than internal focus on the subordinate levels of the central nervous system that are responsible for coordination and control of movements. In fact, external focus compared to internal focus of attention allows self-organizing system dynamics to function in the most optimal fashion for coordination and control of movement. In other words, external focus instructions encourage self-organization processes to function in the most effective fashion (Peh, Chow, & Davids, 2011).

1.1.4.2 *Mediating or moderating role of vision on attentional focus instructions?*

Vision as the main source of sensory information plays a critical role in controlling motor actions. It has been suggested that motor actions are controlled via either open-loop (feedforward) or closed-loop (feedback) control systems. As attention and vision are closely related (Gottlieb, 2012), the use of visual information in different types of motor skills may also influence planning and programming of an action when individuals respond to different attentional focus instructions. It has been suggested that an alternative explanation for the advantages of external focus over internal focus might be due to the mediating role of visual information (Hodges & Ford, 2007; Maurer & Zentgraf, 2007; Russell, 2007). This suggestion is based on studies that have shown that gazing at a target before initiation of movement is more useful for motor performance (Vickers, 2007). Hence, some researchers have proposed that external focus of attention compared to internal focus of attention might increase the perception of specific visual information on the target (Hodges & Ford, 2007). Also, based on studies that have shown that optic flow is critical for postural control (e.g., Lishman & Lee, 1973), it has been suggested that external cues may change optic flow in comparison with internal focus on body movements, which limits the perception of relevant optical information (Russell, 2007). In other words, internal attentional focus instructions may disrupt the visual information processing of a performer’s visual perception system.

It should be noted that researchers have presented different classifications of motor skills (Schmidt & Lee, 2011). In this dissertation, projection of body versus projection of an object has been considered one of the criteria for classification of motor skills (Gallahue, Ozmun, & Goodway, 2012; Haywood, Roberton, & Getchell, 2012) in regard to attentional focus instructions. It is also important to highlight that object projection actions are discrete ones (e.g., dart throwing, or golf putting tasks, interceptive tasks), whereas body projection motor tasks could be performed in a discrete (e.g., countermovement jump), serial (e.g., balance on stabilometer, gymnastics routine) and continuous (e.g., walking, running) fashion.

Previous studies have shown that the underlying mechanisms that cause the beneficial effects of external focus instructions are independent of vision for discrete object projection motor actions such as targeting tasks (Land, Tenenbaum, Ward, & Marquardt, 2013; Schlesinger, Porter, & Russell, 2013; Sherwood, Lohse, & Healy, 2014). It should be noted that discrete object projection motor tasks typically use an open-loop (feedforward) control system, which is less dependent on visual information for motor planning/programming of the movement. Other types of object and body projection motor skills may use a different motor control system or may involve different use of visual information. For example, discrete body projection actions (e.g., jumping) are also controlled by an open-loop control system for motor planning/programming, however, they are more dependent on visual information for motor execution in order to monitor body position in space and also for landing. Therefore, it is necessary to investigate the influence of attentional focus instructions and vision in other types of object and body projection motor skills.

It is also important to investigate the influence of attentional focus and visual inputs on motor performance and learning in different coordinative types of motor tasks. As the outcome of movement is one of the four sources of information for correcting the motor program (Mass et al., 2008), the influence of attentional focus and visual feedback on the movement outcome provides an insight into the possible moderating role played by visual information on motor planning and programming in different types of coordinative motor tasks. Therefore, two experiments in this dissertation (studies III & IV) were carried out in order to investigate the influence of attentional focus and vision on motor performance in two different types of motor skills.

1.2 Purpose of this dissertation

The main purpose of the current dissertation was to examine the effects of different types of attentional focus instructions, i.e. internal and external focus, on motor performance and learning of different coordination types of movement tasks such as object projection skills (aiming, catching) and body projection skills (e.g., vertical jump, gymnastic jump with turn). Studies I and II were carried out to examine the possibility of generalizing with regard to the beneficial effects of external over internal focus of attention in two different coordinative types of motor skills in children. Specifically, the effects of attentional focus instruction on motor performance were examined in an interceptive motor task (catching), which requires a higher demand on visual information to predict the optimal time of contact to move and adjust the position of the hands in time to conform to the trajectory of the ball (Gentile, 2000; study I). In addition, the effects of attentional focus instructions on enhancement of movement outcome and movement form in a body projection motor skill were examined (study II). Another aim of this dissertation was to investigate the role of visual information as a potential mechanism that underlies the effects of attentional focus instructions on motor skills execution (study III & IV). Different tasks were chosen in the studies under this dissertation, as previous studies have shown that the beneficial effects of external over internal focus of attention are independent of task constraints in different coordinative types of motor tasks (Wulf, 2007, 2013; Wulf & Lewthwaite, 2016).

1.2.1 Study I

Is an external focus more beneficial than an internal focus of attention to ball catching in children? (Abdollahipour & Psotta, 2017)

The majority of previous studies have examined the effects of attentional focus instructions on the performance and learning of discrete object projection motor skills such as targeting tasks (Hadler et al., 2014; Perreault & French, 2015). It should be noted that targeting tasks are considerably controlled via an open-loop (feedforward) control system for action planning. Actions that use a feedforward control system usually are planned to perform the task without using online sensory feedback (Kawato, 1999). Open-loop actions are usually rapid and discrete, and they are not substantially dependent on using online feedback via other sources of sensory information, including vision (Desmurget, & Grafton, 2000).

Interceptive motor skills such as catching are also controlled by an open-loop (feedforward) control system. However, these kind of interceptive motor skills (i.e., catching) are more dependent on visual information for anticipation of action, as well as the adoption of spatial-temporal movement coordination to adjust the position of the hands in time to conform to the trajectory of the ball and avoid potential errors during the task performance (Schmidt & Lee, 2011). Therefore it was necessary to examine the effects of attentional focus instructions on interceptive motor skills which place a higher demand on visual information. Also, most of the previous studies on the effectiveness of attentional focus instructions were carried out on targeting and balance tasks in adults (for a review see Wulf, 2013), and few studies on targeting tasks in children (Hadler et al., 2014; Perreault & French, 2015; Wulf, Chiviacowsky, et al., 2010). For this reason, we conducted an experiment on the effects of attentional focus instructions on an interceptive motor task (e.g., catching) in children (Abdollahipour & Psotta, 2017). As proposed in CAH, the mechanisms that underlie attentional focus instructions represent a cognitive process that is independent of visual information. Therefore, the dependency of motor tasks on visual information may not have an influence on the advantages of external focus over internal focus of attention. As a result, the following hypothesis was proposed for study I:

H 1: External focus of attention is more beneficial than internal focus of attention for motor performance in an interceptive motor task (catching) in children.

1.2.2 Study II

Performance of gymnastics skill benefits from an external focus of attention (Abdollahipour, Wulf, Psotta, & Palomo Nieto, 2015)

Study II was carried out due to the gap in the literature on the effects of attentional focus instructions on body projection motor tasks that do not involve an implement. Although numerous studies have supported the benefits of external over internal focus of attention in motor tasks that involve an implement, few studies have been conducted on motor skills that do not involve an implement. For example, external focus instructions were more beneficial than internal focus for enhancing performance outcome in swimming (Freudenheim et al., 2010) and long jump (Porter et al., 2010). However, no study had been conducted about the effects of attentional focus on motor tasks that do not involve an implement, requiring perfect movement form (e.g., gymnastics skills). This gap in the literature 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). It is also critical to find an external cue for these kind of motor skills. As a result, there was a question about the possibility of generalizing the beneficial effects of external focus over internal focus for motor tasks in which not only performance outcome is critical, but also movement form. To fill this gap in the literature we carried out an experiment using a gymnastics skill (i.e., jump and half turn) under different attentional focus instructions (Abdollahipour et al., 2015). Also, due to the importance of providing appropriate instructions for experienced athletes to enhance their performance, it was also interesting to examine the effects of attentional focus instructions on the immediate performance of young experienced gymnasts in terms of both movement outcome and movement form. Therefore, performance outcome (jump height) and movement form (execution deduction) were assessed in order to understand the effects of different attentional focus instructions. The following hypothesis was proposed for study II:

H 2: External focus of attention is more beneficial than internal focus of attention for enhancing motor performance in a discrete body projection motor task that requires movement form.

1.2.3 Study III

Effects of attentional focus instructions on the learning of a target task: A moderation role of visual feedback (Abdollahipour et al., 2014)

An interesting issue concerning the interactions of vision and attentional focus is the role of visual feedback on movement outcome as a possible moderator for upgrading the motor program in Schmidt's conceptual model of human performance. According to Schmidt's schema theory of motor learning (Schmidt, 1975, 2003; Schmidt & Lee, 2011), availability of movement outcome (KR) is necessary for updating the motor schema. In other words, when access to movement outcome is limited, the chance for updating the motor schema will be decreased (Mass et al., 2008). Therefore, it is interesting to understand to what extent access to visual feedback on movement outcome would impact on the influence of attentional focus instructions. Therefore, the role of vision as a possible moderator of attentional focus instructions should be investigated more deeply in object projection motor tasks that are dependent on a feedforward control system for motor control (i.e., targeting tasks). For this reason, we carried out an experiment using a dart throwing task (Abdollahipour et al., 2014). In this study we manipulated the availability of visual feedback (vision vs. non-vision conditions) on the results for participants under different attentional focus instructions.
The following hypotheses were proposed for study III:

H 3: The advantages of external over internal focus of attention on learning of an object projection motor task (dart throwing) is not affected by the availability of visual feedback.

H 4: External focus of attention is more beneficial than internal focus of attention for motor learning of an object projection motor task (dart throwing).

1.2.4 Study IV

The influence of attentional focus instructions and vision on jump height performance. (Abdollahipour, Psotta, & Land, 2016)

Another aspect of the interactions of vision and attentional focus is the role of inherent visual feedback as a possible mediator for upgrading the motor program in Schmidt's conceptual model of human performance. In the cycle of inherent feedback, visual feedback from the environment provides information about the location of the object, changes in the dimensions of the object, or the position of the body in space. Therefore, there is a question as to how attentional focus instructions affect visual perception and thus execution of a discrete body projection action (e.g., jumping). Previous studies have shown that vision does not interact with attentional focus instructions in discrete object projection actions.

These studies have shown that although performance under full vision compared to non-visual condition is better, the beneficial effects of external focus instructions remain constant regardless of visual information. As vision is more critical for discrete body projection actions (e.g., jumping) due to its provision of information about the position of the body in space, the interactive role of attentional focus instructions and vision in these types of motor skills remained unclear. To answer this question, we carried out a second experiment with a body projection motor skill (i.e., jump) under full vision and non-vision conditions under different attentional focus instructions (Abdollahipour et al., 2016). Performance outcome (jump height) was assessed by an optical device (Optojump Next) in order to understand the possible interactions of attentional focus and vision. The following hypothesis was proposed for study IV:

H 5: The advantages of external over internal focus of attention do not depend on vision in body projection motor tasks.

Chapter 2

2.1 Methods

Detailed information about the methods has been described in the method section of each article. The subjects' characteristics, the tasks and the effect studied for all experiments are presented in Table 1.

2.1.1 Participants

All the participants were healthy. Informed consent was obtained from the participants before the experiments. All the studies were approved by the ethical committee of the Faculty of Physical Culture, Palacký University Olomouc.

Table 1. Participants' characteristics, task and effect studied in experiments I, II, III, & IV

Study	N	Characteristics of subjects	Age (years)	Task	Effect studied
I	24	Children	8.8 ± 0.8	Catching	Performance
II	24	Trained children	12.0 ± 2.1	Jump and ½ turn	Performance
III	100	University students	21.1 ± 2.1	Dart throwing	Learning
IV	24	University students	25.0 ± 3.3	Jumping	Performance

Due to the different purposes of each study, children participated in studies I and II, and young adults took part in studies III and IV. In studies I and II, children were tested with regard to the possibility of generalizing concerning the beneficial effects of external focus compared internal focus. In studies III and IV, young adults were used, as the purpose of the studies was to investigate the underlying mechanisms of attentional focus instructions. An a priori power analysis was conducted in each study in order to verify that there was a sufficient number of participants for identifying the significant effect of the independent variables on dependent variables according to the design of each study, considering minimum power (1 - b) of 0.90, effect size of 0.25, and an α of 0.05 (Faul & Erdfelder, 1992).

2.1.1 Tasks

In studies I and II, two different coordination types of discrete object projection motor tasks, i.e., an interceptive timing motor task (catching) and a body projection motor task, namely jump and half turn, were applied to children.

In studies III and IV, two discrete types of object projection motor task, i.e., dart throwing task, and a body projection motor task, i.e. countermovement jump, were also used in adults.

2.1.2 Apparatus

Different devices were used in each study. In study I, a tennis ball throwing machine (Lobster Elite Grand 4, Lobster Sports, Inc., North Hollywood, CA, USA) was used. The software of the tennis ball machine was adjusted to throw the tennis balls at the same angle at the moment of release, in which the balls arrive at the level of the participant's chest area. Also, the speed of the balls for the tennis ball machine was set at the same speed at the moment of release. To obtain the accuracy of the tennis ball machine, the speed of the balls thrown by the tennis machine was measured with a radar gun (Stalker Radar, Applied Concepts, Inc., Dallas, TX, USA) before the experiments. All the catching trials were recorded using two cameras (Panasonic HDC-TM900, Panasonic, Kadoma, Japan) at a frequency of 50 Hz, positioned 3 m to the left and right sides of the participants. The cameras were mounted on tripods at a height proportional to the shoulder height of the participants.

Also, the check list of movement assessment battery for children – the second version (Henderson, Sugden, & Barnett, 2007) for the age band 7-10 was used by physical education teachers to assess the level of motor skills and for screening of potential motor impairments. *The exclusion criteria* for participation of the children were any perceptual, visual, physical or mental disabilities, as well as psychological and specific developmental disorders. These exclusion criteria were checked according to the report provided by the school psychologist, special educators and teachers of the schools. In addition, potential developmental coordination disorder (DCD) or moderate to significant motor difficulties of the children were checked by two diagnostic methods: 1) the MABC-2 Checklist (Henderson et al., 2007), in the Czech version (Psotta, 2014), to assess criterion B for the diagnosis of DCD (according to DSM 5th ed., APA, 2013); 2) the MABC-2 Test (Henderson et al., 2007; Czech version of the MABC-2 Test, Psotta, 2014) to assess criterion A for DCD.

In studies II and IV, an Optojump Next instrument (Optojump Next, Version 1.3.20.0, Microgate, Bolzano, Italy) was used to record jump height. The Optojump consists of 2 transmitting and 2 receiving bars (100 × 8 cm) that were joined together. Each bar contains 96 light-emitting or light-receiving diodes (approximately one every centimeter) that were located 3 mm above floor level. The series of transmitting and receiving bars was placed on the floor opposite each other. The participants jumped between the bars. Data was sampled at 1000 Hz and processed into 1D footfall patterns using dedicated software. The validity of the Optojump data has already been proven in previous research (Glatthorn et al., 2011). In study II, all jumps were also recorded by a video camera mounted onto a tripod at a distance of 3 m and at a 45 degree angle. The recordings were used for later ratings of movement form. Each rater judged each jump execution according to the general and specific regulations of the FIG-COP (2009-2012) for aerobic gymnastics.

In study III, a dartboard and some darts were used. The dartboard was 40 cm in diameter, with nine concentric rings, each 2 cm in width, and a 2 cm diameter bull's-eye in the center. These concentric rings are designed to assess the accuracy of each dart throw in terms of distance to the bull's eye. The dartboard was installed so that the bull's-eye was 1.70 m above the floor and the participants stood 2.50 m from the dartboard.

2.1.3 General procedure

Informed consent was obtained from the participants before they took part in the experiments. The experiments were conducted in a gymnastics hall on a standard surface (Conipur KF protect+, Conica, Schaffhausen, Switzerland). The participants received basic information about each task before all the experiments. The protocols of each experiment were explained to the participants in the same manner. The participants had an equal number of warm-up trials before the beginning of the experiments in order to familiarize themselves with the task. Rest intervals were provided equally to all the participants between trials. Attentional focus instructions were given before each trial. In all the studies, the participants were not asked for visual fixation on the objects or cues under external focus instructions. The participants were not provided with feedback about their performance. They were thanked for taking part in the study after finishing each experiment.

2.1.4 Specific procedure

A summary of the specific procedures used in studies I to IV is presented in Table 2. Studies I, II and IV were conducted in a within-subject design, with repeated measurements on trials in one day. Study III was conducted in a between-within subject design, with repeated measurements on trials in two days. In study III, the participants received attentional focus instructions for acquisition of the motor task on day 1. Also, retention and transfer tests without giving any attentional focus instructions were applied for examining the learning process on day 2.

The number of trials was calculated according to the purpose of each study and experimental designs. Also, pilot experiments were conducted to estimate the sufficient number of trials for the effects of independent variables on dependent variables. The purpose of studies I, II and IV was to assess motor performance in a within-subject design, therefore, the number of trials was lesser. In study I, each participant was required to perform 10 catching trials in each attentional focus condition. In study II, each subject performed 5 jump and ½ turn in each attentional focus condition.

In study III, the purpose of the study was manipulation between attentional focus instructions and vision during the acquisition phase, and to test the effects in retention and transfer tests. The participants were asked to perform 42 dart throwing trials in different attentional focus groups on day 1. They were asked to perform 7 trials for either retention or transfer tests on day 2. In study IV, each subject was asked to perform 6 jumps under each attentional focus condition. In each attentional focus condition, 3 jumps were performed with full visual information and 3 jumps were performed without using visual information.

2.1.5 Dependent variables

In study I, the dependent variable was children’s motor performance of catching, indicated by the mean score out of ten catches. The child’s performance was assessed by two independent researchers via video analysis, according to three criteria used by Cesqui, d’Avella, Portone, and Lacquaniti (2012). In studies II and IV, the mean jump height in each attentional focus condition served as a quantitative measure. Maximum vertical jump height (cm) for each trial was provided by Optojump software. In study II, movement form was also assessed by two experienced gymnastics judges. In particular, deductions were made for incorrect body alignment, uncontrolled feet position, legs/feet bent or apart, incomplete rotation, uncontrolled arm movements and incorrect landing. The raters' (jointly agreed upon) deductions for each trial were used as a measure of movement quality or form. In study III, the mean score of dart-throwing accuracy achieved in each block during the acquisition phase on day 1, and the mean score of dart-throwing accuracy for retention and transfer tests on day 2, served as dependent variables.

2.1.6 Data analysis

In the first step, data was analyzed in order to search for any possible extreme outliers. A criterion (cut-off scores) was applied, determined by a distance of 1.5 times the interquartile range from the 1st and 3rd quartile (Tukey, 1977). In the next step, assumptions of normality were tested using a Shapiro-Wilk test (alpha = .05).

For all the studies, data was analyzed using an analysis of variance with repeated measures (RM ANOVA) based on the number of trials and research designs, including within-subject design (studies I, II, and IV) or between-within subject design (study III). The assumptions of sphericity were assessed by Mauchly's test. Bonferroni corrections were performed for all adjustments. Greenhouse-Geisser epsilon values were used when appropriate in order to adjust the degrees of freedom to compensate for deviations from the assumption of sphericity. In addition, Bonferroni *post hoc* test was performed where appropriate and if the ANOVAs were significant. The alpha level was set at .05 for all the statistical tests. The data analyses were performed using the statistical software SPSS-21 (IBM, USA).

2.2 Original manuscripts

Study I:

Abdollahipour, R., & Psotta, R. (2017). Is an external focus more beneficial than an internal focus of attention to ball catching in children? *Kinesiology*, *49*, 235-241.

IS AN EXTERNAL FOCUS MORE BENEFICIAL THAN AN INTERNAL FOCUS OF ATTENTION TO BALL CATCHING IN CHILDREN?

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Original scientific paper
UDC: 159.952-053.2:796.012.576

Abstract:

The performance benefits of adopting an external relative to an internal focus of attention have been demonstrated for many different targeting and balance tasks. No study has examined attentional focus effects for interceptive motor skills. Also, the majority of studies have used adult participants. In this study, children (mean age: 8.75 years, *SD*=0.79; 15 girls, 9 boys) were required to catch tennis balls in the frontal plane under different external focus (EF), internal focus (IF), and control (Cont) conditions. Participants were asked to stand behind a yellow line (2 × 100 cm), placed at a distance of 15 m from a tennis ball throwing machine. In a within-participant design, participants performed 10 trials under each IF ("concentrate on your hands"), EF ("concentrate on the ball"), or Cont (no focus instructions) conditions. The order of conditions was counterbalanced. Performance data were analyzed using a one-way analysis of variance (ANOVA) with repeated measures on attentional focus conditions (internal, external, and control) (alpha=.05). Catching performance was significantly different and more effective in the EF (*M*=1.53, *SD*=0.25) than IF (*M*=1.39, *SD*=0.35) condition, while both EF and IF were not significantly different from the Cont (*M*=1.49, *SD*=0.28) condition. There was no difference between the Cont and IF conditions. The current findings suggest that the external focus of attention is more beneficial, compared to the internal focus, to motor performance of an interceptive motor skill in children.

Key words: *attentional focus, instructions, motor performance, interceptive skills*

Introduction

In order to enhance performance and learning of motor skills, verbal instructions and augmented feedback are probably the most important forms of information that direct performer's focus of attention to specific aspects of a motor task. Current research on attentional focus instructions suggests that the optimal performance outcome can be reached when the performer's concentration is directed to the movement effects, i.e., an external focus (EF) rather than body movements, i.e., internal focus (IF) (see Wulf, 2007, 2013; Wulf & Lewthwaite, 2016). To explain this notion, it has been proposed that an external focus of attention on the intended movement effects promotes concentration on the task-goal, which impacts the optimization of goal-action coupling (Wulf & Lewthwaite, 2016). More specifically, as it has been suggested by the constrained action hypothesis (Wulf, McNevin, & Shea, 2001) about the underlying mechanisms of attentional focus effects on motor control, concentration on the intended movement effects or object (EF) decreases the performer's conscious processes with consequence of facilitation in automatic control processes associated with neuromuscular coordination. In contrast, concentration on bodily movements (IF) raises the performer's conscious processes with the increased chance for interruption in automatic motor control processes.

Studies have supported the constrained action hypothesis by showing that indicators of more advanced motor performance were found under EF rather than IF. For example, it has been shown that EF has increased movement fluency and regulation as indicators of movement automaticity (Kal, van der Kamp, & Houdijk, 2013), correlations among body dimensions with the consequence of reduced variability in the performance outcome (Lohse, Jones, Healy, & Sherwood, 2014), frequency of movement regulation that indicates higher contribution of reflexes (e.g. McNevin, Shea, & Wulf, 2003), optimal and economical use of muscular activities (e.g. Lohse & Sherwood, 2012; Marchant, Greig, & Scott, 2009), and instant modulation of intracortical inhibition within the primary motor cortex (Kuhn, Keller, Ruffieux, & Taube, 2016). The evidence shows that EF accelerates the rate of movement coordination with the consequence of optimizing the task outcome, whereas IF decelerates progress of movement coordination with consequence of preventing performers from achieving the optimal task outcome.

Numerous pieces of research on attentional focus instructions have supported the superiority of EF over IF of attention for the performance and learning of a variety of targeting and balance motor tasks in novice adults (for a review see Wulf, 2013), and in typical children (Hadler, Chiviacowsky, Wulf, & Schild, 2014; Perreault & French, 2015; Wulf, Chiviacowsky, Schiller, & Ávila, 2010). In the current research we chose an interceptive motor task, i.e., two-handed catching task since there is no study about the effects of attentional focus instructions on *interceptive motor skills* (i.e., catching) in *children*. Particularly, for a successful catch the performer needs to predict the optimal time to move and adjust the hands' position in time to conform to the trajectory of the ball (Gentile, 2000). Also, it should be noted that in catching both visual and movement control processes should be continuously updated according to spatial-temporal conditions of the object (Vickers, 2007). Moreover, a functional bimanual co-ordination of the movements of the hands is necessary due to the high demand for coordination of various degrees of freedom (Davids, 2002; Tayler & Davids, 1997). These highlight a relatively higher demand on adaptation of spatial-temporal movement coordination that occurs with rapid adjustments in motor commands in the process of action planning and programing (Gentile, 2000; Magill, Chamberlin, & Hall, 1991). These adjustments in the process of action planning and programming may rapidly impact on relocation of the performer's attention (Hassan, Dowling, & McConkey, 2014; van der Kamp & Renshaw, 2015) and consequently on the performance outcome.

It should be pointed out that the targeting skills such as basketball free throw (Perreault & French, 2015), soccer throw-in task (Wulf, et al., 2010), forehand tennis strokes (Hadler, et al., 2014), and balance motor skills such as riding a pedalo (Flores, Gomes Schild, & Chiviacowsky, 2015) are predominantly controlled by either predictive or prospective control systems. Whereas during performance of interceptive motor skills (i.e., catching), a simultaneous combination of both predictive and prospective control systems is necessary for optimal performance of the action (Panchuk & Vickers, 2009). Therefore, it is questionable which type of attentional focus instructions is more beneficial to the motor tasks that require the rapid adaptation of motor commands for selection of the appropriate motor response (i.e., catching).

Catching is a complex fundamental developmental motor skill that influences involvement of children in sport games during childhood (Heywood & Getchell, 2014). Therefore, providing appropriate instructions for children facilitates performance and learning of catching which leads them to a more active life. Thus, the purpose of the present study was to examine the effects of different attentional focus instructions on execution of an interceptive motor task in school-age children. Specifically, we were interested in understanding whether the beneficial effects of external compared to internal attentional focus instructions could also be found in the performance of a catching task in typically developing children. In the current research we assumed that for an optimized perception-action coupling and successful catching performance, the instructions that direct the attentional focus of performers to the object (e.g. ball) would be more beneficial than the instructions that direct attentional focus of performers to coordination of bodily movement patterns (e.g. hands) in children.

Methods

Participants

Twenty-four children, including fifteen girls and nine boys (mean age: 8.8±0.8 years) participated in the study. The participants were selected from mainstream elementary schools of Czech Republic that adopted the same National Education Curriculum including the program for physical education (PE). Before the catching task, the PE teachers carried out the screening of potential participants. Only the children whose performance grades during the PE classes were below the average grade of the education system were selected for the study. Although children may have had previous experience with similar tasks, they did not have any experience with the task used in this study. Also, the check list of movement assessment battery for children – second version (Henderson, Sugden, & Barnett, 2007) for the age band 7-10 was used by PE teachers to assess the level of motor skills, and screening of potential motor impairments. According to the traffic light system in each age band, only children who were classified in the green zone indicating no detected movement difficulty were included in this study. Moreover, only healthy children without general medical diseases or neurological dysfunction, perceptual, mental and physical disabilities, developmental coordination disorders and *attention deficit hyperactivity disorder* were included in the study. Children were not aware of the purpose of the study. The study was approved by the ethical institutional review board of the university. Informed consent was obtained from the school principals and the parents of the children.

Apparatus and task

The task was two-handed catching of the tennis balls thrown by a tennis ball machine (Lobster Elite Grand 4, Lobster Sports, Inc., North Hollywood, CA, USA). Children were asked to catch the tennis balls in the frontal plane. Each child completed 30 catching trials in three blocks of ten trials under each attentional focus condition in the gym hall. There was a 15-second break between trials during which participants received one of the attentional focus instructions. To avoid the effects of mental and/or physical fatigue on the performance a 1-minute break was applied between each block of 10 trials. The software of the tennis ball machine was adjusted to throw the tennis balls at the same angle of 40° at the moment of release at an initial height of 30 cm from the ground in which the balls arrived at the level of the participant's chest area (see Figure 1).

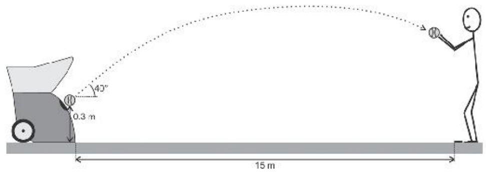

Figure 1. The schematic presentation of catching task.

The speed of the balls for the tennis ball machine was set at 26.00 mph at the moment of release. To obtain the accuracy of tennis ball machine, the speed of the balls thrown by the tennis machine was measured with a radar gun (Stalker Radar, Applied Concepts, Inc., Dallas, TX, USA) before the experiments. The results showed that the average speed of the balls at the moment of release was 26.00±0.94 mph. The pilot results showed the accuracy of ball machine within a circular area with radius of 0.3 m in the frontal plane. A specific sound was made by the machine when each ball was thrown from the machine. This condition was identical for all trials and attentional focus conditions. All the catching trials were recorded using two cameras (Panasonic HDC-TM900, Panasonic, Kadoma, Japan) at a frequency of 50 Hz positioned 3 m to the left and right sides of participants. The cameras were mounted on tripods at a height proportional to the shoulder height of the participants.

Procedure

At the beginning of the experiment children were asked to stand behind a yellow line (2 cm width × 100 cm length) that was located 15 m away from the tennis ball machine and to be ready to catch the ball. The correct form of the catching task was demonstrated to the participants by the experimenter. Then, each participant performed two practice trials to become familiar with the task. Then, in a within-subject design they were required to perform 10 trials under the IF ("Concentrate on your hands"), EF ("Concentrate on the ball"), or Cont (no focus instructions) conditions. It is necessary to highlight that children were not asked for having visual fixation on the ball under EF instructions. Also, in the case that participants were looking at their hands under IF condition, they were told not to look at their hands to ensure that any effect of IF is due to attention and not to interference with visual processes required for catching the ball. The order of the focus conditions for execution of catching task was counterbalanced.

Interviews were carried out with each child after each block of ten trials for each focus condition and the answers were recorded. All the children were asked the two following questions after 10 trials completed under EF or IF conditions, respectively. The first question for the EF condition was "Did you concentrate on the ball?" and for the IF condition was "Did you concentrate on your hands"? The first question for Cont condition was "What did you concentrate on?" The second question for all attentional focus conditions was "On a scale from 1 (not at all) to 5 (extremely), to what extent did you concentrate?" The answers were analyzed to identify to what extent the participants adopted the attentional focus instructions.

Dependent variables

The dependent variable was children's motor performance of catching indicated by the mean score out of ten catches. The child's performance was assessed by two independent researchers via video analysis according to three criteria used by Cesqui, d'Avella, Portone, and Lacquaniti (2012). Specifically, 2 points were awarded for a definite catch of the ball with both hands without the ball falling from the hands; 1 point was given when the ball was touched with the hand(s) but not caught; and 0 point was given for no contact between the hand and the ball. The ratings were compared by the first author subsequently. In the case of two-interrater discrepancy of scores in each trial, the raters were asked to re-analyze a given video sequence and achieve a consensus. The kappa coefficient showed a high inter-rater agreement between the two researchers (κ=.926). The researchers in the role of raters were not aware of the purpose of the study nor of the attentional focus conditions.

Data analysis

To measure the movement functionality associated with catching performance, the mean scores of catching performance across trials were calculated as the performance outcome for each participant in the different attentional focus conditions. In the first step, the Shapiro-Wilks test was used for the assessment of data distribution normality. The results showed that mean scores of catches were distributed normally for all attentional focus conditions.

The data were analyzed using a one-way analysis of variance (ANOVA) with repeated measures on attentional focus conditions (IF, EF, and Cont). The results of Mauchly's test for evaluation of the sphericity assumption showed that there was no violation for the assumption. To test all *post-hoc* comparisons, the Bonferroni adjustments were used. Estimates of effect size were calculated using two measures. First, partial eta squared (η_p^2) was utilized (Larson-Hall, 2009). Then, Cohen's *d* was employed as a measure of the difference between focus conditions in within-subject designs that also takes into account the correlation between the two means (Morris & DeShon, 2002). For all the statistical tests the significance was stated at level of α=.05. Data were analyzed using SPSS 21.

Results

The results of the post-performance interviews revealed that all (100.0%) the children in the EF and IF conditions were reported adaptation of attentional focus instructions. More specifically, children stated relatively a high rate of adherence to the external (4.42±0.97 points, corresponding to 88.4%) and internal (4.08±0.88 points, corresponding to 81.6%) focus instructions. In the Cont condition, most participants (75.0%) reported that they have been focusing on the ball (4.00±0.70 points), and some of them (16.6%) stated the preference of focusing on their hands (4.00±0.00 points), or a few of them (8.4%) declared focusing on both ball and hands (4.00±0.00 points).

Figure 2 shows the catching performance for the children across trials under the different attentional focus conditions. The results revealed that the main effect of attentional focus condition, $F(2, 46)=3.508$, $p=.038$, $\eta_p^2=.132$ was significant. *Post-hoc* analysis showed that the children's performance for catching was significantly more successful in the EF (M=1.53, SD=0.25) than in the IF (M=1.39, SD=0.35) condition (p=.026, d=0.62). There was no significant difference between the Cont condition

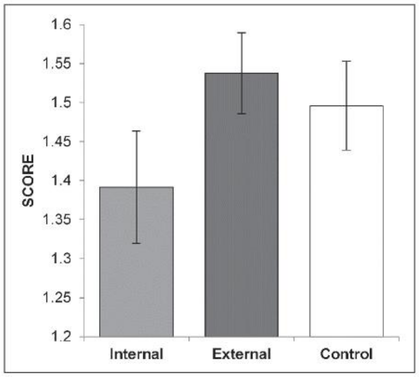

Figure 2. Means of catching scores for the internal focus, external focus and control conditions. Note: Error bars represent standard errors.

(M=1.49, SD=0.28) and either EF (p>.99, d=0.16) or IF conditions (p=.395, d=0.31).

Discussion and conclusions

The beneficial effects of external versus internal attentional focus instructions have been shown in adults and children in a variety of targeting and balance motor skills (for a review see Wulf, 2013; Wulf & Lewthwaite, 2016). The present study showed that these performance advantages could also be found for *interceptive timing motor skills* (e.g. catching task) in *children*. Therefore, the higher beneficial effect of EF rather than IF is not only for targeting and balance motor tasks (Flores, et al., 2015; Hadler, et al., 2014; Perreault & French, 2015, Wulf, et al., 2010), which are predominately controlled by either predictive or prospective control systems, but also for interceptive motor skills (i.e. catching), in which a simultaneous combination of both systems is necessary for optimal action of planning and programing (Panchuk & Vickers, 2009). That is, interceptive motor tasks (e.g. catching) that have a higher demand for updating motor commands and co-ordination of various degrees of freedom (Davids, 2002; Sarlegna & Mutha, 2015; Tayler & Davids, 1997) could also benefit from EF compared to IF. It seems that EF compared to IF helps the motor system to co-ordinate the degrees of freedom more effectively to choose and produce an appropriate and optimal response. One possible explanation for these results might be due to impact of concentration on the intended movement effects in the EF that increases automatic control processes during action planning to facilitate functional linkage of goal-action coupling (Wulf, 2013; Wulf, et al., 2001).

This study also highlights that the performance of young school-age children, who are typically at the early stages of developing their expertise level, could be enhanced more effectively under EF in comparison to IF instructions. Therefore, not only have novice adults benefited from EF instructions (for a review see Wulf, 2013), but children also (Hadler, et al., 2014; Perreault & French, 2015; Wulf, et al., 2010; present study). These results suggest that young children who are in the process of developing their fundamental motor skills could benefit from advantages of EF instructions compared to IF instructions (Emanuel, Jarus, & Bart, 2008; Peh, Chow, & Davids, 2011).

Another interesting result of this study in comparison to previous studies on children (Emanuel, et al., 2008; Hadler, et al., 2014; Wulf, et al., 2010) was obtained from retrospective interviews in the Cont condition. The results showed that when left to their own devices (Cont), 75% of children adopted an attentional focus on the ball to perform this interceptive motor task. These results are not surprising as it could be due to the (target-oriented) nature of the task. It should be noted that even though most of the participants in the Cont condition reported adopting EF, performance outcome in the Cont condition was not as effective as it was in the EF condition compared to IF condition. Therefore, promoting EF instructions was more beneficial than the IF instructions to reaching the optimal performance in children. These results could suggest that attentional focusing on the flying ball may be crucial for successful catching.

An alternative suggestion for the explanation of advantages of EF over IF in the present study might be due to the enrichment of perceiving visual information in EF compared to IF. In other words, adopting internal attentional focus instructions may worsen attunement to visual information processing of a performer's visual perception system in interceptive motor skills. However, this study does not bring direct evidence on the hypothesis on the functional association between the attentional focus on the action and visual attention. Despite that, it should be noted that previous studies have shown that the underlying mechanisms causing the beneficial effects of EF instructions are independent of vision for discrete motor actions such as aiming or jumping (Abdollahipour, Psotta, & Land, 2016; Land, Tenenbaum, Ward, & Marquardt, 2013; Schlesinger, Porter, & Russell, 2013; Sherwood, Lohse, & Healy, 2014), which typically use feedforward control system. It is important to highlight that interceptive skills (i.e. catching) are highly dependent on processing visual information for co-ordination of movement skills (Davids, 2002) and anticipation of the contact time with an object that typically use feedback control system (Gentile, 2000; Magill, et al., 1991). Therefore, future studies should investigate the role of vision and attentional focus instructions on motor tasks that are dependent on feedback control system for motor control.

The current results appear to be the first to provide additional support for the constrained action hypothesis (Wulf, et al., 2001) as regards interceptive motor skills, supporting the idea that an IF of attention increases focusing on the self with the consequence of increasing conscious control processes and debilitating performance (McKay, Lewthwaite, Wulf, & Nordin, 2015). Whereas an EF of attention enhances performance by decreasing the focus on the self (Wulf & Lewthwaite, 2010).

In short, as with other targeting and balance motor tasks (Flores, et al., 2015; Hadler, et al., 2014; Perreault & French, 2015; Wulf, et al., 2010), the performance of an interceptive motor skill of young school-age children could also benefit from an EF compared to an IF of attention. Specifically, the findings suggested that an external attentional focus on the ball seems to be more beneficial than internal focus on the hand's movements to successful performance of the catching task. This study suggests that concentration on the movement effects could be more effective than conscious concentration on body movements for optimal performance of interceptive motor skills (i.e. catching). The results presented in this study suggest that coaches and PE teachers should use EF instruction on the movement effects rather than IF instructions related to movement techniques for teaching interceptive motor tasks.

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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 Fédération 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 0.1	Medium 0.2	Large 0.3	Unacceptable 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, $F(2, 42) = 9.959$, $P < .001$, $\eta_p^2 = .322$.

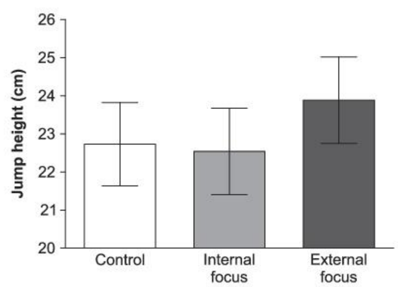

Figure 2. Jump height for the control, internal focus and external focus conditions.

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.

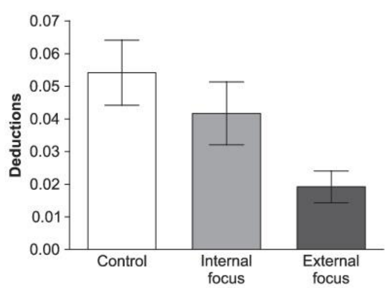

Figure 3. Execution deductions for the control, internal focus, and external focus conditions.

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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Study III:

Abdollahipour, R., Psotta, R., Palomo Nieto, M., Rouzbahani, M., Nikdast, H., & Bahram, A. (2014). Effects of attentional focus instructions on the learning of a target task: A moderation role of visual feedback. *Kinesiology*, *46*, 210-217.

EFFECTS OF ATTENTIONAL FOCUS INSTRUCTIONS ON THE LEARNING OF A TARGET TASK: A MODERATION ROLE OF VISUAL FEEDBACK

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Abstract:

The present study examined whether visual feedback can have a moderating effect on the relation between attentional focus instructions and the learning of a target movement skill. Participants (N: 100, mean age: 21.0 years, SD: 2.1) were randomly assigned into visual feedback versus non-visual feedback groups. Each group was split into five subgroups: control, internal focus on the arm, and three external focus groups including focus on the dart, on the flight of the dart, and on the bull's-eye. Participants in each subgroup were asked to throw the darts at the dartboard using their specified focus instructions with either full-visual or non-visual information on results. The accuracy scores of throws were analyzed in 2 (visual groups) x 5 (focus subgroups) x 6 (trial blocks) analysis of variance with repeated measures on the last factor in acquisition, and 2 (visual groups) x 5 (focus subgroups) analysis of variance in retention and transfer. While the attentional focus instructions were not confirmed as a significant factor in practice, visual feedback was more beneficial than non-visual feedback in the acquisition of a target task. However, the benefits of practicing with visual feedback were not observed in the retention and transfer tests when vision was available. Furthermore, external focus on the flight of the dart was more beneficial than the other attentional focus instructions in transfer test, showing that the optimized distance of external focus of attention for the learning may change when a target task is executed on a stable or variable (moving) target.

Key words: *attention, vision, acquisition, aiming skill, retention, transfer*

Introduction

Ample investigations have illustrated that attentional focus instructions adopted by a performer are one of the most effective strategies in optimizing human actions including motor skills performance. The benefits of focusing attention on the indented outcome of the movement called *an external focus* rather than focusing attention on the execution of bodily movement called *an internal focus* have been demonstrated for acquisition of motor skills (e.g. McNevin & Wulf, 2002; Wulf, Höß, & Prinz, 1998; Wulf, Mercer, McNevin, & Guadagnoli, 2004; for review see Wulf, 2007, 2013), and observed in motor performance and learning in retention or transfer tests (e.g. McNevin, Shea, & Wulf, 2003, Wulf, et al., 1998; Wulf, Shea, & Park, 2001; for a review see Wulf, 2007). The positive effects of adopting an external focus of attention were also found for performance and learning of various types of sport-specific skills involved in some invasion and net/wall games such as a basketball free shooting task (Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002), volleyball serve and soccer kick (Wulf, McConnel, Gartner, & Schwarz, 2002), throwing tennis balls at a target (Pascua, Wulf, & Lewthwaite, 2014), golf (Wulf, Lauterbach, & Tool, 1999; Wulf, McNevin, Fuchs, Ritter, & Toole, 2000), and a dart throwing task (Marchant, Clough, & Crawshaw, 2007).

To explain the benefits of an external focus of attention during the learning of movement skills, *constrained action hypothesis* was suggested (McNevin, et al., 2003; Wulf, 2013; Wulf, McNevin, & Shea, 2001). According to this hypothesis disruption in automatic control processes may occur when individuals focus their attention internally, while focusing attention externally may organize the automatic control processes more efficiently and effectively (Wulf, 2013). This hypothesis has emerged from "*the common-coding hypothesis*" (Prinz, 1990, 1997). As stated by this hypothesis, a commensurate coding procedure for action planning in relation to perception occurs when afferent and efferent codes are generated and maintained at a distal level of representation of action.

Recently, the optimized level of distance in external focus instructions at two levels "close or far distance" has also been the subject of debate in some research studies. Particularly, some investigations have shown that increasing the distance of an external focus of attention enhances motor learning (McKay & Wulf, 2012; McNevin, et al., 2003). For instance, McKay and Wulf (2012) have illustrated that dart throwing accuracy was enhanced when participants adopted a distal external focus by directing attention to the dartboard rather than a proximal focus by directing attention to the flight of the dart. In the other study on a dart throwing task, Lohse and colleagues (Lohse, Jones, Healy, & Sherwood, 2013)) compared the effects of internal focus on the motion of arm (IF-MA), versus external focus on the release of the dart (EF-RD), the flight of the dart (EF-FD), and the bull's-eye (EF-BE). The results demonstrated that participants in the external focus conditions on EF-FD and EF-BE performed with less errors than IF-MA. However, EF-FD was the most effective instruction relative to IF-MA.

Besides the attentional focus instructions, the role of concurrent visual feedback for acquiring motor skills has especially been considered for target tasks. The visual feedback can provide information on body movements, task environment and/or knowledge of results of an action (Schmidt & Lee, 2011). In fact, the advantages of external rather than internal focus of attention for skill learning/performance have mostly been illustrated in which participants looked at the target. For instance, subjects could receive visual feedback while and after performing trials of movement action in tossing a tennis ball (Saemi, Porter, Wulf, Ghotbi-Varzaneh, & Bakhtiari, 2013), basketball free throw (Zachry, Wulf, Mercer, & Bezodis, 2005), dart throwing task (Marchant, et al., 2007), discus throw (Zarghami, Saemi, & Fathi, 2012), and shot put (Makaruk, Porter, & Makaruk, 2013). The disadvantage of the internal focus on execution of bodily movements observed in these studies could be explained by a disruption in receiving visual feedback information during execution of an action.

The study by Perkins-Ceccato, Passmore, and Lee (2003) showed that there is no difference between internal versus external attentional focus groups when novice participants did not receive any visual information about the results of their action in acquisition of a golf swing task. In that study, opaque occlusion goggles prevented direct vision of performers' results after each instructional trial for reducing the effects of visual information about the results of the subsequent shots. In another piece of research on golf putting, Land and his colleagues (Land, Tenenbaum, Ward, & Marquardt, 2013) tested the role of visual information on the effectiveness of an external focus of attention. Conversely, they reported that the beneficial effects of focusing on the direction and speed of the ball (external focus) rather than focusing on a secondary tone-counting task (irrelevant focus) and no focus instructions did not rely on visual information during performance, or on access to knowledge of results.

According to Mass et al. (2008), there would be no optimizing schema unless four different sources of information—the relations among the initial conditions, the generated motor commands, the sensory consequences of the motor commands, and the outcome of the movement—are available following the movement. Based on this view, motor learning is associated with forming a connection among the various sources of information. For example, if a learner does not know whether the produced action was correct, then the schemas cannot be updated (Mass, et al., 2008). Therefore, the aim of the current study was to examine the effect of external versus internal focus instructions on acquiring a target task practiced under the condition of visual and no visual information about the result of an action. We wanted to address the question of whether the benefits of external focus instructions depend on visual access to knowledge of action results. We assumed that the beneficial effects of an external focus of attention are independent of visual feedback for a target task. In addition, as regards the external focus instructions specifically, we also tested the level of distance of external focus progressively to find out which set of instructions is optimal as a factor of motor learning for a target skill. Our assumption was that focusing attention externally on longer distances would be more beneficial than focusing attention on distances closer to the body movements.

Methods

Ethics

As the part of the research project, the protocols were submitted and approved by the review board of the university. Informed consent was used to gain written permission from the subjects participating in the study.

Participants

Female college students (N=100, mean age: 21.0, SD: 2.1 years, range 18–25 years), with no previous experience in a dart throwing task and without physical or mental disabilities, participated in this study. The other inclusion criterion was right-handed functional dominance identified by the Edinburgh Handedness Inventory (Oldfield, 1971).

Apparatus and the target task

The participants were asked to throw darts at a dartboard. The dartboard was 40 cm in diameter, with nine concentric rings, each 2 cm in width, and a 2 cm diameter bull's-eye in the center. The dartboard was installed so that the bull's-eye was 1.70 m above the floor and participants stood 2.50 m from the dartboard. The task was to throw regular-sized darts at the bull's-eye on the dartboard. A dart that struck the bull's-eye received a score of 10 points, with a dart that struck the outermost ring receiving a score of 1, and so forth. Shots that missed the board entirely were given 0 points.

Procedures

Before the beginning of the experiment, all participants were asked to throw two darts to become familiar with the task. There was no instruction in this phase. Then, according to the average of warm-up scores, participants were randomly divided into two groups, one with visual feedback (VF) and the other with non-visual feedback (No-VF) about the results, with 50 subjects in each group. Then, each of these two groups were split into five subgroups: control (Cont), internal attentional focus on the arm (IntF), and three external attentional focus groups with a difference in distance of attentional focus – external focus on the dart (ExtF-D), external focus on the flight of a dart (ExtF-F), and external focus on the bull's-eye of the dartboard (ExtF-B subgroup). Consequently, there were 10 subjects in each group.

Learning conditions

The subjects of the VF groups practiced under normal visual conditions including visual feedback on the result of each throw trial. In the No-VF groups as soon as a participant released the dart, the experimenter who stood one meter away from the throw line (Figure 1, A) raised a 50 cm x 50 cm cardboard cut-out to occlude the view of the performance and prevent knowledge of the accuracy of dart throws (Figure 1, B). The subjects of both IntF subgroups were asked to: 1) feel the weight of the dart in their fingertips 2) bring the fingertips toward their ear while bending the elbow, and 3) feel the dart as it left the fingertips (Marchant, et al., 2007).

The subjects of the ExtF-D subgroups were required to: 1) take the dart; 2) bring the dart toward the wall behind them, and 3) throw the dart at the bull's-eye. There were only two instructions for the ExtF-F and ExtF-B subgroups. The first instructions were the same for both subgroups: "take the dart". In the second instructions, they were asked to adopt directly a distal focus of attention (movement effect) and "focus on the flight of the dart" (ExtF-F) or "focus on the bull's-eye" (ExtF-B). There were no attentional focus instructions for Cont subgroups.

The acquisition session

All the participants completed a total number of 36 trials of throwing a dart in 6 blocks with six trials in each block. The blocks of trials were interspersed with a rest interval for all the subgroups. The importance of a given attention focusing on the instruction was highlighted at the beginning of each six-trial block. After execution of each block, a participant was given the two following short verbal questions to check the attentional focusing of the

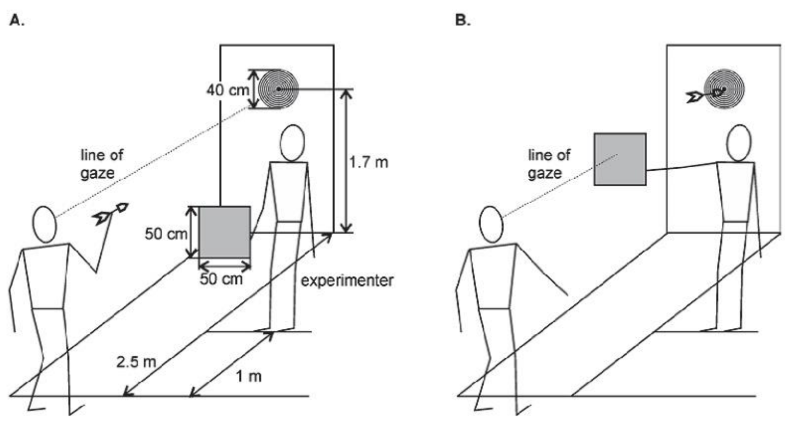

Figure 1. Scheme of the dart throwing task in acquisition phase, (A): before throw, (B): after throw.

subject while performing the dart throw: “Did you focus on the instructions given?”; and “What did you focus on?”. However, for the Cont subgroups, the only question was “What did you think about during the execution of the throw”? All the answers were recorded using a tape recorder. The main goal of these questions was only to remind the participants that focusing attention on the requested instructions is important. After each throw, the experimenter recorded the accuracy score and removed the dart from the board.

Retention and transfer tests

One day after the acquisition session, the retention and transfer tests were performed. In both tests participants from all subgroups completed one block of six trials of throwing a dart. However, no attentional focus instruction was given.

The transfer test was performed 10 minutes after the retention one. In the transfer test, the participants were asked to throw the darts at the pendulum board. Before each trial the experimenter moved the hanging board to the starting position in which the bull's-eye was parallel to the ground. Then, he let the dartboard go. The participants were asked to throw the dart before the 4th pendulum movement of the board to complete the task. They were told that if they threw the dart after the fourth pendulum movement, the score would be zero.

In the transfer test we were interested in examining the effect of the acquisition of dart throwing at a stable target when assisted by different attentional focus instructions accompanied by visual or no visual feedback on the result of the skill of a dart throw at a moving target, i.e. aiming performance in a variable environment.

Data analysis

The mean of the score of dart-throwing accuracy achieved in the given six-trial block presented the dependent variable. For the acquisition phase the accuracy scores were analyzed by a three-way ANOVA in 2 (VF vs. No-VF condition) x 5 (the attentional focus: IntF, ExtF-D, ExtF-F, ExtF-B, Cont) x 6 (trial blocks of practice, as the factor of the amount of practice), with repeated measures of the last factor. A one-way ANOVA was conducted to assess the average of accuracy scores in the warm-up phase to ensure that all the groups were not different at the beginning of practice.

The scores achieved in the retention and transfer tests were analyzed using a two-way ANOVA in 2 (groups: VF vs. No-VF) x 5 (the attentional focus sub-groups: IntF, ExtF-D, ExtF-F, ExtF-B, Cont). The Bonferroni corrections were performed for all adjustments. Also, the Bonferroni *post-hoc* test was performed where appropriate and if the ANOVAs were significant. The level of significance was set at .05 for all statistical tests.

Greenhouse-Geisser epsilon values were used to adjust the degrees of freedom in the ANOVAs with repeated measures to compensate for deviations from the assumption of sphericity. The data analyses were performed using the statistical software SPSS-21 (IBM, USA).

Results

Manipulation check

The analysis of responses to the first question indicated that all the participants in the internal and different external focus groups followed instructions as directed. However, a descriptive analysis of answers to the second question revealed that participants claimed that they adopted related-focus instructions through blocks of trials, respectively (90, 90, 93, 95, 95, and 95%). These findings indicated that participants in each group obtained particular focus instructions in line with the goal of study.

Throwing performance during the acquisition session

All the groups showed considerable improvement in dart throwing accuracy across the six blocks of six trials (Figures 2 and 3). The main effect of the trials was significant $F(4.74, 427.43)=11.860$, $p=.000$, $\eta p^2=.116$, demonstrating the improvement of participants through practice in both VF and No-VF groups. A *post-hoc* test revealed that in the VF group the participants had a better performance from the 2nd to 6th in contrast to the 1st trial (Figure 2), while the participants in No-VF group had a better performance in the 6th compared to the 1st block of trials (Figure 2).

The main effect of visual feedback was significant $F(1, 90)=4.785$, $p=.031$, $\eta p^2=.050$, with the VF group showing more accurate scores than the No-VF group (Figure 3). In addition, the interaction of trials and attentional focus groups was significant, $F(18.99, 427.43)=2.132$, $p=.004$, $\eta p^2=.087$. The subsequent *post-hoc* tests demonstrated that

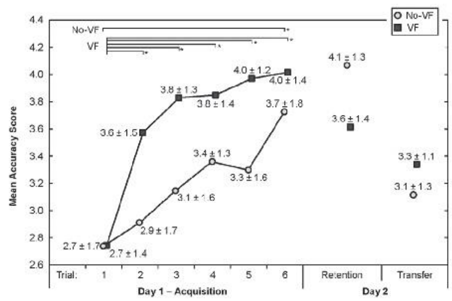

Figure 2. *The mean accuracy scores of throws across 6 blocks of 6 trials in the acquisition, retention and transfer for the visual feedback (VF) and non-visual feedback (No-VF) groups ($p \leq .05$).*

VF group had a better performance than No-VF group in the 2nd, 3rd, and 5th blocks of trials (Figure 3). Also, the main effect of attentional focus instructions, $F(4, 90)=1.012$, $p=.406$, $\eta p^2=.043$, and the interactions of VF and attentional focus instructions, $F(4, 90)=.764$, $p=.551$, $\eta p^2=.033$, and VF and trials, $F(4.74, 427.43)=1.409$, $p=.222$, $\eta p^2=.015$, were not significant.

The type of attentional focus instructions showed that it is not a significant factor for the mean score of throwing accuracy (Figure 4). Also, no significant interaction effects of trials, the visual feedback condition and attentional focus were found.

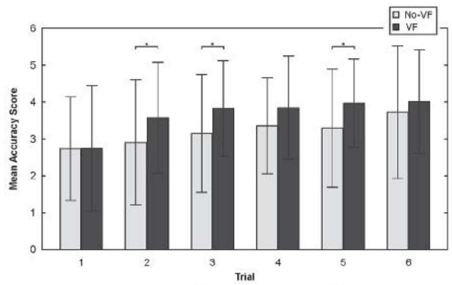

Figure 3. Comparison of the mean scores of throw accuracy for the visual feedback (VF) vs. non-visual feedback (No-VF) groups in the separate blocks of trials in practice. Error bars represent standard deviations ($p\leq.05$).

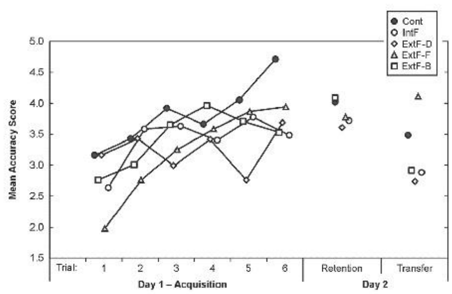

Figure 4. The mean scores of throw accuracy achieved in the control (Cont), internal focus (IntF), external focus on the dart (ExtF-D), external focus on the flight of a dart (ExtF-F) and external focus on the bull's-eye of the dartboard (ExtF-B) subgroups, regardless of type of visual feedback condition.

Performance in the retention test

The mean performance score for VF and No-VF groups, and specifically for the different attentional focus subgroups in the retention test is presented in Figures 2 and 4 (middle panel). The main effects of VF, $F(1, 90)=2.615$, $p=.109$, $\eta p^2=.028$, the attentional focus, $F(4, 90)=.420$, $p=.794$, $\eta p^2=.018$, and the interactions of VF and attentional focus groups, $F(4, 90)=1.174$, $p=.328$, $\eta p^2=.050$, failed to reach significance.

Performance in the transfer test

As can be seen in Figures 2 and 4 (right panel), the main effects of attentional focus subgroups, $F(4, 90)=4.727$, $p=.002$, $\eta p^2=.174$, was significant. The *post-hoc* test showed that the ExtF-F group was better than the other attentional focus and control groups. The main effects of VF, $F(1, 90)=.940$, $p=.335$, $\eta p^2=.010$, and the interactions of VF and attentional focus groups, $F(4, 90)=1.376$, $p=.249$, $\eta p^2=.058$, were not significant.

Discussion and conclusions

The aim of the study was to examine how the different visual vs. no-visual feedback on the performance results of novice learners during and after execution of a target task could affect the expected advantages of external over internal attentional focus instructions. In other words, we examined how visual feedback can moderate the relation between attentional focus instructions and motor performance/learning. The visual feedback reduction for the No-VF group consisted of preventing the vision from both the flight of the dart to the target for 60% of the distance of its flight, and also the dart landing point on the dartboard, i.e. no visual feedback on the result was available in each trial.

In the current study, the performance enhancement with visual feedback on the results illustrated more effective skill acquisition than non-visual feedback condition, with no dependency or interaction with the type of attentional focus instructions. These findings are in line with the results of Perkins-Ceccato et al. (2003) who used a golf putting skill. These results suggest that if visual feedback during a goal-directed movement skill is strongly limited by non-visual feedback about the results, the advantage of the external focus over the internal focus fades. Our results were not consistent with the study by Land et al. (2013) who found that beneficial effects of adopting an external focus of attention is not dependent on receiving visual information by accessing knowledge of results during and after executing a golf putting task. However, using within-subject group design (Land, et al., 2013) might be the cause for having different results from the present study.

Also, we examined the effects of external attentional focus on further locations in learning condition through retention and transfer tests in a variable but predictable environmental condition. Although particular attentional focus instructions in retention were not different from each other, the ExtF-F was the best attentional focus strategy in transfer test when participants threw the darts at a pendulum board which moved regularly. Our results for the ExtF-F group agreed with the results of previous studies (Abdollahipour, Bahram, Shafizadeh, & Khalaji, 2008; Land, Frank, & Schack, 2014; Landers, Wulf, Wallmann, & Guadagnoli, 2005; Poolton, Maxwell, Masters, & Raab, 2006; Totsika & Wulf, 2003; Wulf, Landers, Lewthwaite, & Töllner, 2009; Wulf & Su, 2007; Wulf, Töllner, & Shea, 2007), thus showing the advantage of external over internal attentional focus when subjects were faced with a more challenging task or condition. Also, our results are in line with the previous studies that demonstrated that the external cues should be divided between execution of the movement and environmental information (Shumway-Cook & Woollacott, 2007; Lohse, et al., 2014), and that there is an optimum limit for external focus of attention for novice performers in the golf putting task (e.g. Shafizadeh, Mcmorris, & Sproule, 2011; Wulf, et al., 2000, experiment 2). However, in contrast with the other studies (McKay & Wulf, 2012; McNevin, et al., 2003), increasing the distance of external focus as far as possible (ExtF-B) and close external focus (ExtF-D) were not more beneficial than internal focus for throwing darts at the pendulum dartboard (an unstable target). It is possible that object orientation in the environment affects visual processing strategies (Smeets, Brenner, De-Grave, & Cuijpers, 2002).

Interestingly, enhancement of accuracy scores during the practice phase under both VF (normal condition) and No-VF on the results in the present study is not in line with the suggested theories of motor control and learning which explain that if any of various sources of information is unavailable following a movement, no motor schema updating (learning) can occur (Mass, et al., 2008). Therefore, it can be pointed out that it is impossible for performers to not notice and therefore not alter their attentional focus to use biased or another source of information, especially proprioception and audition (in our study, the sound from a dart hitting the dartboard), when vision is unavailable (Wulf & Prinz, 2001; Trembly, 2010). Perhaps a shift in the use of sensory sources of other modalities and/or compensation for a lack of visual information by proprioceptive and auditory information met the demands of target task coordination. Nonetheless, the benefit of visual information on the results mostly at the beginning of the acquisition session indicates that the withdrawal of visual feedback on the performance results may not degrade the importance of visual information (in a target task) when available. These sensory-motor mechanisms could explain the similar tempo of increasing performance during practice conditions under both VF and No-VF on the performance results, and also no significant difference in performance of throwing the dart in both retention and transfer tests (between the two groups which were practicing under these two different visual feedback conditions). The other possible reason for the results is that when the advantage of one source of afferent information (e.g. vision) is not available, the brain may process other sources of afferent information which are not influenced by vision to certify performance accuracy (Toussaint, Robin, & Blandin, 2010). In other words, when there are actions but the sensory consequences cannot be observed, states decay at various rates, but uncertainty grows. Increased uncertainty encourages learning (Kording, Tenenbaum, & Shadmehr, 2007).

There were some limitations in the present study that could be a concern for future experiments. First, we suggest that the number of practicing trials should be increased to give a more precise information about the actual skill acquisition processes. It could be argued that limited number of practicing trials will be considered as "adaptation" rather than "learning" (Newell, Mayer-Kress, Hong, & Liu, 2009). Second, although using the questionnaire in the present study gave us an estimation about focusing of subjects on particular instructions, yet further information is needed to ensure that participants have been focusing on the given instructions. These methodological approaches can give us a better understanding for the generalizability of the present results.

In conclusion, this study demonstrated that visual feedback on the results can provide a benefit for acquisition of a target task temporarily during practice, in comparison to non-visual feedback on the results. However, the benefits of providing visual feedback on the results were not retained until the following day after practice when both groups received visual feedback on the performance result. The study suggests that the expected advantages of the external attentional focus instructions can be disrupted during acquisition of a target task when visual information are strongly reduced under non-visual feedback on the results. Therefore, the visual feedback on the results was shown to be possibly a more effective factor in acquisition of a target task in learners-beginners than attentional focus instructions. In addition, this study supported the advantages of external focus of attention (when it was shared between execution of the movement and environmental information) rather than internal focus of attention in a more challenging target task that supports *constrained action hypothesis* (McNevin, et al., 2003; Wulf, 2013; Wulf, McNevin, & Shea, 2001) in more challenging motor skills and environments. Hence, it seems that the optimized distance of external focus of attention may be variable with regard to stable or unstable targets. The findings of the present study can practically be used by teachers and coaches in a way that they should carefully provide the correct verbal instructions for learners in different stages of learning processes. Future studies should be conducted to examine the role of vision and attentional focus on motor learning in different types of motor skills.

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RESEARCH NOTE

The Influence of Attentional Focus Instructions and Vision on Jump Height Performance

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ABSTRACT

Purpose: Studies have suggested that the use of visual information may underlie the benefit associated with an external focus of attention. Recent studies exploring this connection have primarily relied on motor tasks that involve manipulation of an object (object projection). The present study examined whether vision influences the effect of attentional focus on the performance of body movements through space (body projection). **Method:** Participants ($N = 24$, $M_{age} = 25.0 \pm 3.3$ years) performed a maximum vertical jump in a room with a 4-m ceiling under full-vision and no-vision conditions. Additionally, participants performed 3 trials under each of 3 attentional conditions, presented in a counterbalanced order: external focus (ExF; "concentrate on the ceiling and try to touch it"), internal focus (InF; "concentrate on your fingers and try to bring them up as high as possible"), and control (Con; no-focus instruction). **Results:** Results indicated that regardless of visual condition, a statistically significant difference was observed such that participants in the ExF condition (30.93 ± 8.37 cm) jumped significantly higher than participants in both the InF (30.09 ± 8.66 cm, $p = .004$, $d = 0.68$) and Con (30.23 ± 8.73 cm, $p = .002$, $d = 0.57$) conditions. Furthermore, jump height was overall significantly higher in the full-vision condition compared with the no-vision condition ($p = .004$, $d = 0.47$). Importantly, there was no interaction between ExF and vision. **Conclusion:** The present findings demonstrate the benefit of an ExF on a body projection task and further provide evidence of the independence of ExF and visual information.

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In recent years, a variety of experimental studies have shown that motor performance and learning can be facilitated when attentional focus is directed to the effects of one's movement in the environment (i.e., external focus) as compared with when one's focus is directed to body movements (i.e., internal focus). To date, the superiority of an external focus compared with an internal focus of attention has been confirmed across a variety of motor skills (for a review, see Wulf, 2013). To account for the mechanisms underlying the influence of attentional focus on performance, Wulf, McNevin, and Shea (2001) proposed the "constrained action hypothesis" (CAH). This hypothesis states that attention directed internally to the processes of skill execution constrains and disrupts the automatic control processes that normally guide motor execution. In contrast, an external focus of attention is suggested to promote more automatic and less conscious (i.e., less attention-demanding) modes of motor control, thus leading to improved performance and learning.

Research has indicated a close neurological relationship between attention and vision. To this extent, attention is seen as the main mediator of the cognitive system during the active search for visual information (Gottlieb, 2012). Given this close relationship, the role of vision has been proposed as a possible alternative mechanism accounting for the differential effects of an internal and external focus of attention (e.g., Al-Abood, Bennett, Hernandez, Ashford, & Davids, 2002; Hodges & Ford, 2007). During learning, performers regularly receive verbal instructions that direct attention and vision to particular aspects of the task, which can influence the rate of learning as well as performance (Williams, Davids, & Williams, 1999; Wulf & Lewthwaite, 2010). Some researchers (Hodges & Ford, 2007; Maurer & Zentgraf, 2007; Russell, 2007) have suggested that an internal focus of attention that applies preferentially to body movements could limit perceiving visual information from the environment, whereas an external focus of attention enriches the use of visual information. In other words, the advantages of an

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external focus of attention might be mediated by better attunement to richer sources of visual information, which can be used to facilitate perception – action coupling (Davids, 2007; Davids, Button, & Bennett, 2008).

To delineate between these theoretical accounts, initial experimental studies designed to examine the role of vision associated with an external focus of attention suggest that the benefits do not directly depend on vision for tasks that involve the use of an implement such as a golf club (Land, Tenenbaum, Ward, & Marquardt, 2013) or dart (Sherwood, Lohse, & Healy, 2014). For instance, Sherwood et al. (2014) reported that the advantages of an external focus compared with an internal focus of attention were not fully due to visual processing when participants performed a dart-throwing task under a nonvisual condition. Similarly, Land and colleagues (2013) reported that the advantages of an external focus are independent of visual feedback during the execution of a golf-putting task. However, based on the classification of fundamental motor skills (Gallahue, Ozmun, & Goodway, 2012; Haywood, Roberton, & Getchell, 2012), the tasks that have examined the relationship between vision and attention have represented motor skills that involve manipulation of an object and are identified as object projection tasks.

Consequently, it is important to consider that different motor skills, such as those involving object projection versus body projection, may place different requirements on the use of visual information during the control of actions (Patla, 1997; Zhao & Warren, 2015). In the tasks that are associated with projection of the body in space such as acrobatic skills in gymnastics and diving, visual information is needed for sufficient control and spatial orientation as the body moves through space. To this extent, studies have shown that vision is indeed important for controlling body projection actions such as backward acrobatic somersaults in expert gymnasts (Bardy & Laurent, 1998), forward acrobatic somersaults for trampolinists (Lee, Young, & Rewt, 1992), and aerial somersaults for collegiate acrobats (Hondzinski & Darling, 2001). As such, optimal performance in aerial tasks requires the visual system to monitor the position and movement of the body in space and also to prepare for landing.

It should be pointed out that research has shown that discrete object projection actions (e.g., golf-putting task) do not depend on visual feedback during execution of skills regardless of attentional focus instructions (Land et al., 2013), whereas discrete body projection actions (e.g., jumping) need visual information before and during skill execution to monitor the external environment for spatial orientation and the body's position in the environment for maintaining postural control and balance and to achieve optimal velocity for body movement (Davids, Glazier, Araújo, & Bartlett, 2003; Eves, 1995; Ives, 2014; Marigold, 2008). Furthermore, previous studies have shown that an external compared with internal focus of attention produces more effective and efficient muscular activity that results in optimized motor coordination of body projection actions such as a jumping task (Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010).

Thus, the purpose of the present study was to examine whether the availability of vision mediates the extent to which an external attentional focus influences the performance of a discrete body projection task—in this case, a vertical jump. If vision underlies the effects of an external focus during a body projection task, then it is predicted that an advantage of an external focus over an internal focus will only be evident during performance with vision. During performance without vision, a smaller difference or no difference between the internal and external conditions is expected. However, if vision does not mediate the advantage of an external focus, then we predict that regardless of the availability of vision, performance with an external focus will be superior to performance utilizing an internal focus of attention. We hypothesized that the beneficial effects of an external focus are due to the allocation of attention and do not depend on the use of visual information (Wulf, 2013).

Method

Participants

Twenty-four university students (16 women, 8 men) with a mean age of 25.0 ± 3.3 years and without any physical or mental disabilities participated in the experiment. A-priori power analysis indicated that a sample size of 24 would be sufficient to detect a significant effect of the independent variables with a repeated-measures within-subjects design with a power ($1 - \beta$) of .90 and an α of .05 (Faul & Erdfelder, 1992). Although participants were familiar with the task under the full-vision condition, they did not have experience with the task under the no-vision conditions. Also, they were neither professional nor semiprofessional athletes. Participants were not aware of the aim of the study. The study's protocols were submitted and approved by the university's institutional review board, and informed consent was obtained by all participants prior to participation in the study.

Experimental task and apparatus

The participants were required to perform a maximal standing two-legged vertical countermovement jump with arm swing. The experiment was carried out on a standard surface (Conipur KF protect +, Conica, Schaffhausen, Switzerland) in a room with a ceiling of 4 m. To record jump height, an optoelectronics measurement system (Optojump Next, Version 1.3.20.0, Microgate, Bolzano, Italy) was used. The Optojump Next instrument was installed with two transmitting and two receiving joined bars (100 cm × 8 cm). Participants were asked to jump between the bars. Data were sampled with an accuracy of 0.001 s and were processed into 1D footfall patterns by the Optojump Next software. Also, an eye mask (Sleep Mask, Prime Effects, Dunedin, FL) was used to cover the participant's eyes in the no-vision condition.

Procedure

At the beginning of the experiment, the experimenter demonstrated the proper execution of a maximal vertical jump to each participant. First, the participants were asked to stand with their arms extended downward. Then, the participants were instructed to pull back their arms, swing them forward and up, and jump straight up as high as possible. The participants were allowed to perform two practice trials to feel comfortable with the task. Following, the participants stood between the Optojump bars to perform the task in both the full-vision and no-vision conditions. In each visual condition, participants performed three trials under each of the following attentional focus conditions: internal focus (InF), external focus (ExF), and control (Con). In the InF condition, the participants were instructed to "concentrate on your fingers to bring them up as high as possible," whereas in the ExF condition, they were instructed to "concentrate on the ceiling and try to reach and touch it." In the Con condition, they only were required to concentrate on jumping as high as possible. The order of the attentional focus instructions as well as the order of the full and no-vision conditions were counterbalanced across all participants. The attentional focus instructions were given to the participants during each 20-s rest interval between trials. Participants performed 18 trials in total. Specifically, they performed 3 trials under each attentional focus condition in the vision and no-vision conditions.

Data analysis

The height of each jump was considered the dependent outcome variable and was recorded by the Optojump software for each trial. To search for any possible extreme outliers within each condition, a criterion (cutoff scores) as determined by a distance of 1.5 times the interquartile range from the 1st and 3rd quartile was implemented (Tukey, 1977). No extreme outliers were identified. In the next step, assumptions of normality were tested using the Shapiro-Wilk test ($\alpha = .05$). The data were normally distributed. Finally, the descriptive analysis of the mean and percentage of intraindividual changes in performance between conditions was conducted.

Jump height was analyzed via a 2 (vision: full vision and no vision) × 3 (attentional focus: ExF, InF, Con) repeated-measures analysis of variance (RM ANOVA). The assumptions of sphericity were assessed by the Mauchly's test and demonstrated that the assumptions were not violated. Bonferroni adjustments were used for all pairwise post-hoc comparisons. The alpha level was set at .05 for all the tests. Estimates of effect size were quantified using two measures. First, partial eta squared (ηp^2) was employed where $\eta p^2 = .01$, .06, and .14 were estimates for small, moderate, and large effects, respectively (Larson-Hall, 2009). Next, Cohen's d was utilized as a measure of the difference between group means using the repeated-measures version of Cohen's d that factors in the correlation between time points (Morris & DeShon, 2002). The evaluation of Cohen's d corresponded to a low ($d = 0.2$), medium ($d = 0.5$), and large ($d = 0.8$) effect (Cohen, 1988). Data analyses were performed with the Statistical Package for the Social Sciences Version 21 (IBM).

Results

Descriptive intraindividual analysis between ExF and InF indicated that the average difference in the individuals' jump performance was 1.21 ± 0.88 cm corresponding to 4.14 ± 3.21%. Additional analyses indicated that the mean jump height increased for 83.33% of participants in the ExF condition compared with 16.67% of participants in the InF condition. The intraindividual analysis between the ExF and Con conditions demonstrated that the average difference in the participants' performance was 0.96 ± 0.71 cm, corresponding to 3.65 ± 3.44%. The mean of jump height increased for 70.83% of participants in the ExF condition in comparison with 29.17% of participants in the Con condition. The intraindividual analysis between the InF and Con conditions indicated that the average difference in performance was 0.85 ± 0.79 cm, corresponding to 2.78 ± 2.55%. More specifically, the mean jump height increased for 54.17% of participants in the Con condition compared with 41.66% of participants in the InF condition. There was no difference for 4.17% of participants in Con condition compared with the InF condition.

The intraindividual analysis between the vision and no-vision conditions indicated that the average difference in performance was 0.78 ± 0.67 cm, corresponding to

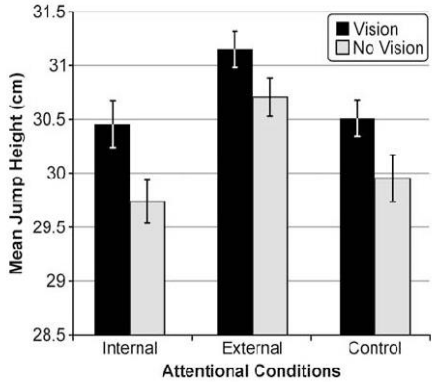

Figure 1. Mean jump height for the internal focus, external focus, and control conditions across visual conditions.
Note. Error bars represent standard error and are calculated on the basis of within-participant error with the method provided by Masson and Loftus (2003).

2.75 ± 2.59%. Mean jump height increased for 75.00% of participants in the full-vision condition compared with 20.83% of participants in the no-vision condition. There was no difference for 4.17% of participants in the full-vision condition compared with the no-vision condition.

Figure 1 illustrates the mean jumping height for participants across both vision and attentional conditions. Results from the RM ANOVA indicated a significant main effect of attentional focus condition, $F(2, 46) = 7.178$, $p = .002$, $\eta p^2 = .238$. Specifically, when participants adopted an ExF ($M = 30.93 \pm 8.37$ cm), they jumped higher than when they adopted an InF ($M = 30.09 \pm 8.66$ cm),or when given no focus instructions (Con condition; $M = 30.23 \pm 8.73$ cm). Post-hoc tests demonstrated a statistically significant difference for the performance of participants in the ExF condition in comparison with both the InF ($p = .004$, $d = 0.68$) and Con conditions ($p = .002$, $d = 0.57$). No statistically significant differences were found between the InF and Con conditions ($p = .574$, $d = 0.11$).

Additionally, the main effect of vision was statistically significant, $F(1, 23) = 10.379$, $p = .004$, $\eta p^2 = .311$. Specifically, jump height was higher during the full-vision condition ($M = 30.71 \pm 8.80$ cm) compared with the no-vision condition ($M = 30.13 \pm 8.57$ cm, $d = 0.47$). The interaction of vision and attentional focus was not statistically significant, $F(2, 46) = 0.293$, $p = .747$, $\eta p^2 = .013$.

Discussion

Research has shown a close link between attention and the direction and pickup of visual information (Gottlieb, 2012). Consequently, it has been proposed that the benefits associated with an ExF stem from instructions regarding one's focus of attention that may likely influence the pickup and use of visual information (e.g., Davids et al., 2008; Hodges & Ford, 2007). Thus, in the present study, we examined whether instructions that induce different foci of attention influenced performance differently under vision and no-vision conditions for a body projection task (e.g., vertical jump).

Our findings from a statistical standpoint indicated that an ExF of attention resulted in a greater jump height compared with both the InF and Con (no focus instructions) conditions. Also, according to the individuals' differences between the jumps, it was observed that the majority of participants demonstrated a successful increase in jump height as a consequence of adhering to the ExF condition compared with the InF and Con conditions. More importantly, the performance advantage associated with an ExF was independent of the availability of visual information. As such, vision did not mediate the role of an ExF in a body projection task.

These findings are consistent with previous research regarding the efficacy of ExF compared with InF instructions exposed by CAH (Wulf et al., 2001). Furthermore, our findings substantiate prior research that has shown that ExF is independent of visual information for tasks that are characterized by object projection (e.g., Land et al., 2013; McNevin & Wulf, 2002; Sherwood et al., 2014). Moreover, our study adds to these previous findings by showing that not only is ExF not mediated by vision for tasks characterized by object projection, but also tasks characterized by fast discrete movement of the whole body through space (i.e., body projection). Thus, even for tasks that rely heavily on visual information to monitor the position and movement of the body in space, the influence of attentional focus is independent from the processing of visual information. To this extent, the results of the present study support the notion that attentional focus refers to the performer's allocation of attention and should not be confused with the direction of visual focus (Wulf, 2013).

Our findings help clarify the underlying mechanisms of attentional focus and show that the performance differences associated with attentional focus are not due to limitations in the pickup of visual information (e.g., InF) nor are they due to the enrichment of visual information under an ExF (Hodges & Ford, 2007; Maurer & Zentgraf, 2007; Russell, 2007). As suggested by Land et al. (2013), other, more cognitive, mechanisms rather than visual information (Davids, 2007; Davids et al., 2008) are likely responsible for the differential effects of attentional focus instructions. For instance, InF has been suggested to increase self-regulatory processes that limit attentional capacity and disrupt automaticity by increasing inefficiencies in muscular activity with the consequence of creating micro-choking episodes that degrade performance outcomes (Wulf & Lewthwaite, 2010). For example, Vance, Wulf, Töllner, McNevin, and Mercer (2004) noted that differences in attentional focus can lead to changes in the coordination patterns between agonist and antagonist muscles, which can result in more or less efficient muscle force production. Specifically, more efficient muscular activity has been associated with an ExF, which could account for better jump performance in the present study. Similarly, other studies have shown changes in coordination patterns under different attentional foci, with more effective coordination associated with an ExF (Wulf & Dufek, 2009; Wulf et al., 2010). Thus, it is more likely that the observed differences in jumping height between the InF or ExF conditions is related to the efficient utilization of muscle forces and motor coordination, rather than reliance on visual information.

Although vision did not mediate the performance advantage associated with an ExF, performance during trials with vision was statistically better than during trials without vision. Also, the individuals' differences between the jumps demonstrated that the majority of participants had a more successful performance in the full visual condition compared with the no-vision condition. In other words, individuals jumped higher when vision was available than when vision was removed. This finding is not surprising, as discrete body projection tasks (e.g., jumping) rely more on visual information for orientation of the body in space and keeping up balance and postural control (Davids et al., 2003; Eves, 1995; Ives, 2014; Marigold, 2008) and also for successful landing (Bardy & Laurent, 1998; Hondzinski & Darling, 2001; Lee et al., 1992). It should also be noted that the decrements in jump performance under the no-vision condition may also be due to feelings of insecurity with falling while blindfolded, which can negatively influence jump performance. Nonetheless, this finding supports the value of visual information for maximizing movement outcome during execution of tasks that require projection of the body. However, the extent to which vision plays a role in aiding motor performance is independent of the mechanisms underlying one's focus of attention.

What does this article add?

A growing body of literature on the underlying mechanisms of attentional focus suggests that vision does not play a mediating role for the benefits associated with an ExF. However, to date, previous studies have only focused on tasks that require projection of an object. To this extent, the present study further adds to this literature by showing that vision also does not mediate the advantages of an ExF for tasks that rely more heavily on vision for body projection. That is, motor tasks that are under a feedforward control system benefit from an ExF regardless of the extent to which the task requires more (current study) or less (Land et al., 2013; Sherwood et al., 2014) visual information during skill execution. Therefore, regardless of task characteristics, the role of visual information functions independently from the mechanism underlying attentional focus. To this extent, these findings point to other cognitively mediated mechanisms (Land et al., 2013; Wulf & Lewthwaite, 2010; Wulf et al., 2001).

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Chapter 3

3.1 Results and discussion

A summary of the experimental designs and the results of all the studies are shown in Table 2. These results are discussed according to the current literature on the effects of attentional focus instructions on motor performance and learning.

3.1.1 Results

3.1.1.1 Study I

The results of study I showed that external focus instructions (i.e., focusing on the ball) are better than internal focus instructions (i.e., focusing on the hands) for motor performance in an interceptive timing motor task (e.g., catching) in children. There was no difference between the control (no focus instructions) and either internal or external focus instructions. The results of the post-performance interviews also showed that 75% of participants in the control condition reported that they had been concentrating on the ball.

Therefore, interceptive timing motor tasks that are typically controlled by an open-loop (feedforward) control system and require visual feedback for co-ordination of movement in order to move and adjust the position of the hands in time to conform to the trajectory of the ball, also benefited from the advantages of external focus compared to internal focus of attention. In fact, study I showed that external focus was also better than internal focus when the visual system sends concurrent feedback to the brain to update the motor program and adjust the parameters involved in the task execution according to the position and location of the approaching object (e.g., ball) (Davids, 2002; Gentile, 2000; Magill, Chamberlin, & Hall, 1991; Tayler & Davids, 1997).

Table 2. Summary of the experimental designs and results of the experiments, I, II, III, & IV

Experiment	Design	Task	Conditions	Attentional focus instructions	Number of trials	Dependent variables	Results		
							Day 1	Day 2	
								Retention	Transfer
I	Within-subject	Catching	EF	Concentrate on the ball	10 trials each	Movement outcome (Successful catching)	EF > IF; EF = C; IF = C	-	-
			IF	Concentrate on your hands					
			C	No instructions					
II	Within-subject	Jump and ½ turn	EF	While airborne, focus on the direction in which the tape marker is pointing after the half turn	5 trials each	Movement outcome (Jump height) & movement form (execution deductions)	EF > IF, C; IF = C	-	-
			IF	While airborne, focus on the direction in which your hands are pointing after the half turn					
			C	No instructions					
III	Between - Within-subject	Dart throwing	VF-EFD; NoVF-EFD	1) take the dart	Practice: 42 trials; Retention & Transfer 7 trials each	Movement outcome (Mean accuracy of throws)	VF > NoVF; EFB = EFF = EFD = IF = C	VF = NoVF; EFB = EFF = EFD = IF = C	VF = NoVF; EFF > EFB, EFD, IF, C
				2) bring the dart toward the wall behind you					
				3) throw the dart at the bull's-eye					
			VF-EFF; NoVF-EFF	1) take the dart					
				2) focus on the flight of the dart					
			VF-EFB; NoVF-EFB	1) take the dart					
				2) focus on the bull's-eye					
			VF-IF; NoVF-IF	1) feel the weight of the dart in your fingertips					
				2) bring the fingertips toward your ear while bending the elbow					
				3) feel the dart as it leaves the fingertips					
			VF-C; NoVF-C	No instructions					
IV	Within-subject	Jumping	EF	concentrate on the ceiling and try to reach and touch it	6 trials each	Movement outcome (Jump height)	EF > IF, C; IF = C	-	-
			IF	concentrate on your fingers to bring them up as high as possible					
			C	No instructions					

VF=Visual feedback; No-VF=No visual feedback; EF=External focus; IF=Internal focus; C=Control; EFB=External focus on the board; EFF=External focus on the flight of the dart; EXD=External focus on the dart.

3.1.1.2 Study II

The results of Study II showed that external focus instructions are more beneficial than either internal focus or control (no focus) instructions, not only in terms of movement outcome (jump height) but also movement form (execution deduction) for a discrete body projection motor skill in gymnastics in children. It should be noted that movement form is critical for some sports such as gymnastics, dance and diving, which involve body projection actions. In these types of sports, proprioception information is usually the main source of information for correction of movement patterns, as performers are not usually able to see their movement form during the execution of an action. Since movement form is the main criterion for assessing the performance of athletes in these kinds of sports, finding appropriate instructions for corrections of movement form is critical. The results of study II showed that discrete body projection actions, which require movement form and do not involve an implement, could also benefit from external focus instructions (e.g., using an external cue) for corrections of movement patterns.

3.1.1.3 Study III

The results of Study III showed that accuracy of dart throws was reduced in limited visual feedback in comparison to full visual feedback on the movement outcome, regardless of the attentional focus instructions. In other words, visual feedback including KR on the results is critical for the performance of a discrete object projection action (e.g., dart throwing task) during the acquisition phase. During the acquisition phase, there was no significant difference between attentional focus instructions when the participants were asked to focus internally on body movements (e.g., hand) or to focus externally on the object (e.g., dart), on the flight of the object (e.g., dart), on the target (bull's eye), or no focus instructions (control), regardless of the visual conditions. In addition, there was no interaction between vision and attentional focus instructions during the acquisition phase.

In the retention test, the accuracy of throws was not significantly different between the attentional focus groups when vision was available for all participants. In the transfer test, the participants in the optimal external focus instructions, i.e., focusing on the flight of the dart, performed significantly better than the other groups when they were asked to throw the darts at a moving target.

3.1.1.4 Study IV

The results of Study IV showed that the advantage of external vs. internal focus of attention is independent of visual information for motor performance in a body projection motor task (e.g., counter movement jump). Also, jump height was higher in full vision vs. non-vision condition, demonstrating that vision is critical for monitoring body position in space and perhaps for landing (Bardy & Laurent, 1998; Hondzinski & Darling, 2001; Lee, Young, & Rewt, 1992). These results indicated that although vision was critical for optimal performance of discrete body projection actions (e.g., jumping), external focus instructions on movement effects led to better performance than internal focus or control conditions, regardless of the availability of vision.

3.2 General discussion

The results of studies I and II showed that the advantages of external over internal focus of attention were found in both discrete object (e.g., interceptive timing task) and discrete body projection motor actions in children. Specifically, the results of study I showed that external focus is better than internal focus for enhancing motor performance in an interceptive motor task (e.g., catching) in children who were in the early stages of learning motor skills. These results suggest that the children's performance was better when they adopted external focus instructions compared to internal focus instructions in an interceptive timing motor task (e.g., catching) that is under an open-loop (feedforward) control system, but is highly dependent on visual information for the final adjustments of movement execution. In other words, participants in the external focus conditions could optimally adapt their action with online information (i.e., position of the ball in space) compared to the internal focus condition (Figure 3, black upward arrow). These results correspond with previous studies, which have shown that children benefited from external focus compared to internal focus of attention in discrete object projection actions (e.g., basketball free throw, forehand tennis strokes, soccer throw-in) which are less dependent on using visual information (Hadler et al., 2014; Perreault & French, 2015, Wulf, Chiviacowsky, et al., 2010).

Performance advantages of external over internal focus of attention were also found in study II for a discrete body projection motor task in gymnastics (jump and ½ turn), in terms of movement outcome and movement form. The results of study II also suggested that children who had experience of gymnastics could immediately benefit from external focus instructions for correcting their movement patterns, resulting in enhanced movement outcome. Therefore, characteristics of movement patterns could be enhanced optimally and immediately with external focus rather than internal focus even in experienced gymnasts for a discrete body projection task without using an implement. These results are in line with previous studies, which have shown advantages of external focus of attention with movement form measures in discrete object projection actions using an implement such as golf putting (An, Wulf, & Kim, 2013; Christina & Alpenfels, 2014), soccer throw-in (Wulf, Chiviacowsky, et al., 2010), and dart throwing (Lohse et al., 2014; Lohse et al., 2010), and discrete body projection tasks without an implement such as jumping (Wulf & Dufek, 2009).

The results of studies I and II are in line with previous studies (Hadler et al., 2014; Perreault & French, 2015; Wulf, Chiviacowsky, et al., 2010), which support the notion of advantages of external focus over internal focus of attention in different types of coordinative motor tasks in children. However, a number of studies have not shown any difference between attentional focus instructions in children. For example, internal focus was more beneficial than external focus for performance of a body projection action such as a standing broad jump (Chow, Koh, Davids, Button, & Rein, 2014), or for acquisition and retention of object projection actions such as dart throwing (Emanuel et al., 2008 or a basketball free throw (Perreault & French, 2016). Methodological differences might be the reason for the fact that no significant differences were found between attentional focus effects in children (see Wulf, 2013). Nonetheless, more studies on children are necessary in order to verify this conclusion.

The results of study III indicated that visual feedback on movement outcome, including preventing vision from both the flight of the dart to the target for 60% of the distance of its flight, and also the dart's landing point on the dartboard, is critical for motor planning and upgrading the motor program in a discrete object projection action (e.g., dart throwing). These results correspond with Schmidt’s schema theory, which explains that an understanding of the relations of four elements of skill execution – including initial conditions, generated motor commands, the sensory consequences of these motor commands, and movement outcome – is necessary for creating memory representation in the brain (Mass et al., 2008; Schmidt & Lee, 2011). Therefore, visual feedback on movement outcome is important for acquisition of a discrete object projection motor skill in order to correct the motor program for forthcoming trials, regardless of attentional focus instructions. In addition, there was no difference between attentional focus instructions, regardless of whether or not the subject received visual feedback on movement outcome in the acquisition phase. These results suggest that if visual feedback during a goal-directed movement skill is strongly limited by non-visual feedback about the results, the advantage of external focus over internal focus is reduced.

Furthermore, there was no difference between the attentional focus groups in the retention test. However, external focus instructions were better than internal or no-focus instructions in a transfer test, when the discrete object projection motor task was more challenging and visual feedback on the movement outcome was available. These results may indicate that an optimal external focus of attention establishes a better connection among the four elements of the motor schema in discrete object projection motor tasks. As a result, a motor program that has been instructed with optimal external focus instructions has the potential to be used in a more effective way later, when performers are faced with a more challenging task (Figure 3, white upward arrow). Therefore, discrete object projection motor tasks that are typically controlled via a feedforward control system could also be learned with external focus instructions, regardless of the availability of visual feedback on the movement outcome. The difference between the results of the acquisition and transfer test will be discussed later. In short, the results of the transfer test showed that a beneficial effect of external focus instructions could emerge when the motor task is more challenging in a discrete object projection motor task (Abdollahipour, Bahram, Shafizadeh, & Khalaji, 2008; Landers, Wulf, Wallmann, & Guadagnoli, 2005; Wulf, 2007, 2013).

In addition, receiving or not receiving visual feedback on the movement outcome does not prevent learning advantages of external over internal focus of attention when individuals are faced with a more challenging task in object projection motor skills (study III). Specifically, motor tasks that are under a feedforward control system benefit from external focus of attention, regardless of the demand on visual information during the skill execution. To this extent, these findings point to other cognitively mediated mechanisms such as the one that has been proposed in the constrained action hypothesis (Wulf & Lewthwaite, 2010; Wulf, McNevin, & Shea, 2001).

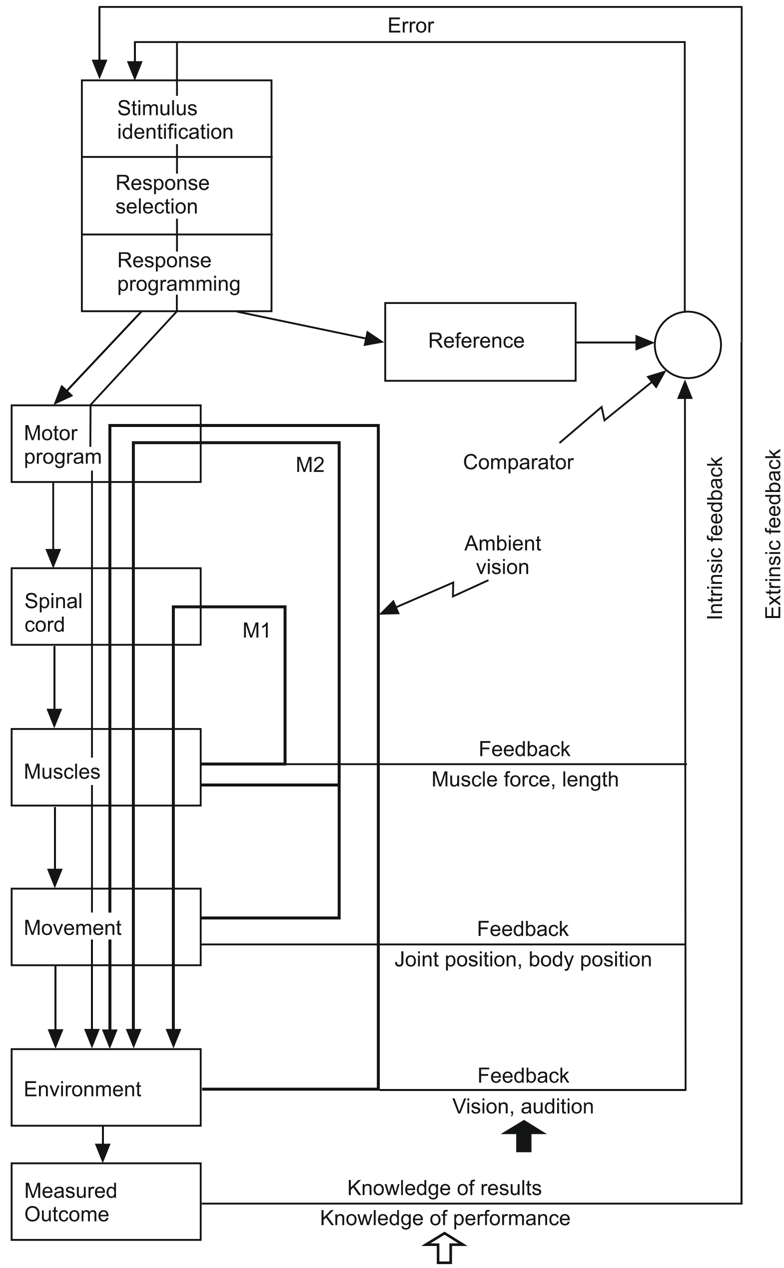

Figure 3. The completed conceptual model of human performance. Adapted with permission, from R.A. Schmidt and C.R. Wrisberg, 2000, *Motor learning and performance*, 2nd ed. (Champaign, IL: Human Kinetics), p. 291.

The results of study IV suggested that external focus of attention is better than internal focus of attention for motor performance of a discrete body projection motor task, regardless of availability of vision. According to Schmidt's schema theory for motor control and learning (Schmidt, 1975, 2003; Schmidt & Lee, 2011), visual information is among the most important sensory information before, during and after the execution of a movement. Although discrete body projection actions are predominantly controlled by an open-loop (feedforward) control system, studies have shown that for optimal performance in discrete body projection actions such as aerial tasks (e.g., jumping, gymnastics skills), the visual system is necessary for monitoring the position and movement of the body in space and also in preparation for landing. When vision is unavailable, feelings of insecurity concerning landing increase. Therefore, planning and programming of an action in a blindfold condition rely more on other sources of sensory information such as proprioception. The results of study IV showed that the beneficial effects of external focus are independent of vision, indicating that other cognitive mechanisms such as CAH might be the reason for the advantages of external compared to internal focus instructions in discrete body projection actions.

The results of the studies conducted within this dissertation suggest that vision is not the main mediator of the beneficial effects of external over internal focus of attention. These results apply for both discrete object projection tasks (Land et al., 2013; Sherwood et al., 2014), and discrete body projection tasks (Study IV). Also, external focus instructions on a cue (i.e., marker on the chest of gymnasts) that was virtually not visible during the execution of the task enhanced movement outcome and movement form in comparison with internal focus instructions on body movements (i.e., arm) in a body projection motor skill (jump and half turn) (study II). Although in study II there was no direct manipulation with visual information, the cue – the marker attached to the chest of performers – was not visible during the execution of the task. Thus the performers in all attentional focus conditions were not able to see the marker during the jump and half turn. Perhaps the image produced by external focus (not visual focus) on the marker compared to internal focus on the hands could play a mediating role to enhance movement outcome as well as movement form. This study also provides indirect evidence for the independence of vision from the mechanisms that underlie the advantages of external focus compared with internal focus in body projection motor tasks.

As already mentioned, the constrained action hypothesis (Wulf, McNevin, & Shea, 2001; Wulf, Shea, & Park, 2001) states that internal focus of attention interrupts the automatic mode of motor control by increasing conscious control of body movements (muscle activity), resulting in freezing degrees of freedom for non-optimal execution of a motor action. By contrast, external focus of attention promotes more automatic modes of motor control by decreasing conscious attentional demands, resulting in triggering degrees of freedom for optimal execution of a motor action.

Also, less than optimal performance in internal focus compared to external focus conditions suggests that internal focus instructions may interrupt automaticity in movement control by sending noise to the motor system, thereby increasing unnecessary concentration on the self. Therefore, concentration on body movements may prevent performers from making use of the benefits of concentration on the goal of action. A recent study by Perreault and French (2015) has provided initial evidence for the notion of enhanced goal-action coupling with an external focus of attention when children reported more goal-related thought in the external focus condition, compared to self-related thoughts in the internal focus condition. Our recent study (Abdollahipour, Palomo Nieto, Psotta, & Wulf, 2017) provided additional evidence for this claim that external focus compared to internal focus instructions directed children's concentration toward the goal of a task, as children in the external focus condition were less able to detect other distracting/unrelated stimuli. Previous studies (e.g., Boot, Brockmole, & Simons, 2005) have suggested that the functional attention system adjusts concentration on the goal of a task by blocking out salient events that usually interrupt attention. The results of a later study (Abdollahipour et al., 2017), also suggest that external focus of attention most probably optimizes the functional attention system by helping subjects concentrate on the goal of a task, resulting in them paying less attention to salient stimuli. These results also suggest that an optimal goal-action coupling occurs by decreasing concentration on one's body parts (internal focus) and increasing concentration on the action goal (external focus).

3.2.1 Motor performance versus motor learning in attentional focus instructions

The difference between the results of acquisition, retention and transfer tests in study III is not surprising, due to the consolidation effect for motor learning. The majority of studies have shown the advantages of external focus over internal focus in retention or transfer tests. For example, it has been shown that external focus is better than internal focus during retention or transfer tests for motor learning of serial body projection motor tasks such as balance on a stabilometer (e.g., Wulf et al., 1998), and in discrete object projection motor tasks such as a basketball free shooting task (e.g., Al-Abood et al., 2002), volleyball serve and soccer kick (e.g., Wulf et al., 2002), throwing tennis balls at a target (e.g., Pascua et al., 2015), golf (e.g., Wulf et al., 1999; Wulf, McNevin, Fuchs, Ritter, & Toole, 2000), and a dart throwing task (e.g., Marchant, Clough, & Crawshaw, 2007). In addition, external focus has been shown to be more beneficial than internal focus for discrete body projection tasks such as standing long-jump (e.g., Porter et al., 2010).

Also, some studies have shown *immediate* benefits for performance associated with an external focus of attention. For example, studies have shown that external focus relative to internal focus has an immediate effect on the performance outcome of serial body projection motor tasks such as standing still on an inflated rubber disc (e.g., Wulf, Landers, Lewthwaite, & Töllner, 2009) or Balance Master and Biodex Stability systems (e.g., Landers et al., 2005), and in discrete object projection motor tasks such as a disc throwing task (Zarghami, Saemi, & Fathi, 2012), or a dart throwing task (e.g., Lohse et al., 2010). In addition, external focus has been shown to have *immediate* advantages for performance over internal focus in discrete body projection tasks such as vertical jump (e.g., Wulf & Dufek, 2009; Wulf, Dufek, Lozano, & Pettigrew, 2010; Wulf, Zachry, Granados, & Dufek, 2007).

It should be noted that the difference between practice performance and performance in retention or transfer tests does not mean that learning processes do not occur during practice (Soderstrom & Bjork, 2015). Studies have proposed that learning of motor skills needs time to be sustained due to the consolidation effect (Walker, 2005). The theory of consolidation for motor learning (Walker, 2005, 2008) proposes that there should be a distinction between stabilization, which occurs immediately after practice, and enhancement, which relies on sleep and involves sustaining what is learned. Therefore, it is possible that in certain cases, the advantages of external focus versus internal focus emerge from a sleep-dependent process in certain motor actions.

3.2.2 Limitations and future directions

There may be a few limitations for these studies. Some non-motor factors might affect the motor performance of the participants, but they cannot be under control of the researcher. Also, some features of the participant’s behavior during testing such as hesitation, anxiety, timidity, overestimation and underestimation of their abilities, and lack of persistence might affect the participant's motor performance. As a result, it would also be interesting to know whether a certain personality type or trait of the participants could be responsible for the effects of attentional focus instructions. In addition, due to the time limitation we did not examine the effects of attentional focus instructions on continuous body projection motor tasks. To have a clearer conclusion about the underlying mechanisms of attentional focus instructions, it would be beneficial to investigate the interactions of attentional focus instructions and vision on motor performance of continuous body projection motor actions that are highly dependent on online visual information.

Moreover, our observations during the experiments with children (study I) indicated that there might be some problems with understanding verbal attentional focus instructions for children. Therefore, more accurate manipulation checks should be used in future studies in order to understand whether children understand verbal instructions in different types of motor skills. Also, the experience of children in physical activity and their familiarity with certain tasks should be considered. In addition, it is necessary to perform screening of educational background for learning motor skills from different teachers/coaches, as well as the level of mental development for children.

3.3 Conclusions

The findings of the studies in this dissertation have provided empirical evidence for critical questions in the literature on the possibility of generalizing the beneficial effects of external focus of attention versus internal focus on children in motor tasks that use an open-loop (feedforward) control system. These include discrete object projection motor tasks such as interceptive timing motor skills (catching), which also need visual information to move and adjust the position of the hands in time to conform to the trajectory of the ball, or body discrete projection motor tasks (jump and ½ turn) that require visual information for monitoring body position in space and for landing. Additionally, this dissertation addressed critical questions in the literature concerning the role of vision as a potential mechanism for the advantages of external focus of attention, demonstrating the independence of attentional focus effects from visual information in discrete body projection actions. Furthermore, visual feedback on movement outcome is important for the acquisition of discrete object projection actions (e.g., dart throwing), regardless of attentional focus instructions. However, the beneficial effects of practicing with external focus instructions emerged when the motor task is performed in a more challenging environment, regardless of practicing under visual or non-visual conditions.

Some methods were used for the first time in attentional focus studies. For example, in study II concurrent analysis of movement outcome (using Optojump) and movement form (using video analysis) for a gymnastics skill was used. Also, in study I a throwing ball machine (Lobster, Elite Grand 4) was used to increase the accuracy of the thrown balls in catching.

From a practical perspective, the findings of this dissertation provide applicable information for teachers and coaches with regard to how they should use verbal instructions that direct the attentional focus of learners to the movement effects, compared with verbal instructions that direct the attentional focus of learners to the movement techniques in different types of coordinative motor skills, including body and object projection motor tasks. Therefore, instructors should be careful to provide correct verbal instructions for learners in different stages of learning processes.

Also, coaches who are teaching form-based body projection motor skills which do not involve an implement can use verbal instructions that direct the attentional focus of performers to external cues. Additionally, metaphors can be used for body projection actions that do use an implement, and visual information about external cues is limited. These metaphors can produce a mental image of the movement goal without directing attentional focus to the movement techniques that encourage internal focus of attention (Wulf et al., 1999). Those images that have been created by external attentional focus might be responsible for producing enhanced performance. It has also been reported that professional ballet dancers prefer to use images that direct their attentional focus externally (Guss-West & Wulf, 2016). Thus, for body projection actions that do not involve an implement (e.g., jumping, arabesque), external focus cues or metaphors might be a more effective way to promote overall performance.

3.4 Summary

Verbal instructions have been shown to affect the performance and learning of movement skills. These verbal instructions have the potential to direct the attentional focus of performers to specific aspects of the task in direction of body movement (internal focus) or movement effects (external focus). During the past two decades a large body of studies on adults has shown that external focus instructions on movement effects are more beneficial than internal focus instructions on body movement for the enhancement of motor performance in different types of movement skills, including discrete or continuous body projection motor tasks and discrete object projection motor tasks.

The current study addressed the question concerning the possibility of generalizing with regard to the influence of attentional focus instructions on motor performance in different types of coordinative motor tasks in children. The results showed that external focus is better than internal focus for interceptive motor tasks (e.g., catching) in children who are in the early stages of learning (study I). Also, children who had experience of gymnastics could benefit from external focus compared to internal focus of attention in body projection tasks that do not involve an implement in terms of movement outcome and movement form (study II).

The current research also addressed the question about the influence of attentional focus and vision on motor performance and learning in order to understand the role of vision as a possible mechanism underlying attentional focus effects. As attention and vision are closely related, some researchers have suggested that vision might be a mediator of the advantages of external attentional focus relative to internal attentional focus. The results of the current research demonstrated that the mechanisms underlying the advantages of external focus of attention are independent of vision in discrete body projection tasks (study IV). These results were in line with previous studies, which have indicated the independence of vision from the beneficial effects of external focus of attention in discrete object projection motor tasks. The current research also addressed the question of the role of visual feedback on movement outcome as one of the sources of information for correction of movement pattern during the acquisition phase. Also, the advantages of external relative to internal focus of attention in retention and transfer tests depend on the availability of visual feedback on movement outcome during the acquisition phase. The results showed that although vision is important for successful performance during acquisition of an object projection motor task, external focus of attention was more beneficial than internal focus when the task was more challenging in the transfer test (study III).

The major contribution of this dissertation to the concept of attentional focus is summarized as follows:

1. The advantages of external focus over internal focus of attention can enhance motor performance in interceptive timing motor actions (e.g., catching) that are dependent on visual feedback in order to move and adjust the position of the hands in time to conform to the trajectory of the ball.
2. External focus compared to internal focus of attention enhanced not only movement outcome but also movement form in discrete body projection motor actions (e.g., jump and ½ turn).
3. Although visual feedback on movement outcome is critical for the acquisition of targeting motor skills regardless of attentional focus instructions, advantages of practicing with optimal external focus relative to internal focus instructions could be found in more challenging situations for discrete object projection motor actions (e.g., dart throw) when individuals perform the motor task in more challenging conditions.
4. The advantages of external over internal focus of attention is independent of visual information from the environment in discrete body projection motor actions (e.g., jumping).

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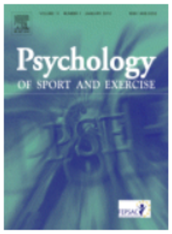

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