

### 3 Effortless Motor Learning?: An External Focus of Attention Enhances Movement Effectiveness and Efficiency

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Skilled movement entails learned motor patterns that are produced with a high degree of accuracy, consistency, and efficiency. The classic definition of skill by Guthrie (1952) captures these important characteristics. According to Guthrie, skill “consists in the ability to bring about some end result with maximum certainty and minimum outlay of energy, or of time and energy” (p. 136.). This definition implies that with skill movement goals are achieved with high reliability. In addition, movements are performed fluently and efficiently, or with relatively little (physical or mental) effort. This can also result in faster movement executions, or time savings. These aspects of skill are seen in experienced performers. For example, skilled golfers typically hit the ball closer to the hole than novice players, and they do so consistently. In addition, an expert golfer is able to hit the ball farther than a novice by generating greater club head speed achieved through fluid, seemingly effortless, motion; indeed, attempts to produce maximal force typically reduce swing fluidity and speed at ball contact. Likewise, the coordination patterns displayed by skilled cross-country skiers are more effective and economical than those demonstrated by most recreational skiers. Skilled individuals have learned to produce the appropriate forces at the right time and in the right directions; they have learned to avoid counterproductive cocontractions and to exploit passive forces, such as gravity. Thus, as a result of practice, movements are produced with less muscular energy—or physical effort (e.g., Lay, Sparrow, Hughes, and O’Dwyer 2002; Sparrow, Hughes, Russell, and Le Rossignol 1999; for a review, see Sparrow and Newell 1998). Moreover, the mental effort associated with movement production lessens with practice (e.g., Abernethy 1988; Leavitt 1979; Smith and Chamberlin 1992), and the movement is thought to become automated—that is, able to be generated without the conscious control of the mover. As the control of movements becomes more automatic, at least some of the available attentional resources can be directed elsewhere (e.g., the traffic in driving, the strategy in ball games, or the artistic expression in ice skating). Thus, relative effortlessness is a defining characteristic of motor skill—even though, somewhat paradoxically, learning is often marked by more, rather than less, effort (Lee, Swinnen,

and Serrien 1994; Salmoni, Schmidt, and Walter 1984; Schmidt 1991; Schmidt and Lee 2005).

Attentional processes and focus have been studied from a wide variety of perspectives and paradigms. The concept of limited attentional capacity or finite attentional resources (e.g., Pashler 1994), often considered to result in the need for selective attention (Sarter, Gehring, and Kozak 2006), has been the subject of much research. Included in this set are studies that overload performers' or learners' attentional capacities to the point of primary task performance disruption, often by dual-task or distracting conditions (e.g., Abernethy 1988; Wilson, Chattington, Marple-Horvat, and Smith 2007). Other researchers have referred to the direction, content, or focus of attention. In this chapter, we discuss a particular line of evidence within the attentional focus literature related to movement that draws a subtle but important distinction between the instructionally induced internal (body-related) and external (movement-effect-related) content of performers' and learners' thoughts.

Research into the effects of attentional focus has shown that an external focus of attention results in more effective performance and learning than an internal focus (see Wulf 2007a, 2007b); moreover, the enhanced outcome seems to be achieved with less effort. Wulf, Höß, and Prinz (1998) first defined an *internal focus* as one that is directed at the performer's own body movements and an *external focus* as one that is directed at the effects that his or her movement have on the environment. Learners, instructors, and theorists do not commonly distinguish between an internal and external focus, haphazardly adopting one or the other without any hard data about effectiveness. In many training situations (e.g., in sports, physical therapy, music), individuals are given instructions about the correct movement pattern—with references being made to the coordination of their body movements. The view that, at the beginning of the learning process, performers need to direct their attention to coordination of their movements can also be seen in the current literature (e.g., Beilock and Carr 2001; Beilock, Carr, MacMahon, and Starkes 2002; Gray 2004). Yet, numerous studies conducted over the past decade or so have provided considerable evidence that an external focus of attention is beneficial not only for more advanced performers but for the inexperienced or novice as well. An external focus is not only more effective for performance and learning, compared to an internal focus, but also results in greater movement economy. That is, an external focus appears to speed the learning process so that a higher skill level is achieved sooner (Wulf 2007b).

To explain the effects of internal versus external foci of attention, Wulf and colleagues put forward the "constrained action hypothesis" (McNevin, Shea, and Wulf 2003; Wulf, McNevin, and Shea 2001; Wulf, Shea, and Park 2001). According to this view, individuals who try to consciously control their movements (i.e., adopt an internal attentional focus) tend to *constrain* their motor system and interfere with automatic control processes. That is, the automatic control mechanisms that have the

capacity to control movements effectively and efficiently are disrupted. In contrast, focusing on the movement's effect allows for a more automatic mode of control. It promotes the utilization of unconscious, fast, and reflexive control processes, with the result that the desired outcome is achieved almost as a by-product.

In this chapter, we examine findings related to the effects of different attentional foci. Specifically, we review findings related to how movement effectiveness ("ability to bring about some end result with maximum certainty"; Guthrie 1952, 136) and movement efficiency ("minimum outlay of energy, or of time and energy"; Guthrie, 136) are affected by the learner's attentional focus. While most studies have been concerned with the former aspect—that is, performance outcomes such as movement accuracy or consistency—as a function of a person's focus of attention (see reviews by Wulf 2007a, 2007b), in this chapter we will particularly focus on the latter aspect. As outlined above, the efficiency of the movement—as indicated by its fluidity or smoothness—is another important criterion of skill. This is often accompanied by subjective feelings of relative effortlessness (e.g., Lay et al. 2002; Sparrow et al. 1999). We will review evidence that a focus on the movement's effects enhances movement efficiency, compared to a focus on the movement per se—which is central to the claim that the adoption of an external focus can speed the learning process (Wulf 2007b).

### Attentional Focus and Movement Effectiveness

Most studies have used outcome measures—such as the accuracy in hitting a target or the minimization of deviations from a balanced position—thus examining participants' "ability to bring about some end result" (Guthrie 1952, 136). This was also the case in the first study that demonstrated the superiority of an external relative to an internal focus (Wulf et al. 1998). In that study, the learning of two dynamic balance tasks was enhanced when participants' attention was directed to the movements of the platform on which they were standing as compared to the movements of their feet. Despite minor difference in the instructions given to different groups, those who focused on the effects their movements had on the support surface (external focus) demonstrated more effective learning than those who focused on their body movements (i.e., feet; internal focus). Specifically, on a ski-simulator task (Wulf et al. 1998, experiment 1), where the goal was to produce slalom-type movements with the largest possible amplitudes, participants who were instructed to focus on exerting pressure on the wheels of the platform under their feet produced larger amplitudes than those who were instructed to exert pressure with their feet. On the stabilometer task (Wulf et al. 1998, experiment 2), learners who directed their attention to markers attached to the platform in front of their feet (without looking at them) were more proficient at keeping the platform in a horizontal position than those who directed attention to their feet. Those group differences were seen on delayed retention tests without focus

reminders, suggesting that they reflected differential effects on learning. Since the publication of the paper by Wulf et al., numerous other studies using balance tasks and populations as diverse as children (Thorn 2006) and persons who had experienced a stroke (Fasoli, Trombly, Tickle-Degnen, and Verfaellie 2002) or who had Parkinson's disease (e.g., Landers, Wulf, Wallmann, and Guadagnoli 2005; Wulf, Landers, Lewthwaite, and Töllner 2009) have replicated the advantages of instructing learners to adopt an external focus of attention.

Other studies have demonstrated learning benefits of external versus internal foci for a variety of sport skills. The accuracy of golf shots has been shown to be enhanced when the performers' attention is directed to the swinging motion of the club rather than to the swing of their arms (Wulf, Lauterbach, and Toole 1999). Interestingly, this is the case not only for novices but even for expert golfers (Wulf and Su 2007). Furthermore, movement accuracy has also been shown to increase with an external focus in basketball free-throw shooting (Al-Abood, Bennett, Hernandez, Ashford, and Davids 2002; Zachry, Wulf, Mercer, and Bezodis 2005), dart throwing (Marchant, Clough, and Crawshaw 2007), football kicks (Zachry 2005), and volleyball serves and soccer kicks (Wulf, McConnel, Gärtner, and Schwarz 2002). Table 3.1 provides an overview of the tasks used, focus instructions given to participants, and the results of some studies examining attentional focus effects. Overall, learning benefits of an external compared to an internal focus—in terms of greater movement accuracy or improved balance performance, for example—have been shown for a variety of skills, levels of expertise, and age groups, as well as for healthy individuals and those with motor impairments, suggesting that this a general and reliable phenomenon (for a review, see Wulf 2007a, 2007b).

### Attentional Focus and Movement Efficiency

An important criterion in Guthrie's (1952) definition of skill is minimal energy expenditure. This can be interpreted as energy savings related to either *physical* (metabolic) or *mental* energy. If the same movement outcome is achieved with less energy, the movement pattern is considered more efficient or economical (distinctions between these terms can be made [e.g., Sparrow and Newell 1998], but for our purposes they are used interchangeably). While movement efficiency typically refers to the metabolic energy required for goal achievement, this concept can also be applied to the mental energy invested in the achievement of the movement goal. If a motor skill is produced with fewer attentional resources (i.e., controlled with a greater degree of automaticity), for example—as is characteristic of skilled performance—one can argue that this is mentally more economical. It can further be suggested that the extent of self-regulatory activity invested in thought and affect management—including that produced by self-focused attention (e.g., Carver and Scheier 1978)—surrounding movement

**Table 3.1**  
Task, instructions provided in internal focus (IF), external focus (EF), and control (C) conditions, and results of selected previous studies

Study	Task	Instructions			Results
		Internal focus	External focus	No focus (control)	
Wulf et al. 1998, experiment 1	<i>Ski simulator</i> : Produce slalom-type movements with largest possible amplitude and frequency	Exert pressure with outer foot	Exert pressure on outer wheels (under feet)	None	Largest amplitude and frequency for EF group (IF = C)
Wulf and McNevin 2003	<i>Stabilometer</i> : Keep platform in a horizontal position	Keep your feet horizontal	Keep markers (in front of feet) horizontal	None	Smallest deviations from horizontal for EF group (IF = C) Greater accuracy for EF group
Wulf et al. 2002, experiment 1	<i>Volleyball serves</i> : Hit target area	For example, shift your weight from the back leg to the front leg	For example, shift your weight toward the target	None	Greater accuracy for EF group
Wulf et al. 2002, experiment 2	<i>Soccer kicks</i> : Hit target area	Position your foot below the ball's midline to lift the ball	Strike the ball below its midline to lift it, that is, kick underneath it	None	Greater accuracy for EF group
Wulf and Su 2007	<i>Golf</i> : Pitch shot	Focus on swing of arms	Focus on swing of club	None	Greatest accuracy for EF group (IF = C)

**Table 3.1**  
(continued)

Study	Task	Instructions			Results
		Internal focus	External focus	No focus (control)	
Zachry et al. 2005	<i>Basketball free-throws</i>	Focus on wrist motion	Focus on rim		Greater accuracy for EF group
Wulf et al. 2007, experiment 1	<i>Jump-and-reach: Jump as high as possible</i>	Focus on finger (touching the rungs)	Focus on rungs (to be touched with finger)	None	Greatest jump height for EF groups (IF = C)
Freedman et al. 2007	<i>Force production/oral-motor control: Exert a given amount of pressure on bulb in mouth</i>	Focus on your tongue	Focus on the bulb		Greater accuracy for EF group
Fasoli et al. 2002	<i>Individuals after stroke: Remove a can from a shelf and place it on a table</i>	Pay attention to your arm: Think about how much you straighten your elbow and how your wrist and fingers move	Pay attention to the can: Think about where it is on the shelf and how big or heavy it is		Shorter movement times, greater peak velocities for EF group
Totsika and Wulf 2003	<i>Pedalo: Ride as fast as possible</i>	Focus on pushing your feet forward	Focus on pushing the platforms (under each foot) forward		Greater speed for EF group

performance and learning contributes to the mental effort, and sense of mental effort, for the motor task (we discuss this proposition further in a later section). Skilled performance is presumably associated with reduced need to engage in active suppression or change of maladaptive thoughts and affective reactions.

From the performer's point of view, increases in movement efficiency are accompanied by feelings of greater effortlessness (e.g., Lay et al. 2002; Sparrow et al. 1999). Given that organisms seem to have a natural propensity to try to conserve energy, it has been argued that they follow the principle of "least effort" (e.g., Hull 1943; Tolman 1932). Interoceptive sensory information about energy expenditure is seen as a means that governs the organism's choice of motor response and that results in the fine-tuning of responses with practice: "...organisms select the least effortful coordination and control function, and, with practice, the selected control parameters are refined to attain the task goal with less metabolic energy expenditure" (Sparrow and Newell 1998, 190).

In the following sections, we describe how an individual's focus of attention influences energy expenditure in the production of motor skills. Specifically, we focus on the physical and mental effort associated with different foci.

## Energy Expenditure

### Physical Effort

The physical energy required to produce movements can be measured by various metabolic indices, such as heart rate or oxygen consumption. Studies that have examined energy expenditure as a function of practice have shown that movement efficiency indeed increases. For example, in a series of studies using a rowing ergometer, the metabolic energy required to produce a given power output decreased across practice days (e.g., Durand, Geoffroi, Varray, and Prefault 1994; Lay et al. 2002; Sparrow et al. 1999). Specifically, decreases were found in heart rate and oxygen consumption. As a consequence of the reduction in oxygen consumption, movement economy (as measured by oxygen consumption at a given workload) increased (Lay et al. 2002). Furthermore, muscle activation—that is, integrated electromyographic (iEMG) activity—decreased across practice days. Finally, perceived exertion—or subjective estimate of effort—was found to decrease with practice (Lay et al. 2002; Sparrow et al. 1999). These changes in energy expenditure are presumably a function of increased movement efficiency brought about by greater movement stability (e.g., Lay et al. 2002), minimized cocontractions, and generally more economical muscle activation patterns.

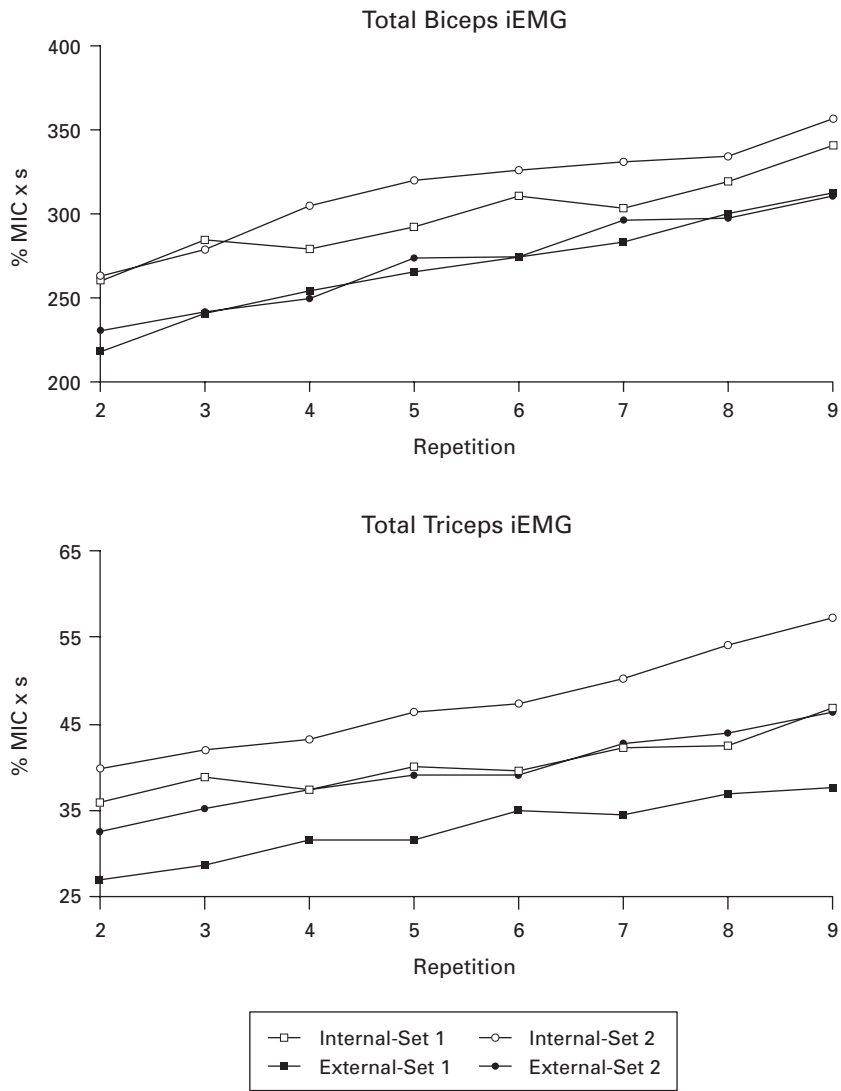
Although not many studies have directly examined movement efficiency as a function of attentional focus, several studies have compared EMG activity when participants adopted an internal or external focus while performing a motor task. One can

argue that if the same outcome is achieved with less muscular activity, the movements that are producing the outcome are more efficient. In the first study that measured EMG activity under different focus conditions, Vance, Wulf, Töllner, McNevin, and Mercer (2004) had participants perform biceps curls with a bar that was weighted with a mass equivalent to an estimated 50% of each participant's maximal force. All participants performed two sets of 10 repetitions under both internal and external focus conditions, with the order of conditions being counterbalanced. In internal focus conditions, participants were instructed to concentrate on their *arms*, whereas under external focus conditions, they were instructed to focus on the *curl bar*. Figure 3.1 shows iEMG activity of the biceps and triceps brachii muscles across repetitions and sets under the two focus conditions. (Only repetitions 2–9 are shown, as the first repetition started from a static position and the last repetition ended in a static position, making them mechanically different from the other repetitions.) As expected, with increasing repetitions of an energy-demanding task, iEMG activity generally increased across repetitions, and, at least for the triceps, iEMG significantly increased from set 1 to set 2. These findings reflect an increase in muscular effort to produce the same result. Importantly, iEMG activity of both biceps and triceps muscles was consistently lower under the external compared to the internal focus condition. This result supports the view that the adoption of an external focus (i.e., on the weight to be lifted) allows the motor system to operate more efficiently—perhaps by recruiting only the absolutely necessary number of motor units required for the task.

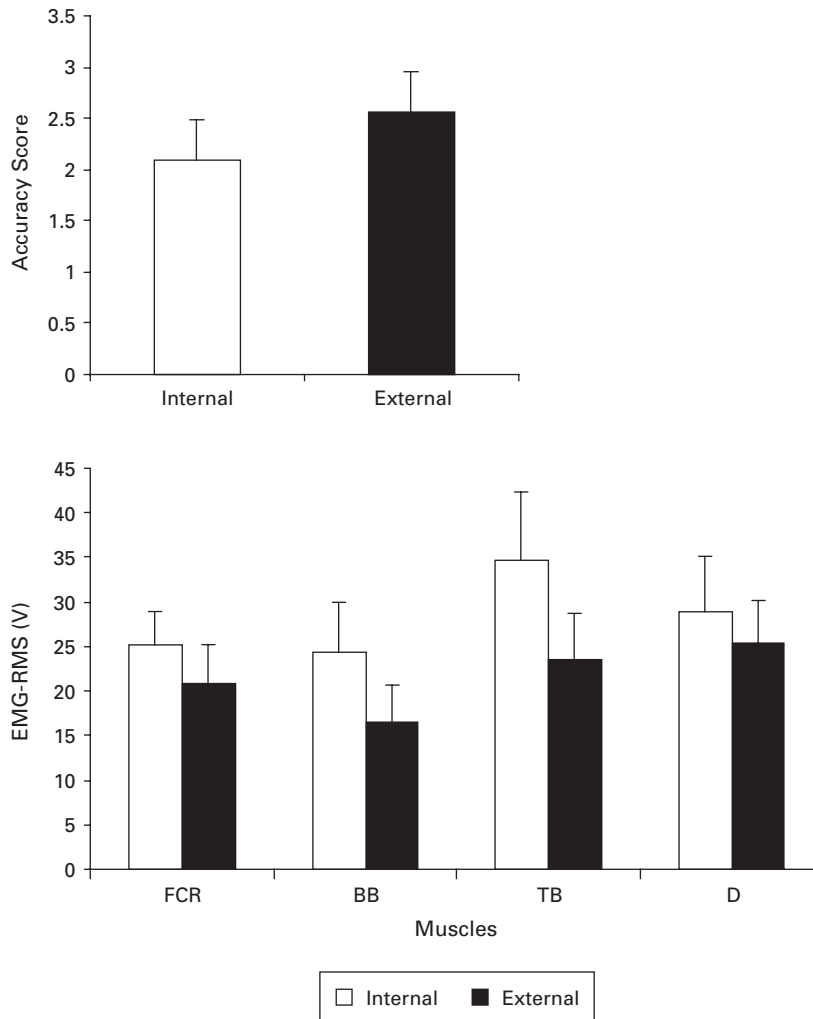
Marchant, Greig, Scott, and Clough (2006) replicated and extended these findings. Their study included a control condition, allowing them to examine whether external focus instructions would increase movement efficiency not only compared to internal focus instructions but also compared to a “natural” condition. Given that weightlifting is a relatively uncomplicated task in terms of motor coordination, one might not necessarily expect to find greater movement efficiency just by changing performers' focus of attention relative to what they normally do, yet Marchant et al. (2006) found that instructions to focus on the bar (external focus), indeed, resulted in less iEMG as well as peak EMG activity in the biceps muscle, compared with instructions to focus on their arms (internal focus) or no focus instructions (control). The latter finding is particularly interesting in that it shows that adopting an external focus reduced muscular activity—or increased movement efficiency—even compared to normal conditions.

In another study examining EMG activity as a function of attentional focus, Zachry, Wulf, Mercer, and Bezodis (2005) used a task that had a clear goal as well as a measurable outcome in terms of movement accuracy. In that study, the participants' task was to shoot basketball free throws under either external focus (rim of the basket) or internal focus (wrist flexion) conditions. The results showed that shooting accuracy was greater with an external focus (see figure 3.2, top), replicating the findings of





**Figure 3.1** Total biceps (top) and triceps (bottom) muscle iEMG activity across sets and repetitions of biceps curls for the internal and external focus conditions in the study by Vance et al. (2004, Experiment 1). MIC, maximal-effort isometric contraction; s, second.



**Figure 3.2**

Average free-throw accuracy scores (higher scores indicate greater accuracy) (top) and EMG root mean square errors (RMSE) of the internal and external focus groups for the four muscle groups (bottom) in the study by Zachry et al. (2005). FCR, flexor carpi radialis; BB, biceps brachii; TB, triceps brachii; D, deltoid.

previous studies (for reviews, see Wulf 2007a, 2007b). In addition, EMG activity in the biceps and triceps muscles was reduced compared to that in the internal focus condition (see figure 3.2, bottom). This study was the first to show that reduced EMG activity with an external focus condition was accompanied by greater movement accuracy. Zachry et al. (2005) argued that increased “noise” in the motor system (i.e., increased EMG activity) resulting from a focus on body movements may hamper fine movement control with the consequence that the movement outcome (e.g., movement accuracy) is less reliable. In other words, an external focus appears to result in more effective and efficient movement patterns, and, as a consequence, movement accuracy is enhanced.

Another interesting finding in the Zachry et al. (2005) study was the fact that attentional focus differences in EMG occurred in muscle groups that participants were not specifically instructed to focus on (i.e., biceps, triceps). This suggests that the effects of attentional focus on the motor system are rather general in nature—“spreading” to muscle groups that are not in the performer’s focus of attention. Even though participants were instructed to focus on the wrist flexor (flexor carpi radialis) in the internal focus condition, significant differences in EMG activity occurred in the biceps and triceps brachii muscles. That is, the focus on a certain part of the body (e.g., hand) had an influence on the control of other parts of the motor system as well (see also McNevin and Wulf 2002; Wulf, Mercer, McNevin, and Guadagnoli 2004; Wulf, Weigelt, Poulter, and McNevin 2003). Thus, the constraining effect on the motor system induced by an internal focus appeared to be relatively general in nature.

Aside from producing a given amount of force with greater efficiency, a minimization of cocontractions between agonist and antagonist muscle groups or a greater synchronization of motor units can also result in increased maximum force. The production of maximal forces requires an optimal activation pattern of agonist and antagonist muscle groups, as well as optimal muscle fiber recruitment within a muscle (Hollmann and Hettinger 2000). Inaccuracies in the timing of these forces, unnecessary cocontractions, or “noise” in the motor system would result in a less-than-maximal force output. In addition, the timing and direction of the generated forces must be optimal in tasks that require maximum force production. This includes tasks in which an object (e.g., shot, discus, football) or one’s own body has to be propelled (e.g., high jump, long jump, volleyball block) or even static force production tasks (e.g., dynamometer). Thus, if an individual produces different amounts of maximum force under external versus internal focus conditions, this can only be attributed to different coordination patterns within or between muscles.

Studies demonstrating increased force production when individuals are instructed to focus on the movement’s effect (i.e., externally; Marchant, Greig, and Scott 2009; Wulf and Dufek forthcoming; Wulf, Zachry, Granados, and Dufek 2007) therefore

provide further evidence for increased movement efficiency with the adoption of an external focus. In a series of experiments, Wulf et al. (2007) and Wulf and Dufek (forthcoming) used a maximum vertical jump-and-reach task to examine effects of attentional focus. Because they used a within-participant design, in which all participants performed the task under counterbalanced internal and external conditions (and under a control condition in Wulf et al. 2007, experiment 1), any differences in jump height would have to be due the coordination of the forces between and/or within muscles. The measurement device used to record maximal vertical jump-and-reach height consisted of plastic rungs at different heights that the participant reached for during the jumps. While no attentional focus instructions were given in the control condition, participants were instructed to concentrate on the tips of their fingers in the internal focus condition and on the rungs in the external focus condition. The results of Wulf et al. showed that participants jumped significantly higher in the external focus condition than in both the internal focus or control conditions, while the latter two resulted in similar jump height. In addition, the vertical displacement of the center of mass (COM) was greatest when participants were instructed to adopt an external focus, providing preliminary evidence that the increase in jump height was due to increased force production.

In a follow-up study, Wulf and Dufek (forthcoming) showed that in addition to jump height and COM displacement, the impulses produced as well as joint moments about the ankle, knee, and hip joints were significantly greater in the external focus condition. Thus, the results provided conclusive evidence that the increased jump height with an external focus was achieved through greater force production. Interestingly, the greater joint moments observed in the external versus internal focus condition (Wulf and Dufek forthcoming) correspond to the increased joint moments found by Vanezis and Lees (2005) for good versus poor jumpers performing a vertical jump. Vanezis and Lees argued that neuromuscular activity was presumably coordinated more effectively (i.e., the coactivation of antagonists was reduced) in the group of good jumpers (although they could not exclude other explanations due to the between-participants design they used). These findings are in line with the view that giving learners instructions that induce an external, rather than internal, focus of attention creates better performance earlier in skill acquisition, effectively accelerating the learning process so that an advanced level of performance is achieved sooner (Wulf 2007b).

A recent study by Marchant et al. (2009) also showed beneficial effects of an external focus on maximum force production. Using an isokinetic dynamometer, these researchers had participants produce maximum voluntary contractions of the elbow flexors under internal focus (i.e., focus on arm muscles) or external focus (i.e., focus on the crank hand bar) conditions. They found that participants produced significantly

greater peak joint torque when they focused externally as compared to internally. Interestingly, this was achieved with significantly *less* muscular (EMG) activity.

A study by Schücker, Hagemann, Strauß, and Völker (forthcoming) showed differential effects of a performer's attentional focus on movement efficiency for a different task. In that study, experienced long-distance runners ran on a treadmill at an individual target speed (corresponding to 75% of their maximum oxygen consumption) under each of three different attentional focus conditions: (1) their running movements (internal focus: motor system), (2) their breathing (internal focus: breathing), or (3) a video clip showing an urban running course from the perspective of a runner (external focus: surroundings). The external focus condition resulted in significantly less oxygen consumption than both internal focus conditions. In addition, the blood lactate level was lowest when performers focused externally. Also, participants rated that condition as the "easiest" one.

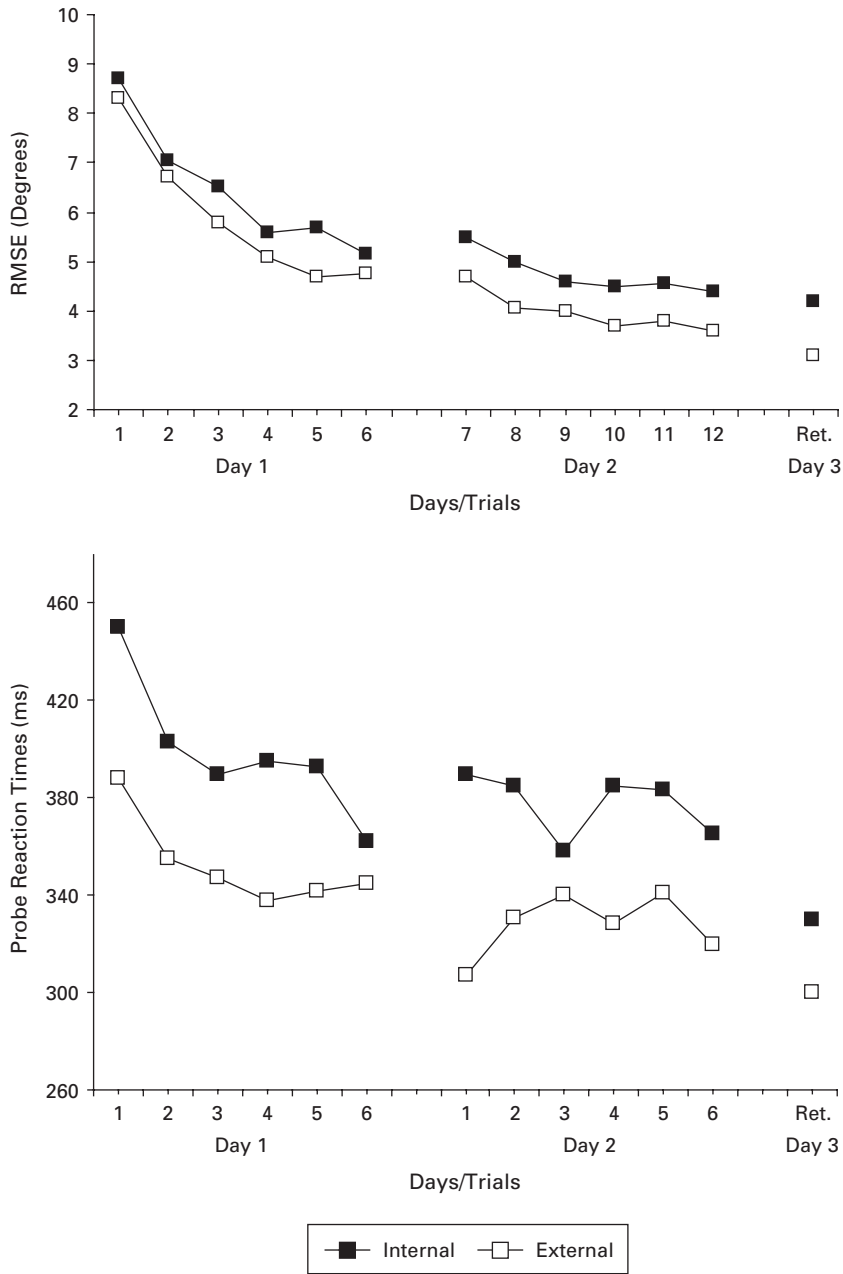
These studies provide converging evidence that movement efficiency—or the physical effort exerted to produce a given outcome—varies greatly with an individual's focus of attention. When an individual adopts an external focus, movements not only are more effective (e.g., Zachry et al. 2005) but also are produced more economically—with the consequence that the resultant maximum forces are greater (Marchant et al. 2009; Wulf et al. 2007; Wulf and Dufek forthcoming), the same forces are produced with less muscular energy (Marchant et al. 2006; Vance et al. 2004; see also Zachry et al. 2005), and oxygen consumption for a given output is reduced (Schücker et al. 2008). Thus, an external focus seems to exploit the energy-conserving nature of the body. Findings showing reduced postural sway with an external compared to an internal focus, for instance, are in line with this view as well (e.g., Wulf et al. 2009; McNevin and Wulf 2002; Wulf et al. 2004). Bringing the center of gravity back to a central position requires more energy if the deviations from this central position are greater. For a motor system to exploit these energy-conserving characteristics, the system has to be sensitive to the movement effects it produces. If attention is directed to the outcome of an action (external focus), there may be a greater coherence between the outcome and the sensory consequences of that action—which allows the motor system to adjust more adaptively to task demands (McNevin and Wulf 2002; McNevin et al. 2003).

### **Mental Effort**

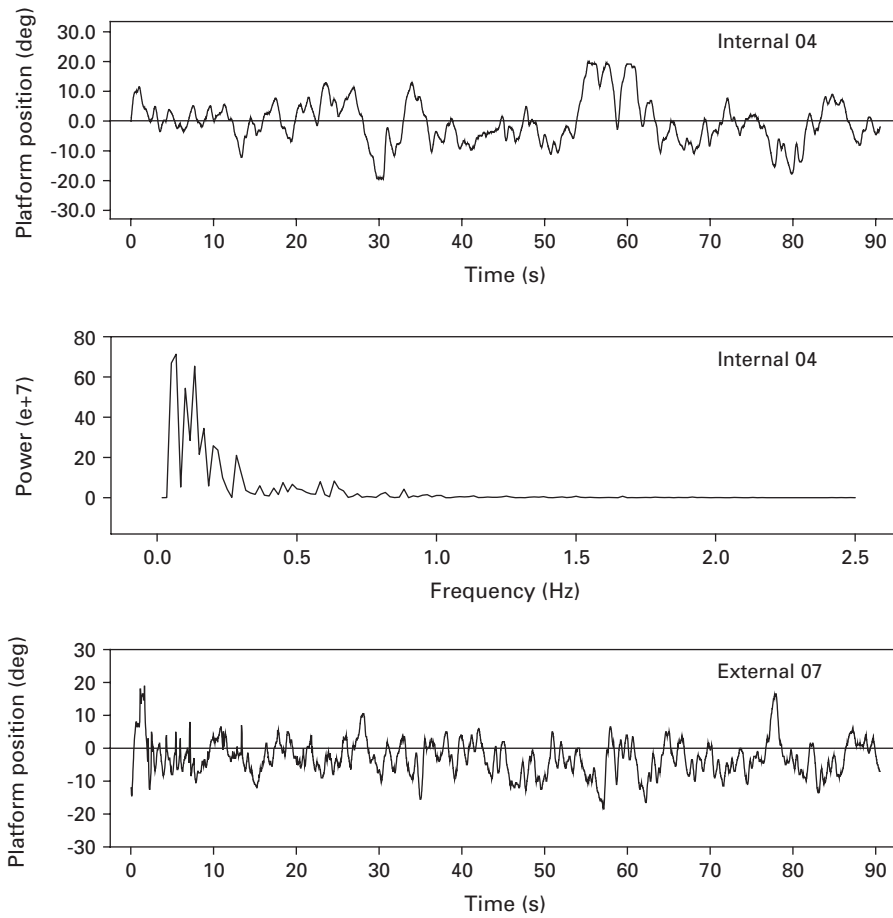
In addition to reducing physical effort, an external focus has been shown to result in greater automaticity in movement control—thus reducing attentional demands, or mental effort. Wulf, McNevin, and Shea (2001) measured participants' probe reaction times (RTs) while they were performing a dynamic balance task (stabilometer) after being given external or internal focus instructions. Dual-task methods are often used

to assess the amount of attention required to perform a certain (primary) task (e.g., Li and Wright 2000; McLeod 1978, 1980; Monno, Chardenon, Temprado, Zanone, and Laurant 2000; Posner and Keele 1969; Salmoni, Sullivan, and Starkes 1976; Temprado, Zanone, Monno, and Laurent 1999; Wright and Kemp 1992; Wrisberg and Shea 1978). Performance on the secondary probe RT task is assumed to be related to the attentional demands of the primary task, with poorer secondary task performance, or longer probe RTs, being interpreted as an indication that the primary task required more attention (e.g., Abernethy 1988). Participants in the Wulf, McNevin, and Shea (2001) study were asked to balance on the stabilometer and to press a response key as quickly as possible when a tone occurred. As can be seen in figure 3.3 (top), participants who were instructed to focus on keeping markers on the platform horizontal (external focus) demonstrated more effective balance learning than participants instructed to focus on keeping their feet horizontal (internal focus). Furthermore, probe RTs generally decreased across practice, indicating that attentional demands of the balance task were reduced as learners became more skilled. More importantly, probe RTs were generally shorter for the external focus group, compared to the internal focus group (see figure 3.3, bottom). This difference in attentional demand was seen not only throughout the two-day practice phase but also on a delayed retention test without instructions. These findings show that the external focus reduced the mental effort associated with the balance task from the beginning of practice, compared to an internal focus. They support the idea that with an external focus of attention, a greater degree of automaticity is achieved sooner than would be the case with an internal focus. Furthermore, the retention results indicated that this advantage was relatively permanent and thus represented a learning effect.

Another piece of evidence for the facilitation of automaticity through an external focus comes from analyses of the frequency of movement adjustments produced by performers who were given external or internal focus instructions. In some of the studies using balance tasks, power spectral analyses were used to determine the dominant frequency components of the movement patterns (e.g., McNevin, Shea, and Wulf 2003; Wulf, McNevin, and Shea 2001; Wulf, Shea, and Park 2001). Faster movement adjustments indicate the utilization of reflexive feedback loops that operate at an automatic or unconscious level. In contrast, relatively slow adjustments reflect the use of more conscious feedback loops. Analyses of the balance records indeed revealed that learners instructed to adopt an external focus (i.e., markers on the stabilometer platform) made more frequent and, as a result, smaller corrections in maintaining their balance than did learners instructed to focus internally (i.e., on their feet; Wulf, McNevin, and Shea 2001; Wulf, Shea, and Park 2001). Figure 3.4 shows the position–time curves of the stabilometer platform across 90-second trials for representative participants in the internal focus (top) and in the external focus (bottom) groups in the Wulf, McNevin, and Shea study. As can be seen, the external focus participant



**Figure 3.3** Balance performance (i.e., platform deviations from the horizontal; root-mean-square errors, RMSE) (top) and probe reaction times (RTs) (bottom) for the internal and external focus groups with auditory stimuli during practice (days 1 and 2) and in retention (day 3) in the study by Wulf, McNevin, and Shea (2001). Ret., retention.



**Figure 3.4**

Examples of platform displacements on a retention trial for one participant in the internal (top) and external (bottom) condition in the study by Wulf, McNevin, and Shea (2001).



displayed higher frequency adjustments than did the internal focus participant. The results of a frequency analysis of the platform movements confirmed this effect, indicating significantly greater frequencies (i.e., mean power frequencies) when learners adopted an external focus.

Interestingly, this effect was even more pronounced in groups of participants that focused on markers that were further away from participants' feet, as compared to participants who focused on markers close to their feet (McNevin et al. 2003). That is, focusing on the more remote movement effects—which are presumably more easily distinguishable from the body movements—resulted in even higher frequencies of responding, and thus greater automaticity, than focusing on effects closer to the body or adopting an internal focus. Thus, there is converging evidence that a focus on the desired movement effect, or outcome, facilitates automatic control processes—thereby reducing mental effort.

### Time and Energy Expenditure

Skilled performance is characterized by the fluidity and smoothness of the movements that are performed. This, in turn, may result in faster movement execution. For example, the well-timed coordination of the arm and leg actions in breaststroke swimming will result in a relatively constant velocity, thereby allowing the performer to swim faster with a given amount of metabolic energy expenditure. In his definition of skill, Guthrie also included as a criterion the capability of achieving the movement goal with a “minimum outlay .... of time and energy” (Guthrie 1952, 136).

Only a few studies that examined the effects of attentional focus used movement speed as a dependent variable (Freudenheim, Corrêa, Corrêa, Ried, and Wulf 2009; Totsika and Wulf 2003; Vance et al. 2004), and these studies showed increases in movement speed with external compared to internal focus instructions. In the Vance et al. (2004) study discussed earlier, participants spontaneously executed the biceps curls faster (i.e., with greater angular velocity) when they adopted an external relative to an internal focus (experiment 1). (In experiment 2, the timing was kept constant through the use of a metronome.) The finding that movements were performed more rapidly when participants focused on the curl bar, rather than their arms, is in line with the automaticity notion (e.g., Wulf, McNevin, and Shea 2001). A more automatic mode of control typically results in more fluid movement patterns and, consequently, can increase the speed of movement production.

This effect was seen more directly in a study by Totsika and Wulf (2003). In that study, two groups of participants practice riding a pedalo. The pedalo consists of two platforms (one for each foot) between sets of wheels. It moves by alternately pushing the upper platform forward and downwards, similar to the pedals on a bicycle. Totsika and Wulf asked participants to ride a distance of 15 m at their “own pace,” with instructions to focus either on pushing their feet forward (internal focus) or on

pushing the platforms forward (external focus). While both groups of participants increased their speed with practice, those who were instructed to adopt an external focus were significantly faster than those who adopted an internal focus. This was the case during the practice phase as well as on various transfer tests, which included (1) riding as fast as possible, (2) riding as fast as possible while counting backward by threes from a two-digit number, and (3) riding backward as fast as possible. These findings show that external focus can result in greater movement speed, facilitated by smoother and more fluid movements. In addition, they indicate that the benefits of practicing with an external focus are generalizable to novel situations (i.e., time pressure, riding backward) and persist when participants' attention was directed elsewhere (i.e., to counting backward).

Freudenheim et al. (2009) recently showed that swimming speed (16 m crawl) can be increased by instructing swimmers to focus on pushing the water back (external) instead of pulling their hands back (internal), or pushing the water down (external) instead of pushing the instep down (internal). With all participants performing under both external and internal focus conditions, swimming times were generally reduced when the swimmers focused on the water. Again, a minor difference in the wording of instructions presumably resulted in greater movement efficiency and, as a consequence, shorter movement times.

Thus, from the available evidence, it appears that an external focus indeed has the capacity to result in time savings. The automaticity in movement control induced by an external focus of attention seems to have concomitant effects on the fluidity and, consequently, speed of motion. Overall, it is clear that, compared to focusing on a movement, focusing on a movement's effect enhances movement effectiveness and economy—speeding the learning process so that a higher skill level is achieved sooner (Wulf 2007b). In the following section, we discuss potential mechanisms underlying this effect.

### **Mechanisms Underlying the Constrained Action Hypothesis**

#### **Why Do Minor Wording Differences in Instructions Induce Performance and Learning Effects?**

A number of commentators have posed explanations for attentional focus effects (Hossner and Wenderoth 2007). These explanations range from presumed visual advantages (Hodges and Ford 2007; Maurer and Zentgraf 2007; Russell 2007) to a greater functional relevance (e.g., Hommel 2007; Künzell 2007; Wrisberg 2007; Ziessler 2007) to reduced information-processing demands of an external relative to an internal focus (Poolton, Maxwell, Masters, and van der Kamp 2007). However, several studies reviewed above within the attentional focus line of inquiry provide evidence that the external focus advantage cannot be attributed to any of those factors (see

Wulf 2007a). For example, visual information is usually kept constant between focus conditions by having participants look straight ahead on balance tasks (e.g., McNevin et al. 2003; Wulf et al. 1998; Wulf, McNevin, and Shea 2001) or by having them close their eyes (McNevin and Wulf 2002). The concept that an external focus of attention facilitates use of more functionally relevant, goal-directed actions is perhaps the most commonly expressed notion regarding the external focus advantage. It might be argued, for example, that external foci may make use of action-oriented capabilities of the neuromuscular system, enabling biomechanical advantages of anticipatory postural adjustments or goal-directed synergies (such as a raised head oriented toward the environmental target). A greater goal relatedness of an external versus internal focus of attention, however, cannot explain some key findings, for instance, differential balance performance when the focus is on the feet as opposed to boards (Totsika and Wulf 2003), rectangles (Landers et al. 2005), disk (Wulf et al 2009) or wheels (Wulf et al. 1998) under one's feet, or differences in muscle activity via EMG recordings as a function of attentional focus (e.g., Marchant et al. 2006; Vance et al. 2004). Finally, it is difficult to argue that the movement-related information-processing demands of internal compared with external focus conditions cause the ongoing differential effects on performance and learning, as proprioceptive and outcome information must be processed under both conditions (for further arguments against this view, see Wulf 2007a).

If the explanations discussed above cannot account for key findings, what might? The explanation might be so straightforward as to note that under internal focus conditions participants simply follow instructions that cause them to deconstruct available automated control sequences into chunks marked by bodily sensations, which presumably cannot well utilize transitions between parts in ways that long strings of linked and automated sequences can. External focus instructions may prevent this decomposition or facilitate performance and learning in other, currently unexplicated, ways.

Here, we speculate about a new perspective on the highly reliable attentional focus effects. This perspective involves what can be called the "self-invoking trigger" and is consistent with our already proffered constrained action hypothesis (see above) but addresses a potential proximal cause of more automatic or conscious control of movements. It is important at this point to recall that external and internal attentional focus effects can occur as the result of as little as one- or two-word differences in instruction (see table 3.1; e.g., Wulf and Su 2007; "Focus on the swing of your arms" [internal] vs. "Focus on the swing of the club" [external]). Wording differences in instructions have been shown in other circumstances (e.g., Cimpian, Acre, Markman, and Dweck 2007; Jourden, Bandura, and Banfield 1991) to result in a range of self-evaluative and behavioral effects. In the case of the movement-related attentional focus literature described in this chapter, external focus instructions often involve a

movement's effect on a "natural" sport-related (e.g., Wulf et al. 1999) or home-related (Fasoli et al. 2002) implement, an artificial target for external focus such as rectangles under one's feet (see table 3.1), or a metaphor (e.g., Wulf et al. 2002). Conversely, internal focus instructions typically contain references to body parts (feet, arms). Thus, the primary distinction between these sets of attentional focus instructions is whether or not they involve the human body.

We speculatively suggest that the mere mention within the internal focus instructions of the participant's body ("your fingers," "your arm," "your feet") or bodily sensation (Marchant et al. 2007; "the feel of the dart") provokes implicit, probably unconscious, access to the self. The self construct has increasingly been recognized in a variety of circumstances to "lurk" within social environments, including all movement contexts and laboratory experimental settings, influencing thoughts, actions, and behavior (see Bargh and Morsella 2008; Stapel and Blanton 2004; Leary 2004).

Self-consciousness or self-focus may lead readily to self-evaluation and activate self-regulatory processes in attempts to manage thoughts and affective responses (Carver and Scheier 1978). It is assumed that this sequence of self-related processing may at times be unconscious (Bargh and Morsella 2008; Chartrand and Bargh 2002), although it may often rise into consciousness. This activity may produce what amounts to a series of ongoing "microchoking" episodes with attempts to right thoughts and bring emotions under control. A number of researchers have posed hypotheses about the nature of the relationship between attentional control for automated skills and for self-regulatory activities (e.g., Beilock et al. 2002; Kanfer and Stevenson 1985). When movement skills are automated, some degree of self-regulatory activity may be accommodated through available "excess" attentional capacity (e.g., Beilock et al. 2002). However, cognitive and affective activity ensuing from ubiquitous social influences (e.g., Stapel and Blanton 2004) and self-evaluation may eventually redirect attention to active attempts at negative thought and emotion suppression or substitution. The switching of attention to this self-regulatory activity may necessitate or activate a switching of control for the concurrent motor task from a more automatic mode to one requiring conscious control in efforts to reestablish control over movement. Alternatively, efforts to manage self-related thoughts and emotions may be so demanding that available attentional capacity is exceeded and performance suffers, prompting the individual to attempt task- and self-related regulatory activity, which may promote a more conscious control of both movement and self-regulatory activities (see Sarter et al. 2006).

A number of social-cognitive variables with ties to the self—including anxiety, fear, performance pressure, and self-efficacy—have been found to influence or correlate with the neuromuscular coordination or control of movement tasks and skills (e.g., Adkin, Frank, Carpenter, and Peysar 2002; Gray 2004; Pijpers, Oudejans, and Bakker

2005; Slobounov, Yukelson, and O'Brien, 1997; Williams, Vickers, and Rodrigues 2002). These findings are consistent with the proposition that a more negative self-focus (reflected in higher anxiety and fear levels and lower levels of self-efficacy) is associated with more widespread, inefficient activation of the muscular system, disruption of automaticity, and the use of more conscious control over ongoing movement. Exploration of the possible role of positive self-evaluations and affective responses for facilitation of automatic control is currently limited. It may be that active self-regulatory activities do not ensue, or at least demand less effort and attention, when positive self-regard and optimal task performance are experienced. As noted earlier, the self-invoking trigger potentially associated with internal focus instructions is speculative and has not been directly examined, nor have the potential sequelae of self-regulatory activity and subsequent impacts on conscious control of movement. Investigation of the mechanisms involved in the external focus advantage will likely involve not only the experimental and behavioral methods utilized thus far but the methods of social-cognitive psychology and social-cognitive affective neuroscience (Lieberman 2007; Ochsner and Gross 2008; Sarter et al. 2006) as well as the continued application of neurophysiological and biomechanical approaches.

### Summary and Conclusion

From the findings reviewed in this chapter, it is clear that the effectiveness and efficiency of motor skill performance is affected by the individual's focus of attention. In particular, focusing on the movement's effect (i.e., adopting an external focus) has been shown to result not only in greater accuracy but also in enhanced efficiency of movement—both physically and mentally. The production of the same outcome (e.g., weight lifted, distance run) with reduced muscular activity or reduced oxygen consumption, or even greater maximum force production, when the performer adopts an external relative to an internal focus is an indication of decreased physical effort. In addition, an external focus appears to reduce mental effort—as indicated, for example, by improved secondary-task performance. Finally, there is evidence that movements are executed faster with an external focus, presumably as a result of greater fluidity and smoothness in movement production.

To account for the differential effects of external versus internal foci of attention, we originally proposed the constrained action hypothesis, according to which an external focus promotes automaticity in movement control (Wulf, McNevin, and Shea 2001). Here we expanded this view by suggesting a possible self-invoking trigger that may accompany an internal focus of attention or be prevented by an external focus. Regardless of cause, an external focus of attention appears to produce more effective performance achieved with minimizations of physical and mental effort. Ironically, however, it seems that a focus on achieving effortlessness (arguably an internal sensa-

tion) might result in a Sisyphean frustration in which a state of effortlessness is never reached.

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Bruya—Effortless Attention