Human Movement Science 40 (2015) 176–184

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

External focus and autonomy support: Two important factors in motor learning have additive benefits

Gabriele Wulf [a,*], Suzete Chiviacowsky [b], Ricardo Drews [b]

[a] *University of Nevada, Las Vegas, USA*
[b] *Federal University of Pelotas, Brazil*

ARTICLE INFO

Article history:

PsycINFO classification:
2330
2343
3720

Keywords:
Self-controlled practice
Self-efficacy
Throwing
Fundamental psychological needs

ABSTRACT

We examined whether the combination of two factors that have consistently been found to enhance motor learning – an external focus (EF) of attention and autonomy support (AS) – would produce additive benefits. Participants practiced throwing with their non-dominant arm. In a 2 × 2 design, they were or were not asked to focus externally (i.e., on the target), and were or were not given a choice (autonomy support). The latter involved choosing 2 5-trials blocks during practice on which they used their dominant arm. All four groups – EF/AS, EF, AS, and C (control) – completed a practice phase consisting of 60 trials. The distance to the target (bull's eye) was 7.5 m. One day later, participants performed retention (same target distance) and transfer tests (8.5 m). Both external focus instructions and autonomy support enhanced retention and transfer performance. Importantly, the combination of these factors resulted in additive learning advantages. The EF/AS group showed the greatest throwing accuracy, and the EF and AS groups outperformed the C group. In addition, self-efficacy measured after practice and before retention and transfer was increased by both factors. Thus, promoting an external focus of attention and supporting learners' need for autonomy seem to independently influence learning.

* Corresponding author at: Department of Kinesiology and Nutrition Sciences, University of Nevada, Las Vegas, 4505 Maryland Parkway, Las Vegas, NV 89154-3034, USA. Tel.: +1 (702) 895 0938.

E-mail address: gabriele.wulf@unlv.edu (G. Wulf).

http://dx.doi.org/10.1016/j.humov.2014.11.015

1. Introduction

In a new theoretical account of motor learning (Wulf, 2014; Wulf & Lewthwaite, 2014), two motivational (autonomy support, enhanced expectancies) and one attentional factor (external focus) are considered key "ingredients" for successful learning. In recent years, these three variables – external-focus instructions or feedback (for a review, see Wulf, 2013), practice conditions that support learners' need for autonomy, typically termed self-controlled practice in the motor learning literature (for reviews, see Sanli, Patterson, Bray, & Lee, 2013; Wulf, 2007b), and conditions that lead to enhanced expectancies for future performance (e.g., Chiviacowsky & Wulf, 2007; Wulf, Chiviacowsky, & Lewthwaite, 2010) – have consistently been shown to positively affect motor skill learning. In two recent studies, we combined external focus instructions with enhanced expectancies (Pascua, Wulf, & Lewthwaite, 2014), or autonomy support with enhanced expectancies (Wulf, Chiviacowsky, & Cardozo, 2014). In both studies, combining the two factors produced additive advantages for learning. In the present study, we examined the third and last combination – an external focus and autonomy support – to determine whether their combination would also yield greater learning benefits than each variable alone. If so, this finding would provide critical support for new theoretical assumptions (Wulf, 2014; Wulf & Lewthwaite, 2014).

Adopting an *external focus of attention* (i.e., a focus on the intended movement effect) has reliably been found to enhance learning relative to an internal focus on body movements or control conditions (see Wulf, 2013). The performer's attentional focus seems to fundamentally affect motor control processes and consequently performance and learning – independent of the type of task, the individual's skill level, age, or (dis)ability. More specifically, concentrating on the planned effect of one's movements (e.g., on an implement), as opposed to body movement per se, promotes automaticity (e.g., Lohse, 2012; Wulf, McNevin, & Shea, 2001). This is evidenced, for example, by more effective dual-task performance (Kal, van der Kamp, & Houdijk, 2013; Wulf, McNevin, & Shea, 2001), increased use of reflexive movement adjustments (e.g., McNevin, Shea, & Wulf, 2003), and greater movement fluidity (Kal et al., 2013). The result is generally enhanced movement effectiveness (e.g., accuracy, balance) and efficiency (e.g., muscular activity, oxygen consumption, heart rate) (see Wulf, 2013). In essence, by adopting an external focus, learners reach a higher skill level sooner (Land, Frank, & Schack, 2014; Wulf, 2007a).

Autonomy-supportive practice conditions – that is, those in which participants are granted control over certain practice conditions – have also been shown to benefit learning in numerous studies (for reviews, see Sanli et al., 2013; Wulf, 2007b). In the motor learning domain, these manipulations are typically referred to as self-controlled practice. Motor learning has consistently been shown to be enhanced by self-controlled practice conditions compared with yoked control conditions. In previous studies, the variables participants were allowed to control have included, for example, the delivery of feedback (Chiviacowsky & Wulf, 2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997), use of assistive devices (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012; Hartman, 2007; Wulf & Toole, 1999), practice amount (Post, Fairbrother, Barros, & Kulpa, 2014), or frequency of skill demonstrations (e.g., Wulf, Raupach, & Pfeiffer, 2005). Interestingly, in separate lines of research in the social-psychological literature, findings show that providing individuals with task-relevant autonomy support can result in superior (Wulf, Clauss, Shea, & Whitacre, 2001) outcomes when compared with conditions that do not offer choices, or do not support participants' need for autonomy. Lewthwaite and Wulf (2012) first pointed out those related findings in the social-psychological realm and the motivational underpinnings of "self-controlled" practice. Being autonomous, that is, having choices and being able to make decisions that affect one's life, is considered a fundamental psychological need (Deci & Ryan, 2000, 2008). Autonomy-supportive conditions, in which individuals are given choices, have been shown to increase individuals' motivation and performance or learning in a variety of situations (e.g., Reeve & Tseng, 2011; Wulf, Freitas, & Tandy, 2014). Interestingly, even apparently inconsequential choices can have a positive effect on learning (e.g., Tafarodi, Milne, & Smith, 1999). With respect to motor learning, recent studies have supported the motivational interpretation by showing that even relatively trivial choices, and those that are not directly relevant to task performance, can provide learning benefits (e.g., Wulf & Adams, 2014; Wulf et al., 2014). For example, in the latter study, allowing participants to choose the color of balls they were throwing led to more effective task learning than not giving them that choice.

Given the relatively strong impact each factor – external-focus instructions and autonomy-supportive practice conditions – has on learning, an important question is: would combining both factors yield even greater advantages than each factor alone? It is conceivable that one variable is sufficient to produce optimal learning. Or, if one variable has a stronger influence than the other, adding one (e.g., autonomy support) to the other (e.g., external focus) may further promote learning, but not vice versa. However, if both are essential and irreplaceable preconditions for optimal skill learning (Wulf, 2014), one might see a double advantage relative to the presence of only one factor, or none. To examine this issue, we used a factorial design in which we crossed external-focus instructions with autonomy support. This resulted in 4 groups: external focus/autonomy support, external focus, autonomy support, and control groups. Participants practiced a novel motor task (i.e., throwing at a target with their non-dominant arm). In the autonomy-supportive groups (external focus/autonomy support, autonomy support), participants were allowed to choose 2 5-trials blocks out of 60 practice trials during which they used their dominant arm. The external focus and control groups were yoked to these two groups, respectively. An external focus was induced by asking learners to focus on the target (e.g., Pascua et al., 2014). Learning was assessed by delayed retention and transfer tests.

Of additional interest was the question whether self-efficacy, that is, a person's confidence in her of his ability to perform a certain task successfully in the future (Bandura, 1977, 1997), might play a mediating role in the effects, if any, of external focus instructions or autonomy support. The relation between self-efficacy and motor performance is well known (e.g., Feltz, Chow, & Hepler, 2008; for a meta-analysis of 45 studies, see Moritz, Feltz, Fahrbach, & Mack, 2000), and self-efficacy has been also been shown to be a mediator of motor learning (e.g., Stevens, Anderson, O'Dwyer, & Williams, 2012). In previous studies, both an external focus (Pascua et al., 2014) and autonomy support (Chiviacowsky, 2014; Hooyman, Wulf, & Lewthwaite, 2014; Wulf et al., 2014) increased learners' self-efficacy. Therefore, we wanted to examine whether self-efficacy would be further increased by the presence of both factors. We measured self-efficacy before and after practice, as well as before the retention test. We also performed regression analyses to examine possible relations between self-efficacy, practice performance, and learning (i.e., retention and transfer performance).

To summarize, we hypothesized that an external focus and autonomy support would have additive benefits for motor learning (i.e., retention and transfer performance), as evidenced by main effects for each factor. We also expected to see increases in self-efficacy resulting from each factor (i.e., main effects for each factor). Finally, we hypothesized that self-efficacy at the end of practice and/or before the retention test would predict learning.

2. Method

2.1. Participants

Sixty-eight university students (16 females, 52 males), with a mean age of 21.8 years ($SD = 2.60$) participated in the study. None of them were ambidextrous (4 were left-handed). All were naïve as to the purpose of the experiment. Before participating in the study, all participants signed an informed consent form, which was approved by the university's institutional review board.

2.2. Apparatus and task

Participants were asked to throw beach-tennis balls (5.5 cm in diameter) overhand at a target, using their non-dominant arm. The target was hung in a net ($2.4 \times 2.4 \times 1.0$ m). It consisted of a bull's eye with a 20-cm radius, which was surrounded by 9 concentric circles (see Fig. 1). The center of the bull's eye was 1.2 m above the ground. The concentric circles had radii of 20, 30, 40 ... and 100 cm. One hundred points were awarded when the ball hit the bull's eye. Ninety points were given for hitting the next circle, and so forth. If a ball hit a line separating two zones, the higher score was awarded. Throws that completely missed the target were given 0 points. The distance of the target was 7.5 m

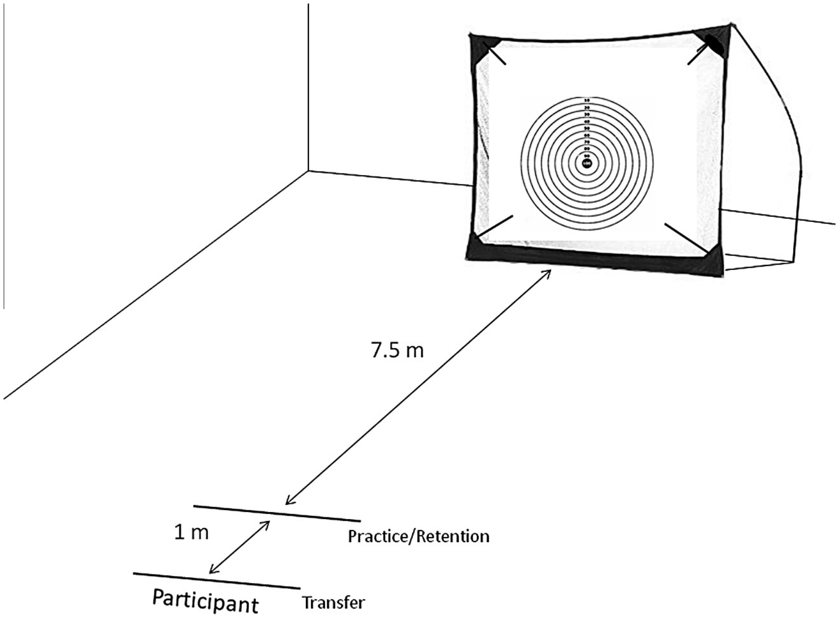

Fig. 1. Experimental set-up.

during pre-test, practice phase and retention test, and 8.5 m on the transfer test. The experiment was conducted in an indoor gym.

2.3. Procedure

Before the beginning of the practice phase, participants received basic instructions for the overhand throw with the non-dominant arm (e.g., stay behind the line, throw with the left arm, take a step forward with the right foot) and one demonstration by the experimenter. Handedness was determined by asking participant which hand they typically used to throw balls (e.g., handball, basketball). Participants first performed a 5-trial pre-test. This was followed by the practice phase, which consisted of 6 blocks of 10 practice trials, with 2-min rest period between blocks. After each block, participants were given feedback about their average accuracy score on that block. Participants were randomly assigned to one of four groups: external focus and autonomy support (EF/AS), external focus (EF), autonomy support (AS), or control (C) groups. In the groups that involved an external focus (EF/AS, EF), participants were instructed (or reminded) before each 10-trial practice block to concentrate on the target. Furthermore, all participants were informed that occasionally using the dominant arm for throwing would help them learn to throw with the non-dominant arm. However, only in the groups that included autonomy support (EF/AS, AS) were participants provided the opportunity to choose 4 5-trial blocks, out of their 60 practice trials, on which they used their dominant arm. EF group participants were yoked with EF/AS participants, and C group participants were yoked with the AS group with regard to those blocks. Before the beginning of the practice phase, participants were informed that they would only use their non-dominant arm on Day 2. One day later, participants performed retention and transfer tests, which consisted of 10 trials each. No instructions or feedback were provided, and participants only used their non-dominant arm on the retention and transfer tests.

Participants were asked to complete self-efficacy rating scales after the pre-test, after the practice phase, and prior to the retention test on the following day. They rated their confidence, on a scale from 1 (not confident at all) to 10 (extremely confident), that they would be able to achieve an average score of 50, 60, 70, or 80 "on the last 10 trials today" (after the pre-test), "tomorrow" (after practice), or "today" (before the retention test).

2.4. Data analysis

Accuracy scores on the pre-test were averaged across 5 (pre-test) or 10 trials (practice, retention, transfer), respectively. The pre-test data were analyzed in a 2 (EF: yes, no) × 2 (AS: yes, no) analysis of variance (ANOVA). The practice data were analyzed in a 2 (EF) × 2 (AS) × 6 (block) ANOVA with repeated measures on the last factor, while the retention and transfer data were analyzed in 2 (EF) × 2 (AS) ANOVAs. Self-efficacy scores were averaged across the 4 questions (i.e., score of 50, 60, 70, 80) and analyzed separately in 2 (EF) × 2 (AS) ANOVAs for each phase. We conducted simple linear regression analyses to determine relations between self-efficacy, end-of-practice performance (block 6), and retention and transfer test performance.

3. Results

3.1. Throwing performance

The 4 blocks of 5 consecutive trials on which participants used their dominant arm were relatively evenly distributed across the practice phase and did not differ much among groups. The EF/AS and (yoked) EF groups had, on average, 2.0 dominant-arm blocks in each of the first and second half of the practice phase, while the AS and (yoked) C groups had an average of 2.12 and 1.88 blocks in each half, respectively.

All group performed similarly on the pre-test (see Fig. 2). There were no differences among groups. The main effects of EF and AS were not significant, Fs (1, 64) < 1. Also, there was no interaction of EF and AS, F (1, 64) < 1.

During the practice phase, throwing accuracy increased across blocks. The EF/AS group tended to have the highest accuracy scores, while the C group demonstrated the lowest scores. The main effect of block, F (5, 320) = 3.02, p = .011, η_p^2 = .045, was significant. The main effects of AS, F (1, 64) = 5.70, p < .05, η_p^2 = .082, was also significant, while the main effects of EF, F (1, 64) = 3.60, p = .06, was only marginally significant. There was no interaction of EF and AS, F (1, 64) = 1.02, p > .05. Also, none of the other interactions were significant.

On both the retention and transfer test, the EF/AS group showed the highest throwing accuracy, while the EF and AS groups had intermediate scores, and the C group had the lowest scores. On the retention test, the main effects of both EF, F (1, 64) = 13.31, p < .001, η_p^2 = .172, and AS, F (1,

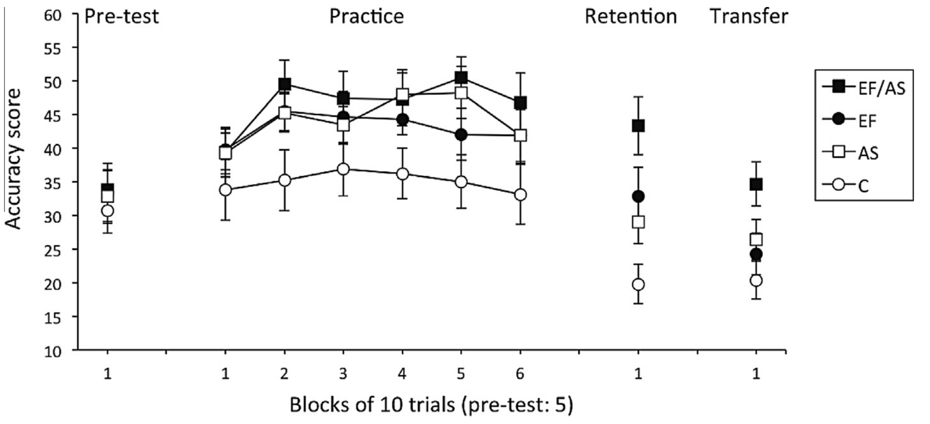

Fig. 2. Throwing performance of the four groups on the pre-test, during practice (Day 1), and on the retention and transfer tests (Day 2). *Note:* Error bars indicate standard errors.

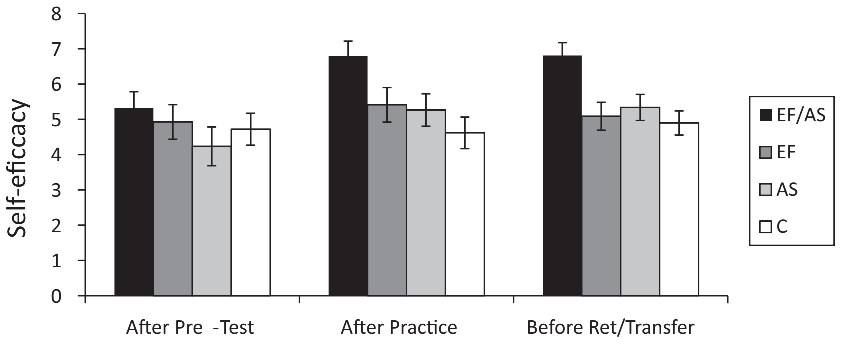

Fig. 3. Self-efficacy scores after the pre-test, after practice (Day 1), and before retention and transfer (Day 2). *Note:* Error bars indicate standard errors.

64) = 6.98, $p < .01$, $\eta_p^2 = .098$, were significant. There was no interaction of EF and AS, $F\,(1, 64) < 1$. On the transfer test, the main effects of EF, $F\,(1, 64) = 4.07$, $p < .05$, $\eta_p^2 = .060$, and AS, $F\,(1, 64) = 7.26$, $p < .01$, $\eta_p^2 = .102$, were also significant, while the interaction of EF and AS was not significant, $F\,(1, 64) < 1$.

3.2. Self-efficacy

There were no group differences in self-efficacy after the pre-test (see Fig. 3). The main effects of EF, $F\,(1, 64) = 1.75$, $p > .05$, and AS, $F\,(1, 64) < 1$, were not significant. Also, there was no interaction of EF and AS, $F\,(1, 64) < 1$.

At the end of practice, self-efficacy was increased by EF or AS. The highest self-efficacy was seen in the EF/AS group, and the lowest in the control group. The main effects of both EF, $F\,(1, 64) = 6.51$, $p < .05$, $\eta_p^2 = .092$, and AS, $F\,(1, 64) = 4.97$, $p < .05$, $\eta_p^2 = .072$, were significant. The AS × EE interaction was not significant, $F\,(1, 64) < 1$.

This pattern of results was also seen before the retention and transfer tests on Day 2. The main effects of EF, $F\,(1, 64) = 5.09$, $p < .05$, $\eta_p^2 = .074$, and AS, $F\,(1, 64) = 8.61$, $p < .05$, $\eta_p^2 = .119$, were significant. There was no interaction between EF and AS, $F\,(1, 64) = 3.02$, $p > .05$.

3.3. Regression analyses

End-of-practice performance (practice block 6) predicted self-efficacy after practice, $F\,(1, 66) = 5.90$, $p < .05$, *Adjusted* $R^2 = .068$, $\beta = .286$, but not before the retention test, $F\,(1, 66) = 2.30$, $p > .05$, *Adjusted* $R^2 = .019$, $\beta = .183$. Self-efficacy after practice, $F\,(1, 66) = 6.65$, $p < .05$, *Adjusted* $R^2 = .078$, $\beta = .303$, and before retention, $F\,(1, 66) = 5.74$, $p < .05$, *Adjusted* $R^2 = .066$, $\beta = .283$, predicted retention performance. Similarly, self-efficacy after practice, $F\,(1, 66) = 4.61$, $p < .05$, *Adjusted* $R^2 = .051$, $\beta = .256$, and before retention, $F\,(1, 66) = 5.05$, $p < .05$, *Adjusted* $R^2 = .057$, $\beta = .267$, was a predictor of transfer performance. Finally, retention performance predicted transfer test performance, $F\,(1, 66) = 24.75$, $p < .001$, *Adjusted* $R^2 = .262$, $\beta = .522$.

4. Discussion

Instructions to focus externally on the target (EF) and supporting learners' need for autonomy (AS) each benefitted learning. More importantly, the combination of the two factors (EF/AS) produced even greater learning advantages (i.e., retention and transfer test performance) than did each factor alone. Even though accuracy scores were generally somewhat lower on the transfer test due to the greater target distance relative to the retention test, the overall pattern of results was similar on both tests of learning. The EF/AS group demonstrated the greatest accuracy, while the control group was least accurate. Having only one factor (EF or AS) yielded similar and intermediate benefits for learning.

Furthermore, both factors influenced performance during practice, and this performance affected learners' self-efficacy. Self-efficacy in turn was a predictor of motor learning.

In the present study, we used the same task as in two previous studies (Pascua et al., 2014; Wulf et al., 2014) in which we examined the two other combinations of three important learning variables (i.e., external focus, autonomy support, enhanced performance expectancies). Interestingly, all three studies yielded a very similar pattern of results. Combing an external focus with enhanced expectancies (positive social-comparative feedback) produced additive benefits (Pascua et al., 2014). That is, each factor alone enhanced learning to a similar degree compared with a control condition, but the presence of both factors essentially doubled the benefit. Similarly, the combination of autonomy support (choice of ball color) and enhanced expectancies resulted in additive learning benefits relative to each factor alone or a control condition which produced the least effective learning (Wulf et al., 2014). It is also interesting to note that in all three studies, learners' self-efficacy was enhanced by each factor, but self-efficacy was highest in the "combined" groups. While associations of self-efficacy and motor performance are well known (e.g., Feltz et al., 2008; Moritz et al., 2000), it is becoming increasingly clear that practice conditions that tend to increase self-efficacy also promote learning (see also, Chiviacowsky, Wulf, & Lewthwaite, 2012; Hooyman et al., 2014; Ste-Marie, Vertes, Law, & Rymal, 2013; Stevens, Anderson, O'Dwyer, & Williams, 2012) (see below for further discussion).

The learning advantages associated with an external focus of attention have been attributed mainly to the automaticity in movement control resulting from a concentration on the intended movement effect and away from body movements (see Wulf, 2013). Without explicit external focus instructions, learners tend to focus internally (e.g., Land, Tenenbaum, Ward, & Marquardt, 2013; Pascua et al., 2014), with the result that learning is less than optimal. This appears to be largely due to superfluous muscular activity (e.g., Lohse & Sherwood, 2012; Zachry, Wulf, Mercer, & Bezodis, 2005) that disrupts the fluidity of movements and adds "noise" to the motor systems which degrades accuracy, balance, etc. (Wulf et al., 2001). Yet, the present findings, together with those of Pascua and colleagues, which show increased self-efficacy with an external focus, add another important aspect to this picture. In addition to its direct influence on performance and learning, an external focus also seems to have indirect learning benefits by increasing learners' confidence in their ability to perform well in the future. That is, presumably as a result of their effective performance with an external focus, learners' self-efficacy is enhanced – and this likely increases the learning benefits further.

Giving learners the opportunity to choose when to throw with their dominant arm, thereby acknowledging and supporting their need for autonomy (e.g., Deci & Ryan, 2000, 2008), also increased their self-efficacy. Autonomy-supportive conditions have previously been shown to enhance performers' situation-specific confidence. For example, task instructions that imply a certain degree of freedom in terms of how a given task is performed or practiced have been found to lead to higher self-efficacy (Hooyman et al., 2014) or perceived competence (Reeve & Tseng, 2011) compared with controlling instructions that leave learners with no choices. Allowing learners to make their own decisions presumably imparts a sense of trust in their ability, with the consequence that their confidence in being able to do well increases. It is particularly interesting that even incidental choices have been shown to increase their task-related confidence (Tafarodi et al., 1999) and motivation (e.g., Wulf et al., 2014), as well as performance and learning (e.g., Wulf & Adams, 2014; Wulf et al., 2014). Almost 40 years ago, Langer (1975) demonstrated that even the illusion of having a choice can increase individual's confidence in their ability to produce a certain outcome. She argued that simply the perception of being able to control the environment enhanced feelings of competence.

How exactly does self-efficacy facilitate learning? We surmise that it reduces a self-focus. Some support for this notion comes from findings showing reduced nervousness (Wulf, Chiviacowsky, & Lewthwaite, 2012) or diminished concerns about their performance or ability (Lewthwaite & Wulf, 2010; Wulf, Lewthwaite, & Hooyman, 2013) when learners' expectancies for performance were enhanced. Several lines of research have identified self-focused attention as detrimental to motor skill learning and performance (e.g., self-focus, Baumeister, 1984; explicit monitoring, Beilock & Carr, 2001; skill-focused attention, Gray, 2004; reinvestment, Masters & Maxwell, 2008; internal focus of attention, Wulf, 2013) due to a disruption of automaticity resulting from conscious control attempts. Interestingly, self-referential activity appears to be related to the brain's default mode (e.g., Buckner, Andrews-Hanna, & Schacter, 2008). Thus, optimal task performance seems to require a switch to a task-oriented focus, or task-related activation (Northoff, Qin, & Nakao, 2010). Practice conditions that enhance self-efficacy may enable the performer to direct more attention to the task at hand by minimizing a self-focus (e.g., Lewthwaite & Wulf, 2010; Wulf et al., 2012). The result is more effective learning.

Taken together, it has become clear that the learning variables examined in the present study and in two previous studies (Pascua et al., 2014; Wulf et al., 2014) make unique contributions to learning (Wulf, 2014; Wulf & Lewthwaite, 2014). An external focus of attention, autonomy-supportive practice conditions, as well as conditions that enhance learner's expectancies all seem to be necessary if optimal learning is the goal, as each combination of two of these factors has now been demonstrated to yield superior learning relative to one factor (or none). Important next steps will include examinations of the effectiveness of combinations of three versus two factors, in addition to further investigations into the underlying psychological mechanisms (e.g., self-efficacy, positive affect) that make them seemingly irreplaceable.

References

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*, 191–215.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: Freeman.

Baumeister, R. (1984). Choking under pressure: Self-consciousness and paradoxical effects of incentives on skillful performance. *Journal of Personality and Social Psychology, 46*, 610–620.

Beilock, S. L., & Carr, T. H. (2001). On the fragility of skilled performance: What governs choking under pressure? *Journal of Experimental Psychology: General, 130*, 701–725.

Buckner, R. L., Andrews-Hanna, J. R., & Schacter, D. L. (2008). The brain's default network: Anatomy, function, and relevance to disease. *Annals of the New York Academy of Sciences, 1124*, 1–38.

Chiviacowsky, S. (2014). Self-controlled practice: Autonomy protects perceptions of competence and enhances motor learning. *Psychology of Sport and Exercise, 15*, 505–510.

Chiviacowsky, S., & Wulf, G. (2002). Self-controlled feedback: Does it enhance learning because performers get feedback when they need it? *Research Quarterly for Exercise and Sport, 73*, 408–415.

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport, 78*, 40–47.

Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012a). Self-controlled learning: The importance of protecting perceptions of competence. *Frontiers in Psychology, 3* (Article 458). http://dx.doi.org/10.3389/fpsyg.2012.00458.

Chiviacowsky, S., Wulf, G., Lewthwaite, R., & Campos, T. (2012b). Motor learning benefits of self-controlled practice in persons with Parkinson's disease. *Gait & Posture, 35*, 601–605.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227–268.

Deci, E. L., & Ryan, R. M. (2008). Self-determination theory: A macrotheory of human motivation, development, and health. *Canadian Psychology, 49*, 182–185.

Feltz, D. L., Chow, D. M., & Hepler, T. J. (2008). Path analysis of self-efficacy and diving performance revisited. *Journal of Sport and Exercise Psychology, 30*, 401–411.

Gray, R. (2004). Attending to the execution of a complex sensorimotor skill: Expertise differences, choking, and slumps. *Journal of Experimental Psychology: Applied, 10*, 42–54.

Hartman, J. M. (2007). Self-controlled use of a perceived physical assistance device during a balancing task. *Perceptual and Motor Skills, 104*, 1005–1016.

Hooyman, A., Wulf, G., & Lewthwaite, R. (2014). Impacts of autonomy-supportive versus controlling instructional language on motor learning. *Human Movement Science, 36*, 190–198.

Janelle, C. M., Barba, D. A., Frehlich, S. G., Tennant, L. K., & Cauraugh, J. H. (1997). Maximizing performance effectiveness through videotape replay and a self-controlled learning environment. *Research Quarterly for Exercise and Sport, 68*, 269–279.

Kal, E. C., van der Kamp, J., & Houdijk, H. (2013). External attentional focus enhances movement automatization: A comprehensive test of the constrained action hypothesis. *Human Movement Science, 32*, 527–539.

Land, W. M., Frank, C., & Schack, T. (2014). The influence of attentional focus on the development of skill representation in a complex action. *Psychology of Sport and Exercise, 15*, 30–38.

Land, W. M., Tenenbaum, G., Ward, P., & Marquardt, C. (2013). Examination of visual information as a mediator of external focus benefits. *Journal of Sport and Exercise Psychology, 35*, 250–259.

Langer, E. J. (1975). The illusion of control. *Journal of Personality and Social Psychology, 32*, 311–328.

Lewthwaite, R., & Wulf, G. (2010). Social-comparative feedback affects motor skill learning. *Quarterly Journal of Experimental Psychology, 63*, 738–749.

Lewthwaite, R., & Wulf, G. (2012). Motor learning through a motivational lens. In N. J. Hodges & A. M. Williams (Eds.), *Skill acquisition in sport: Research, theory & practice* (2nd ed., pp. 173–191). London: Routlegde.

Lohse, K. R. (2012). The influence of attention on learning and performance: Pre-movement time and accuracy in an isometric force production task. *Human Movement Science, 31*, 12–25.

Lohse, K. R., & Sherwood, D. E. (2012). Thinking about muscles: The neuromuscular effects of attentional focus on accuracy and fatigue. *Acta Psychologica, 140*, 236–245.

Masters, R., & Maxwell, J. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology, 1*, 160–183.

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research, 67*, 22–29.
Moritz, S. E., Feltz, D. L., Fahrbach, K., & Mack, D. (2000). The relation of self-efficacy measures to sport performance: A meta-analytic review. *Research Quarterly for Exercise and Sport, 71*, 280–294.
Northoff, G., Qin, P., & Nakao, T. (2010). Rest-stimulus interaction in the brain: A review. *Trends in Neurosciences, 33*, 277–284.
Pascua, L. A. M., Wulf, G., & Lewthwaite, R. (2014). Additive benefits of external focus and enhanced performance expectancy for motor learning. *Journal of Sports Sciences*. http://dx.doi.org/10.1080/02640414.2014.922693.
Post, P., Fairbrother, J. T., Barros, J. A., & Kulpa, J. D. (2014). Self-controlled practice within a fixed time period facilitates the learning of a basketball set shot. *Journal of Motor Learning and Development, 2*, 9–15.
Reeve, J., & Tseng, C. M. (2011). Cortisol reactivity to a teacher's motivating style: The biology of being controlled versus supporting autonomy. *Motivation and Emotion, 35*, 63–74.
Sanli, E. A., Patterson, J. T., Bray, S. R., & Lee, T. D. (2013). Understanding self-controlled motor learning protocols through self-determination theory. *Frontiers in Psychology, 3* (Article 611). http://dx.doi.org/10.3389/fpsyg.2012.00611.
Ste-Marie, D. M., Vertes, K. A., Law, B., & Rymal, A. M. (2013). Learner-controlled self-observation is advantageous for motor skill acquisition. *Frontiers in Psychology, 3* (Article 556). http://dx.doi.org/10.3389/fpsyg.2012.00556.
Stevens, D., Anderson, D. I., O'Dwyer, N. J., & Williams, A. M. (2012). Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills? *Consciousness and Cognition, 21*, 1122–1128.
Tafarodi, R. W., Milne, A. B., & Smith, A. J. (1999). The confidence of choice: Evidence for an augmentation effect on self-perceived performance. *Personality and Social Psychology Bulletin, 25*, 1405–1416.
Wulf, G. (2007a). *Attention and motor skill learning*. Champaign, IL: Human Kinetics.
Wulf, G. (2007b). Self-controlled practice enhances motor learning: Implications for physiotherapy. *Physiotherapy, 93*, 96–101.
Wulf, G. (2013). Attentional focus and motor learning: A review of 15 years. *International Review of Sport and Exercise Psychology, 6*, 77–104.
Wulf, G. (2014). Changing our view of motor learners: From information processors to human beings. *Journal of Sport and Exercise Psychology, 36*, S4.
Wulf, G., & Adams, N. (2014). Small choices can enhance balance learning. *Human Movement Science, 38*, 235–240.
Wulf, G., & Lewthwaite, R. (2014). *The OPTIMAL theory of motor learning* (submitted for publication).
Wulf, G., Chiviacowsky, S., & Cardozo, P. L. (2014). Additive benefits of autonomy support and enhanced expectancies for motor learning. *Human Movement Science, 37*, 12–20.
Wulf, G., Chiviacowsky, S., & Lewthwaite, R. (2010). Normative feedback effects on the learning of a timing task. *Research Quarterly for Exercise and Sport, 81*, 425–431.
Wulf, G., Chiviacowsky, S., & Lewthwaite, R. (2012). Altering mindset can enhance motor learning in older adults. *Psychology and Aging, 27*, 14–21.
Wulf, G., Clauss, A., Shea, C. H., & Whitacre, C. (2001). Benefits of self-control in dyad practice. *Research Quarterly for Exercise and Sport, 72*, 299–303.
Wulf, G., Freitas, H. E., & Tandy, R. D. (2014). Choosing to exercise more: Small choices increase exercise engagement. *Psychology of Sport and Exercise, 15*, 268–271.
Wulf, G., Lewthwaite, R., & Hooyman, A. (2013). Can ability conceptualizations alter the impact of social comparison in motor learning? *Journal of Motor Learning and Development, 1*, 20–30.
Wulf, G., McNevin, N. H., & Shea, C. H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *The Quarterly Journal of Experimental Psychology Section A, 54*, 1143–1154.
Wulf, G., Raupach, M., & Pfeiffer, F. (2005). Self-controlled observational practice enhances learning. *Research Quarterly for Exercise and Sport, 76*, 107–111.
Wulf, G., & Toole, T. (1999). Physical assistance devices in complex motor skill learning: Benefits of a self-controlled practice schedule. *Research Quarterly for Exercise and Sport, 70*, 265–272.
Zachry, T., Wulf, G., Mercer, J., & Bezodis, N. (2005). Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Research Bulletin, 67*, 304–309.