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Additive benefits of autonomy support and enhanced expectancies for motor learning

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ABSTRACT

Two factors that have been shown to facilitate motor learning are autonomy support (AS) and enhanced expectancies (EE) for performance. We examined the individual and combined influences of these factors. In a 2 × 2 design, participants learning a novel motor skill (throwing with the non-dominant arm) were or were not provided a choice (AS) about the ball color on each of 6 10-trial blocks during practice, and were or were not given bogus positive social-comparative feedback (EE). This resulted in four groups: AS/EE, AS, EE, and C (control). One day after the practice phase, participants completed 10 retention and 10 transfer trials. The distance to the target – a bull's eye with a 1 m radius and 10 concentric circles – was 7.5 m during practice and retention, and 8.5 m during transfer. Autonomy support and enhanced expectancies had additive advantages for learning, with both main effects being significant for retention and transfer. On both tests, the AS/EE group showed the greatest throwing accuracy. Also, the accuracy scores of the AS and EE groups were higher than those of the C group. Furthermore, self-efficacy measured after practice and before retention and transfer was increased by both AS and EE. Thus, supporting learners' need for autonomy by given them a small choice – even though it was not directly related to task performance – and enhancing their performance expectancies appeared to independently influence learning.

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1. Introduction

Two factors that have consistently been shown to benefit learning are autonomy support – in the motor learning domain typically operationalized by giving participants self-control over certain aspects of practice (for reviews, see Sanli, Patterson, Bray, & Lee, 2013; Wulf, 2007) – and enhanced expectancies for performance (e.g., Wulf, Chiviacowsky, & Lewthwaite, 2012). The present study addressed the question whether combining both factors would yield additive benefits. Thus, we hoped to gain a better understanding of the relative contributions of these influential variables as well as a potentially mediating variable (i.e., self-efficacy).

Autonomy, or having choices and being able to make one's own decisions, has been identified as a fundamental psychological need (Deci & Ryan, 2000, 2008). Autonomy-supportive environments, in which individuals are given choices – including apparently inconsequential ones (e.g., Tafarodi, Milne, & Smith, 1999; Wulf, Freitas, & Tandy, 2014), or instructions that provide the learner with a sense of choice (Hooyman, Wulf, & Lewthwaite, 2014; Reeve & Tseng, 2011) – have been shown to increase individuals' motivation and performance or learning in a variety of situations. The learning of motor skills has been found to be enhanced by giving learners the opportunity to make decisions about the delivery of feedback, the frequency of skill demonstrations, the use of assistive devices, practice schedules, or other practice variables. For example, more effective learning with self-controlled feedback, relative to externally controlled feedback (yoked control conditions), has been demonstrated for different movement tasks, including throwing (e.g., Chiviacowsky, Wulf, Medeiros, Kaefer, & Tani, 2008; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997) and sequential timing (Chen, Hendrick, & Lidor, 2002; Chiviacowsky & Wulf, 2002; Patterson & Carter, 2010). Furthermore, allowing learners to decide when and how often to observe a demonstration of the skill (e.g., basketball jump shot; Wulf, Raupach, & Pfeiffer, 2005) or how many practice trials to perform (basketball set shot; Post, Fairbrother, Barros, & Kulpa, 2014) has been shown to lead to superior learning relative to yoked control conditions. The learning of balance tasks has been found to benefit from giving learners control over the use of assistive devices, such as balance poles (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012; Hartman, 2007; Wulf, Clauss, Shea, & Whitacre, 2001; Wulf & Toole, 1999). Interestingly, even giving individuals choices that are incidental to the motor task can have a positive effect on the learning of that task. In one experiment (Lewthwaite, Chiviacowsky, & Wulf, 2014, Experiment 1), allowing participants to choose the color of golf balls they were putting led to more effective task learning than not having a choice.

A potential mediator of learning under autonomy-supportive conditions is self-efficacy. Self-efficacy reflects a person's confidence in their ability to perform a certain task successfully in the future (Bandura, 1977, 1997). In a few studies, self-efficacy has been found to be correlated with perceptions of autonomy. Autonomy-supportive task instructions, which implied that participants had some freedom in how they performed or practiced a given task, resulted in higher self-efficacy (Hooyman et al., 2014) or perceived competence (Reeve & Tseng, 2011) than did controlling-language instructions that left participants with no choices. Granting learners the opportunity to make their own decisions may convey a sense of trust in their capability that increases their own confidence in being able to do well on a given task. Even providing participants incidental choices (i.e., choosing names of characters in a story) has been shown to increase their task-related confidence (reading comprehension) (Tafarodi et al., 1999). Thus, there is reason to believe that supporting learners' need for autonomy, by giving them relatively insignificant choices, might enhance their self-efficacy and in turn learning.

Learners' expectancies have been enhanced through various manipulations. For instance, by providing feedback after relatively successful trials, as opposed to less successful ones, learning is facilitated (Badami, VaezMousavi, Wulf, & Namazizadeh, 2011, 2012; Chiviacowsky & Wulf, 2007; Chiviacowsky, Wulf, Wally, & Borges, 2009; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012; Saemi, Wulf, Varzaneh, & Zarghami, 2011). Furthermore, edited video feedback showing only good performance (so-called self-modeling) rather than actual (i.e., good and poor) performance (so-called self-observation) has been found to result in more effective learning (e.g., Clark & Ste-Marie, 2007). Hypnosis also seems to have the capacity to increase performance outcome expectations (e.g., Barker, Jones, & Greenlees, 2010; Jalene & Wulf, 2014) that can lead to learning enhancements. Even simple statements suggesting that peers typically do well on a task to be learned can lead to learning benefits (Wulf et al., 2012, Experiment 2). Finally, (bogus) positive social-comparative or normative feedback leading learners to believe that they are performing better, or improving more, than their peers has been demonstrated to enhance the learning of balance (Lewthwaite & Wulf, 2010), throwing (Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012), or timing tasks (Wulf, Chiviacowsky, & Lewthwaite, 2010). Compared with negative social-comparative feedback implying below-average performance, or no social-comparative feedback (control conditions), positive normative feedback led to superior retention or transfer test results in those studies.

Enhancing learners' expectancies should, by its very nature, influence self-efficacy. Indeed, positive effects on self-efficacy or perceived competence have been found when feedback was provided after good rather than poor performances (Badami et al., 2012; Saemi et al., 2012), when (false) positive social-comparative feedback was given (Hutchinson, Sherman, Martinovic, & Tenenbaum, 2008; Ávila et al., 2012), or when they were informed that their peers typically did well on a given task (Wulf et al., 2012, Experiment 2). Self-efficacy, in turn, impacts motor learning (Chiviacowsky, Wulf, & Lewthwaite, 2012; Stevens, Anderson, O'Dwyer, & Williams, 2012).

Thus, both autonomy support and enhanced expectancies facilitate motor learning. In addition, there is some evidence that both influence learners' self-efficacy. In the present study, we asked whether combining the two factors would "double" the learning advantage – perhaps by doubling self-efficacy. Another possibility is that the combination of autonomy support and enhanced expectancies does not produce additional learning advantages above and beyond those resulting from one factor alone. Or, if one factor is more powerful than the other, adding one factor (e.g., autonomy support) to the other (e.g., enhanced expectancy) may have the capacity to further promote learning, but not vice versa. To examine these questions, we used a factorial design in which we crossed autonomy support (AS) versus no AS with enhanced expectancies (EE) versus no EE. Participants were asked to learn a novel motor task (i.e., throwing at a target with their non-dominant arm). In the autonomy-supportive conditions (AS, AS/EE groups), participants were allowed to choose the color of the balls during practice (similar to Lewthwaite et al., 2014). Participants' performance expectancies were enhanced (EE, AS/EE groups) by providing them with bogus social-comparative feedback suggesting that their performance was above average (cf. Lewthwaite & Wulf, 2010). Learning was assessed by delayed retention and transfer tests. In addition, we measured self-efficacy as a function of AS and EE, and performed regression analyses to determine relations between self-efficacy, practice performance, and learning.

2. Method

2.1. Participants

Sixty-four high school students (28 females, 36 males), with a mean age of 16.7 years (SD = 1.14) participated in the study. None of them were ambidextrous (4 were left-handed). All were naïve as to the specific purpose of the experiment. Participants signed an informed consent form before participating in the study, which was approved by the university's institutional review board.

2.2. Task and apparatus

Participants were asked to throw colored (yellow, red, blue) beach-tennis balls overhand at a target. The target, hung in a net (2.4 × 2.4 × 1.0 m), consisted of a bull's eye surrounded by 9 concentric circles (see Fig. 1). The bull's eye had a radius of 10 cm, and its center was 1.2 m above the ground. The concentric circles had radii of 20, 30, 40, ... and 100 cm. When the ball hit the bull's eye, 100 points were awarded. Ninety points were given for hitting the next circle, and so forth. Throws that completely miss the target were given zero points. The distance of the target was 7.5 m during pre-test, practice phase and retention test, and 8.5 m on the transfer test. The experiment was conducted in an indoor gym.

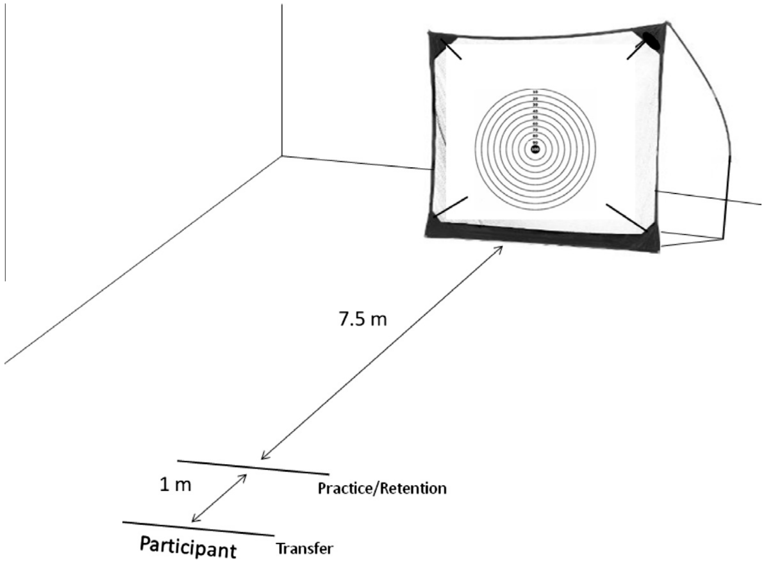

Fig. 1. Experimental set-up.

2.3. Procedure

All participants received basic instructions for the overhand throw (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. Participants then performed a 5-trial pre-test (using red balls). 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 received feedback about their average accuracy score on that block. Participants were randomly assigned to one of four groups: Autonomy support and enhanced expectancy (AS/EE), autonomy support (AS), enhanced expectancy (EE), or control (C) groups. In the groups that included autonomy support (AS, AS/EE), participants were provided the opportunity to choose the ball color before each 10-trial practice block. In the other two groups (EE, C), the ball color was pre-determined for practice blocks 1–6 (blue, red, yellow, blue, red, yellow). To enhance learners' performance expectancies (EE, AS/EE), positive social-comparative feedback was provided in addition to veridical feedback. The social-comparative feedback was a bogus score, allegedly the average score participants in previous experiments had produced on the respective block. That score, which was 20% lower than the participant's score, was calculated by the experimenter after each 10-trial block. Thus, participants were led to believe that their performance was above average (cf. Lewthwaite & Wulf, 2010). C group participants received only veridical feedback. On Day 2, participants performed retention and transfer (8.5 m) tests, which consisted of 10 trials each. No instructions or feedback were provided, and only red balls were used on the retention and transfer tests.

After the pre-test, after the practice phase, and prior to the retention test participants completed self-efficacy rating scales. They were asked to rate how confident they were, 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 all 5 trials and analyzed in a 2 (AS: yes, no) × 2 (EE: yes, no) analysis of variance (ANOVA). The practice data were averaged across blocks of 10 trials and analyzed in a 2 (AS) × 2 (EE) × 6 (block) ANOVA with repeated measures on the last factor. The retention and transfer data were each averaged across all 10 trials and analyzed in 2 (AS) × 2 (EE) ANOVAs. Self-efficacy scores were analyzed separately in 2 (AS) × 2 (EE) ANOVAs for each phase. Furthermore, we conducted simple linear regression analyses to determine possible relations between self-efficacy, end-of-practice performance, and retention and transfer test performance.

3. Results

3.1. Throwing performance

On the pre-test, there were no differences among groups (see Fig. 2). The main effects of AS and EE were not significant, $Fs\ (1, 60) < 1$. Also, there was no interaction of AS and EE, $F\ (1, 60) < 1$.

During practice, throwing accuracy generally increased across blocks. While the AS/EE group tended to have the highest accuracy scores, the C group had the least accurate throws during practice. The main effect of block, $F\ (5, 300) = 7.19$, $p < .001$, $\eta_p^2 = .107$, was significant. The main effects of AS, $F\ (1, 60) = 2.67$, $p > .05$, and EE, $F\ (1, 60) = 1.98$, $p > .05$, were not significant, however. There was no interaction of AS and EE, $F\ (1, 60) < 1$. Also, none of the other interactions were significant.

On both the retention and transfer tests, the AS/EE group showed the highest throwing accuracy, whereas the C group had the lowest scores, and the AS and EE groups had intermediate scores. Furthermore, the AS and EE groups had almost identical scores on both tests. For the retention test, the main effects of both AS, $F\ (1, 60) = 4.00$, $p = .05$, $\eta_p^2 = .062$, and EE, $F\ (1, 60) = 4.00$, $p = .05$, $\eta_p^2 = .062$, were significant. There was no interaction of AS and EE, $F\ (1, 60) < 1$. Similarly, on the transfer test, the main effects of AS, $F\ (1, 60) = 7.03$, $p < .05$, $\eta_p^2 = .105$, and EE, $F\ (1, 60) = 5.32$, $p < .05$, $\eta_p^2 = .081$, were significant, while the interaction of AS and EE was not significant, $F\ (1, 60) = 1.37$, $p > .05$.

3.2. Self-efficacy

After the pre-test, there were no group differences in self-efficacy (see Fig. 3, left). The main effects of both AS and EE were not significant, $Fs\ (1, 60) < 1$, and there was no interaction of these factors, $F\ (1, 60) < 1$.

However, after the practice phase, the groups with AS and/or EE manipulations demonstrated higher self-efficacy than the C group. Also, the AS/EE group had numerically higher self-efficacy than the AS or EE groups. The main effects of both AS, $F\ (1, 60) = 4.49$, $p < .05$, $\eta_p^2 = .070$, and EE,

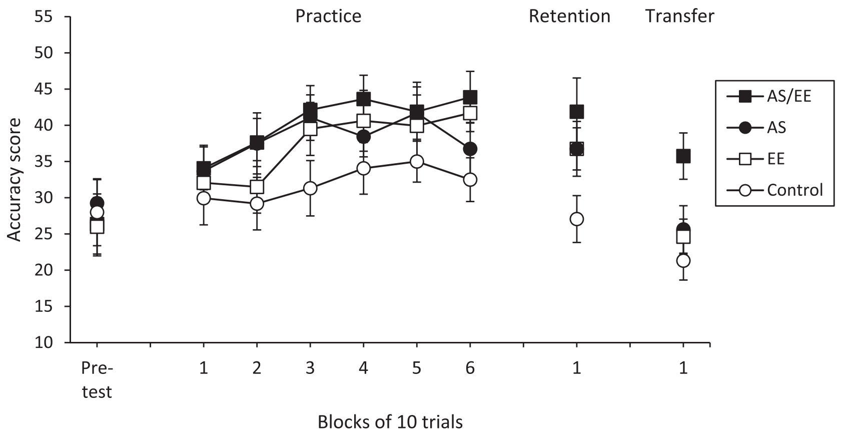

Fig. 2. Throwing performance of the four groups on the pre-test, during practice (Day 1), and on the retention and transfer tests (Day 2). Note: error bars indicate standard errors.

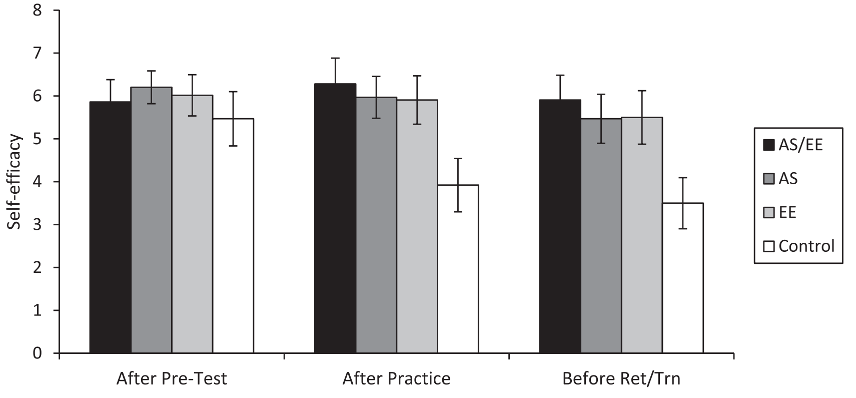

Fig. 3. Self-efficacy scores after the pre-test, after practice (Day 1), and before retention and transfer (Day 2). Note: error bars indicate standard errors.

F (1, 60) = 4.04, $p < .05$, $\eta_p^2 = .063$, were significant. The AS × EE interaction was not significant, F (1, 60) = 2.14, $p > .05$.

A similarly pattern of results was seen before the retention and transfer tests on Day 2 (Fig. 3, right). The main effects of AS, F (1, 60) = 4.01, $p = .05$, $\eta_p^2 = .063$, and EE, F (1, 60) = 4.23, $p < .05$, $\eta_p^2 = .066$, were significant. There was no interaction between AS and EE, F (1, 60) = 1.74, $p > .05$.

3.3. Regression analyses

End-of-practice performance (practice block 6) predicted self-efficacy after practice (i.e., end of Day 1), F (1, 62) = 15.03, $p < .001$, *Adjusted* $R^2 = .182$, $\beta = .442$, and before the retention test (i.e., beginning of Day 2), F (1, 62) = 17.80, $p < .001$, *Adjusted* $R^2 = .210$, $\beta = .472$. Self-efficacy both at the end of Day 1, F (1, 62) = 3.37, $p < .05$, *Adjusted* $R^2 = .079$, $\beta = .305$, and at the beginning of Day 2, F (1, 62) = 7.25, $p < .01$, *Adjusted* $R^2 = .090$, $\beta = .323$, predicted retention, but not transfer performance [Day 1: F (1, 62) < 1; Day 2: F (1, 62) = 1.64, $p > .05$]. Also, retention was a strong predictor of transfer performance, F (1, 62) = 20.96, $p < .001$, *Adjusted* $R^2 = .241$, $\beta = .503$.

4. Discussion

Supporting learners' need for autonomy or enhancing their performance expectancies aided the learning of a novel motor task. Importantly, the combination of the two factors yielded greater learning benefits than did each factor alone. Averaged across retention and transfer, the control group whose learning gains were based solely on practice (and veridical feedback) had an accuracy score of 20.7, corresponding to the second-largest circle of the bull's eye. Adding autonomy support (AS: 31.2) or enhancing expectancies (EE: 30.7) increased throwing accuracy by about another 10-cm circle, while having both resulted in a further increase in accuracy that corresponded to almost another circle (AS/EE: 38.8). Furthermore, the present results revealed that both variables affected learners' self-efficacy, which at least partially explained the advantages seen in motor learning. These findings have interesting theoretical and practical implications.

First, it should be highlighted that the choice participants were given in the AS conditions – the color of the balls they wanted to use on the next block of 10 trials (6 times during practice) – was incidental to the task. That is, it cannot reasonably be argued that ball color per se would have an effect on throwing accuracy. Incidental choices have previously been found to boost learning (computer activities, Cordova & Lepper, 1996; reading comprehension, Tafarodi et al., 1999), in addition to learners' confidence and intrinsic motivation. That the choice of ball color impacted learning replicates findings of a recent study by Lewthwaite et al. (2014), in which participants who were able to choose the color of golf balls demonstrated enhanced learning of a putting task. Why would providing participants with relatively trivial choices facilitate learning? Langer (1975) demonstrated that even the illusion of choice can boost individual's confidence in their ability to produce a desired outcome – even if that outcome is determined by chance. Similarly, participants' predictions of their performance were found to increase when they were given a superficial choice with respect to an upcoming task (i.e., using an almanac to answer a list of questions) (Henry, 1994). As Langer argued, people's perception of their ability to control their environment increases feelings of competence. Feeling competent, or self-efficacious, in turn can result in enhanced performance and learning. Linkages between autonomy support, self-efficacy, and motor learning were also seen in a recent study by Hooyman et al. (2014) (see also Reeve and Tseng (2011) in which autonomy-supportive instructions that suggested to participants they had choices resulted in higher self-efficacy and enhanced learning compared with controlling-language instructions. Together, these findings suggest that the self-efficacy resulting from autonomy support – even if the choices participants have are incidental to the task and relatively trivial – is one factor that is responsible for the learning benefits. Indeed, the learning benefits of self-controlled practice, in general, might be primarily the result of learners' need for autonomy being satisfied (see Lewthwaite & Wulf, 2012; Sanli et al., 2013).

Enhancing learners' performance expectancies by leading them to believe their performance was above average had similar effects on learning as autonomy support. On both retention and transfer tests, throwing accuracy of the two groups was similar. Both conditions also had comparable influences on self-efficacy, as seen after practice and before the retention test. Thus, it appears as if the two variables had the same psychological and learning benefits. Positive social-comparative feedback has previously been found to increase perceived competence (Ávila et al., 2012) and satisfaction with one's performance (Wulf, Lewthwaite, & Hooyman, 2013), and to reduce ability-related concerns and nervousness (Wulf et al., 2012, Experiment 1). The resulting positive psychological state seems to facilitate performance and learning. An increased efficiency in force production (Hutchinson et al., 2008) and running (Stoate, Wulf, & Lewthwaite, 2012), found in studies that examined effects of positive social-comparative feedback on motor performance (although not learning), suggest that performance may be optimized by a reduction of unnecessary co-contractions or recruitment of superfluous motor units. Those findings are in line with demonstrations of more automatic movement control resulting from positive feedback and enhanced balance learning (e.g., Lewthwaite & Wulf, 2010). Confidence in one's ability relative to the task requirements might also promote an attentional focus on the task and desired outcome, and perhaps a reduced focus on the self (see Wulf, 2013; Wulf & Lewthwaite, 2010).

Enhanced expectancies for future performance satisfy another fundamental psychology need, namely, the need to feel competent (Deci & Ryan, 2000, 2008). The present study is presumably the first to examine motor learning as a function of a combination of support for two fundamental needs (i.e., autonomy, competence). Previous studies using self-controlled feedback may also have supported both needs, as participants often report asking for feedback after successful trials, presumably to protect their perceived competence (Chiviacowsky & Wulf, 2002; Chiviacowsky et al., 2008; Patterson & Carter, 2010; Patterson, Carter, & Sanli, 2011). Yet, in such designs it is difficult to separate autonomy (self-control) from perceived competence (due to feedback after successful trials) (but see Chiviacowsky, 2014). In the present study, we were able to manipulate both separately. By providing social-comparative feedback in addition to veridical feedback, we were able to support participants' need for competence in certain, but not in all, conditions. Similarly, autonomy support was present only in some conditions. As the present findings demonstrated, providing support for one need enhanced learning relative to the control group, but supporting both needs resulted in even more effective learning. Thus, both variables seemed to have additive effects.

Self-efficacy – which was enhanced by both factors, although combining did not "double" the effect – was a mediator of learning. The regression analyses showed that performance at the end of practice predicted self-efficacy. Thus, not surprisingly, enhanced practice performance was associated with increased self-efficacy on Days 1 and 2. Self-efficacy, in turn, predicted retention test performance (see also Stevens, Anderson, O'Dwyer, & Williams, 2012), even though the amount of variance explained was relatively small. Self-efficacy was not related to transfer performance, though. Yet, transfer performance was predicted by retention performance. Thus, immediate past performance (retention) was a stronger predictor of future performance (transfer) than self-efficacy resulting from performance on the previous day. The relation between self-efficacy and motor performance has long been recognized (e.g., Feltz, Chow, & Hepler, 2008; Moritz, Feltz, Fahrbach, & Mack, 2000). As the present findings show, there are different ways of increasing learners' self-efficacy and thereby learning. Other factors associated with autonomy or competence support likely contribute to learning as well. For instance, positive affect – which appears to play an important role in memory consolidation (Trempe, Sabourin, & Proteau, 2012) – has been found to be linked to both autonomy-supportive (e.g., Hooyman et al., 2014) and expectancy-enhancing conditions (e.g., Pascua, Wulf, & Lewthwaite, 2014; Stoate et al., 2012). Future research examining the processes of these and other learning variables will continue to advance our understanding of motor learning.

5. Conclusion

Giving learners a seemingly incidental choice and enhancing their performance expectancies during practice increased self-efficacy and facilitated learning. Thus, the present findings demonstrate that motivational variables, such as support for autonomy and competence needs (Deci & Ryan, 2000, 2008), are important factors for motor skill learning. Moreover, it is evidently not sufficient to satisfy one need if optimal learning is desired. Evidence for additive effects of other motivational variables (i.e., support for competence and social-relatedness needs) comes from a study by Sheldon and Filak (2008) using a game-learning task. Furthermore, in a recent study on motor learning by Pascua et al. (2014), enhanced expectancies added to the benefits of another key variable, an external focus of attention (Wulf, 2013). Thus, it is becoming increasingly clear that effective learning is dependent on the confluence of various factors, including the support of learners' fundamental psychological needs. Moreover, neglecting even some of those needs means forgoing learners' potentials.

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