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Choice of practice-task order enhances golf skill learning

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ABSTRACT

Objective: The purpose of the present study was to examine whether supporting learners' autonomy, by giving them a small choice (i.e., order of practice devices) while practicing a golf putting task, would enhance learning, confidence, and positive affect.

Design: Experimental, between-participants, and yoked design.

Methods: Two groups of participants practiced a golf-putting task under choice or control conditions. Choice group participants selected the order of three practice devices (visual cues, auditory cues, chest bar), while control group participants had to use those devices in the same order as their yoked choice-group counterpart. Learning was assessed by a delayed retention test. In addition to putting accuracy, we measured learners' perceived choice, confidence, and positive affect.

Results: Practice and retention performance were enhanced in the choice relative to the control group. Perceived choice, confidence, and positive affect were rated higher by choice group participants as well.

Conclusions: Providing performers with a small choice during task practice had motivational benefits that resulted in enhanced learning, increased confidence, and more positive emotional responses.

1. Introduction

Practice or performance conditions that provide performers with the opportunity to make choices – thus conveying some autonomy – have been shown to benefit both immediate performance and longer-term learning (for a review, see Wulf & Lewthwaite, 2016). The types of choices participants were given in previous studies ranged from more substantial ones to those that were relatively small or even incidental to the task. Task-related choices included allowing learners to decide when to receive feedback (e.g., Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997), when to watch a demonstration of the skill (e.g., Lemos, Wulf, Lewthwaite, & Chiviacowsky, 2017), or how much to practice (e.g., Post, Fairbrother, & Barros, 2011). Smaller choices can involve the order in which participants want to perform different tasks (e.g., Halperin, Chapman, Martin, Lewthwaite, & Wulf, 2017) or the order of right and left hand performance (e.g., Iwatsuki, Abdollahipour, Psotta, Lewthwaite, & Wulf, 2017). Incidental choices can be related to the color of objects to be used (e.g., Wulf, Iwatsuki, Machin, Kellogg, Copeland, & Lewthwaite, 2018), which pictures to view while performing (e.g., Iwatsuki, Navalta, & Wulf, 2019), or they can be ostensibly irrelevant to the task at hand (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015, Experiment 2). Performance or learning are typically enhanced in groups that are given a choice compared with no-choice control groups in which participants are required to perform under the same condition as their "yoked" choice-group counterparts.

Due to its consistent impact, autonomy is a key motivational factor in the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016). Like two other key factors in the theory (enhanced expectancies, external focus of attention), performer autonomy is thought to contribute in several ways to goal-action coupling – or the fluidity with which movement plans are translated into action. Autonomy effects may be situated at the core of the brain's salience network (Reeve & Lee, 2019), facilitating dynamic switching between task sets (e.g., Menon & Uddin, 2010). The experience of autonomy has been seen as inherently rewarding (Leotti & Delgado, 2011; Murayama, Izuma, Aoki, & Matsumoto, 2017), thus eliciting dopamine release and temporally connecting the reward and motor systems to promote attention and effort. Increases in movement efficiency (Iwatsuki, Navalta et al., 2019; Iwatsuki, Shih, Abdollahipour, & Wulf, 2019), for example, may reflect the relative ease of making large-scale and well-timed linkages (i.e.,

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functional connectivity) among task-relevant neural networks (Menon & Uddin, 2010) as well as more permanent neuroanatomic changes (i.e., structural connectivity) that underlie the translation of goals into actions, and support effective motor performance.

Performer autonomy can enhance performance and learning in multiple ways. According to one prediction of the OPTIMAL theory (Wulf & Lewthwaite, 2016), autonomy support facilitates performance by enhancing performers' expectancies, including confidence in their ability to perform well. For example, learners' inclination to ask for feedback after presumed successful trials (Chiviacowsky & Wulf, 2007) can contribute to building confidence. Also, control over the use of assistive devices that support balance or allow performers to try out different movement or attentional strategies (e.g., Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012; Hartman, 2007; Wulf & Toole, 1999) may function to maintain or increase self-efficacy. The rewarding experience of autonomy support (Leotti & Delgado, 2011), or lack thereof, can also have affective consequences (Wulf, Iwatsuki et al., 2018). These consequences can influence performance and learning. Lack of autonomy in controlling environments may be experienced as stressful and can negatively affect learning (Hooyman, Wulf, & Lewthwaite, 2014; Reeve & Tseng, 2011), perhaps through the down-regulatory effect of stress-related cortisol on the brain's reward circuitry (Montoya, Bos, Terburg, Rosenberger, & van Honk, 2014). Self-regulatory attempts at controlling negative emotional responses would also be expected to take attentional capacity away from the task and result in degraded learning. In contrast, autonomy-supportive conditions reduce the need for self-related activity and allow the performer to focus on the task. Potential consequences of a focus on the task goal include facilitation of performance and learning through enhanced processing of task errors (Grand et al., 2015; Legault & Inzlicht, 2013), or greater neuro-cognitive engagement (Jacquess, Lu, Iso-Ahola, Zhang, Gentili, & Hatfield, 2019).

The present study had several purposes. First, we attempted to replicate and extend previous findings by showing that small choices, such as the order in which different tasks are performed, can enhance skill learning. While a few studies have demonstrated that motor performance (maximum force production, efficient muscular activity) can be enhanced by allowing participants to choose the order of tasks (Halperin et al., 2017; Iwatsuki et al., 2017; Iwatsuki, Shih et al., 2019), only one study examined the effects of choice of task order on motor learning (Wulf & Adams, 2014). Wulf and Adams used three different balance tasks that involved a single-leg stance. A choice group was able to choose the order in which they wanted to perform the tasks. Compared with a yoked control group, the choice group showed superior balance performance on all tasks during practice as well as on a delayed retention test with a fixed order of tasks. In the present study, we used a golf putting task and allowed one group of participants to determine the order in which to utilize different practice devices (visual cues, metronome, chest bar) common in golf training. While all participants had to use each type of guidance on two of six blocks of trials, choice group participants were able to select their order while control group participants were not. We hypothesized that the choice condition would enhance learning as measured by a delayed retention test. Second, unlike previous studies that examined the effects of small choices (e.g., Wulf & Adams, 2014), we included a manipulation check (perceived choice), as well as measures of performer confidence and positive affect. We expected choice group participants to perceive more choice, and show greater confidence after practice and before retention testing on another day. Further, consistent with a heightened experience of reward due to autonomy support, we hypothesized that the choice group would show greater positive affect than the control group at the end of practice.

2. Methods

2.1. Participants

Thirty university students (20 males, 10 females) with a mean age of 22.4 years (*SD*: 1.41) participated in this study. A G*Power 3.1 analysis (Faul, Erdfelder, Lang, & Buchner, 2007) yielded an estimated sample size of 20 participants, with an α value of 0.05, a power value of 0.90, and an estimated η_p^2 value of .07 (Chua, Wulf, & Lewthwaite, 2018; Wulf, Lewthwaite, Cardozo, & Chiviacowsky, 2018). All participants were right-handed. They were enrolled in a semester-long golf class at a university, so they had some experience with putting. Participants were naïve as to the specific purpose of the experiment. They signed an informed consent form prior to participating in the study. The study was approved by the university's institutional review board.

2.2. Apparatus and task

The putting task was performed on a level artificial-turf indoor green (700 × 550 cm). The green speed was measured by a stimpmeter. The recorded length of 8.5 feet corresponded to a medium to high speed. Participants' task was to perform putts to a circular target (hole cup), with a standard-hole diameter of 10.8 cm, from a distance of 2 m. The hole was surrounded by 4 concentric circles with diameters of 30, 50, 70, and 90 cm, respectively, to determine the accuracy of putting performance. Five points were awarded for putting the ball into the hole. Four, 3, 2, and 1 points were recorded for balls stopping in one of the other zones, respectively. Zero points were given for balls coming to rest outside the largest circle. All participants used the same putter (Odyssey Hot 2-Ball Blade) and white golf balls (Titleist Pro V1).

2.3. Procedure

Participants were randomly assigned to one of two groups, the choice and control groups. There were an equal number of females and males in each group. At the beginning of the experiment, the basic putting technique was demonstrated to each participant. All participants received the same instructions regarding grip, stance, ball position, and posture. Each participant then performed a 10-trial pretest. Subsequently, three types of practice devices used to facilitate a pendulum-like putting motion were demonstrated by the experimenter. First, visual cues on the putting surface (see Fig. 1, left) were introduced. They were designed to help performers focus on the equal length of clubhead swing (1:1 ratio for back swing and follow-through). Second, to facilitate a focus on a constant swing tempo, a metronome (60 bpm) was used (Fig. 1, middle). Participants were instructed to use three consecutive beeps to time their swing (1: ready, 2: start, 3: impact). Finally, a chest bar placed between the arms in front of the chest (see Fig. 1, right) was used to provide tactile cues to assist with the performance of a pendulum-like motion. All participants were able to try out each device and to get comfortable with it before the beginning of the practice phase. Choice group participants were informed that they could choose the device they wanted to use before each of six 10-trial practice blocks, with the stipulation that each device had to be used on two practice blocks. Participants in the control group were each yoked to a counterpart participant in the choice group with respect to the order of devices used. Control group participants were informed that the experimenter would determine the order of devices.

Studies of learning can emphasize early versus later stages of skill acquisition. We used a classic learning paradigm common in behavioral studies of motor learning (e.g., Schmidt, Lee, Zelaznik, Winstein, & Wulf, 2019) directed at the early trials of novel skill uptake and denoted by relative group performance on a 24-h delayed retention test employed to allow for memory consolidation (Krakauer & Shadmehr, 2006; Robertson & Cohen, 2006; Robertson, Pascual-Leone, & Miall, 2004). That is, we asked whether, given the same amount of practice,

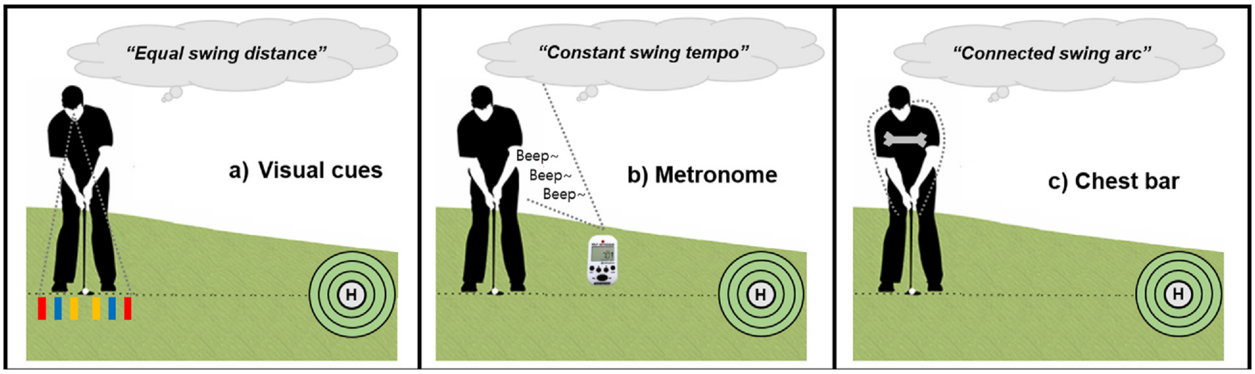

Fig. 1. Devices used: a) visual cues, b) auditory cues, c) tactile cues.

conditions involving choice would be more effective for learning than those without choice. Learning was measured by a retention test one day after practice, consisting of 10 trials without the use of any devices.

After the completion of all practice trials, participants were asked to fill out a questionnaire. The questionnaire consisted of three statements about their perception of choice ("I believe I had some choice regarding this practice; " "I felt as if it was my own choice how to putt in practice," "I felt that I could decide how to perform the putting task"). The statements were adapted from the perceived choice subscale of the Intrinsic Motivation Inventory (McAuley, Duncan, & Tammen, 1989). Participants were asked to rate each statement on a scale from 1 (no choice) to 10 (a lot of choice). We calculated Cronbach's alpha to determine the internal consistency of this measure. The alpha value was 0.97.

Another questionnaire was used to assess participants' confidence in their ability to perform well on the putting task. Before and after practice, as well as at the beginning of the retention test, participants were asked to rate three statements ("I feel confident about my putting performance; " "I expect to get a higher score on each putt; " and "I trust my ability to achieve a higher average score in practice"), on a scale from 1 (not confident at all) to 10 (extremely confident). Cronbach's alpha values were 0.92 (before practice), 0.95. (after practice), and 0.97 (before retention). Finally, a brief set of positive affect items, excerpted from the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegan, 1988), was used to measure positive affect. Specifically, three adjectives were used that described positive (i.e., happy, interested, satisfied) feelings or emotions. Participants were asked to rate each word in terms of how they felt at the present moment on a scale from 1 (very slightly or not at all) to 5 (extremely). Cronbach's alpha for positive affect was 0.72.

2.4. Data analysis

Our main measure of putting performance was the accuracy score (0–5), summed across blocks of 10 trials. In addition, we determined the number of holed putts (i.e., the ball ending up in the hole) for each block. Both dependent variables were analyzed in 2 (groups: choice, control) × 2 (test: pretest, retention test) ANOVAs with repeated measures for the pretest and retention test, and in 2 (groups: choice, control) × 6 (blocks of 10 trials) ANOVAs with repeated measures on the last factor for the practice phase. Participants' ratings of perceived choice, confidence, and positive affect were each averaged across three statements. Perceived choice as well as positive affect after the practice phase were each analyzed in one-way ANOVAs. Confidence ratings were analyzed in a 2 (groups) × 2 (time: before practice, after practice) repeated-measures ANOVA for the practice phase, and in a one-way ANOVA for the retention test. The alpha level was set to a value of 0.05, and partial eta squared (η_p^2) was used to determine effect size. Greenhouse-Geisser adjustments were used in instances where sphericity was violated.

3. Results

3.1. Putting accuracy

Accuracy scores. Average accuracy scores for each group are shown in Fig. 2.[1] While both groups performed similarly on the pretest, the choice group outperformed the yoked group throughout practice and on the retention test. For the practice phase, the main effect of group was significant, F (1, 28) = 7.287, $p < .05$, $\eta_p^2 = .204$. Both groups increased their putting accuracy, with the main effect of block being significant, F (2.990, 83.710) = 39.737, $p < .001$, $\eta_p^2 = .587$. The interaction of group and block was not significant, F (2.990, 83.710) = 2.148, $p = .101$, $\eta_p^2 = .071$. Accuracy scores generally increased from the pretest to the retention test, as indicated by a significant effect of test, F (1, 28) = 41.27, $p < .001$, $\eta_p^2 = .596$. Importantly, the interaction of group and test was significant, with F (1, 28) = 9.06, $p < .01$, $\eta_p^2 = .245$. Follow-up ANOVAs showed that the groups did not differ on the pretest, $t(28) = -0.663$, $p = .513$, $d = -0.24$, 95% CI [-4.63, 2.37], but that the choice group had significantly higher accuracy scores than the control group on the retention test, $t(28) = 3.98$, $p < .001$, $d = 1.45$, 95% CI [2.59, 8.08]. The main effect of group was not significant, F (1, 28) = 3.65, $p = .066$, $\eta_p^2 = .116$.

Number of holed putts. Both groups had a similar number of holed putts on the pretest (see Fig. 3, left). However, over the course of the practice phase that number consistently increased for the choice group, whereas it remained at about the same level for the control group. On the retention test, the choice group again outperformed the control group with regard to the number of balls holed. For the practice phase, the interaction of group and block was significant, F (3.191, 89.347) = 3.196, $p < .05$, $\eta_p^2 = .102$. Furthermore, the main effects of group, F (1, 28) = 19.543, $p < .001$, $\eta_p^2 = .411$, and block, F (3.191, 89.347) = 4.739, $p < .001$, $\eta_p^2 = .145$, were significant. Follow-up analyses on the interaction effect showed that the groups did not differ on Block 1, $t(28) = 1.03$, $p = .313$, $d = 0.38$, 95% confidence interval (CI) [-0.46, 1.40], or Block 2, $t(28) = 1.20$, $p = .239$, $d = 0.44$, 95% CI [-0.49, 1.80], but they differed on Block 3, $t(28) = 3.29$, $p < .003$, $d = 1.20$, 95% CI [0.50, 2.16], Block 4, $t(28) = 3.41$, $p < .002$, $d = 1.25$, 95% CI [0.48, 1.92], Block 5, $t(28) = 5.02$, $p < .001$, $d = 1.83$, 95% CI [1.10, 2.63], and Block 6: $t(28) = 6.07$, $p < .001$, $d = 2.21$, 95% CI [1.28, 2.59]. The number of holed putts increased from the pretest to the retention test, F (1, 28) = 22.73, $p < .001$, $\eta_p^2 = .448$. The interaction of group and test was significant, with F (1,

[1] The three guidance methods resulted in similar accuracy scores. Average scores, across practice blocks and groups, were 3.4 (visual), 3.3 (auditory), and 3.2 (tactile).

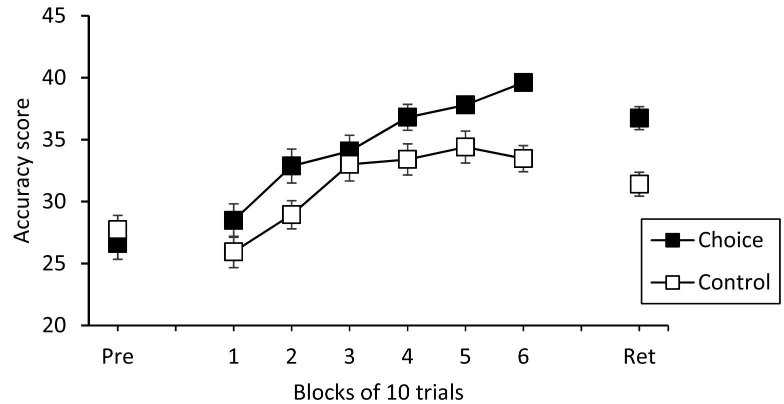

Fig. 2. Accuracy scores (higher scores indicate greater accuracy) for the choice and control group on the pretest, practice blocks, and retention test. Error bars represent standard errors.

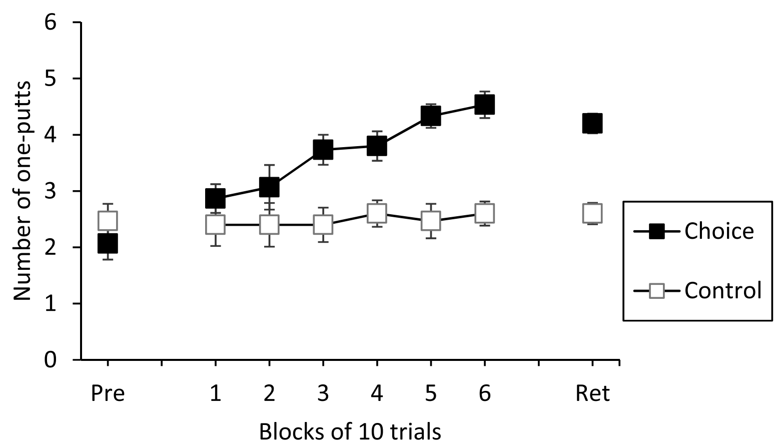

Fig. 3. Number of holed putts for the choice and yoked groups on the pre-test, practice blocks, and retention. Error bars represent standard errors.

28) = 17.70, $p < .001$, $\eta_p^2 = .387$, as was the Group effect, F (1, 28) = 5.61, $p < .05$, $\eta_p^2 = .167$. Follow-up analyses indicated that the group difference was not significant on the pretest, $t(28) = -0.957$, $p = .347$, $d = -0.35$, 95% CI [-1.26, 0.46], but that the groups differed significantly on the retention test, $t(28) = 6.20$, $p < .001$, $d = 2.26$, 95% CI [1.07, 2.13].

3.2. Perceived choice

Choice group participants reported higher levels of perceived choice after the practice phase than did control group participants. The average rating for the choice group was 7.16 ($SD = 1.11$) versus 4.37 ($SD = 1.69$) for the control group. The difference between groups was significant, F (1, 28) = 0.439, $p < .001$, $\eta_p^2 = .502$.

3.3. Confidence

Confidence ratings before the beginning of practice were similar for the choice (3.68) and yoked groups (4.04) (p > 1; Fig. 4, left). However, the choice group (6.13) had higher confidence than the control group (5.26) at the end of practice. The interaction of group and time was significant, F (1, 28) = 7.227, $p < .05$, $\eta_p^2 = .205$. The main effect of time was also significant, F (1, 28) = 65.043, $p < .001$, $\eta_p^2 = .699$, whereas the Group main effect was not significant F (1, 28) < 1. Follow-up tests on the interaction effect indicated that confidence before practice did not differ between groups, $t(28) = -1.01$, $p = .324$, $d = -0.37$, 95% CI [-1.08, 0.37], but was significantly higher for the choice group at the end of practice, $t(28) = 2.59$, $p < .015$, $d = 0.94$, 95% CI [0.18, 1.55]. Before the retention test, confidence was also higher in the choice (5.95) relative to the control group (5.06); the main effect of group was significant, F (1, 28) = 7.315, $p < .05$, $\eta_p^2 = .207$.

3.4. Positive affect

At the end of the practice phase, the choice group had higher positive affect than the control group. Choice group participants' average positive affect rating was 3.8 ($SD = 0.48$), while control group participants' rating was 3 ($SD = 0.55$). This group difference was significant, F (1, 28) = 5.004, $p < .05$, $\eta_p^2 = .152$.

4. Discussion

The present findings confirmed that choices as small as the order in which certain practice tasks are performed can have a beneficial impact on skill learning. Participants who were allowed to choose the order of use of different guidance methods outperformed control group participants who used the same methods, and in the same order, but had no control over that order. Performance advantages for the choice group were already seen during the practice phase (during which they were making choices). While accuracy scores increased across practice blocks for both groups, the choice group demonstrated significantly greater

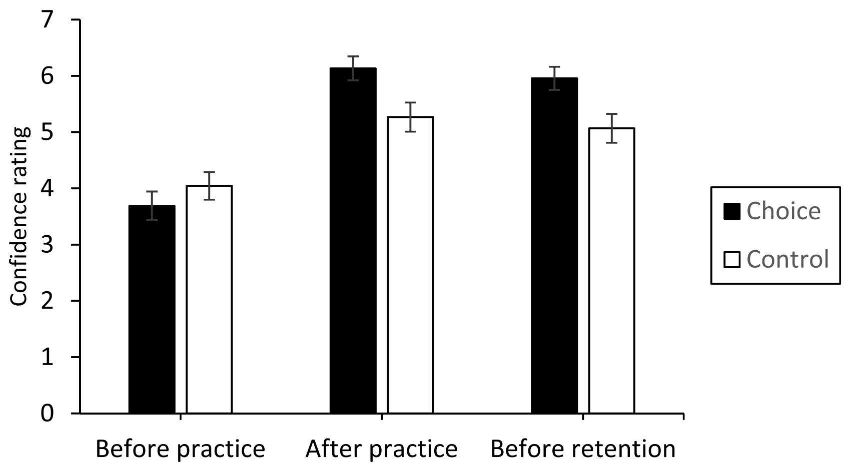

Fig. 4. Confidence ratings of the choice and yoked groups before practice, after practice, and retention. Error bars indicate standard errors.

accuracy relative to the control group. With respect to the number of times the target was hit (holed putts), the choice group showed a significant increase over the course of the practice phase, whereas the control group's performance did not change. Importantly, the superior performance shown by the choice group with regard to both putting measures persisted on a delayed retention test that was performed without guidance. Thus, the autonomy-supportive condition, in which learners were able to choose the order of methods, enhanced learning of the task.

Participants' perceptions of choice were also different, as confirmed by manipulation check. At the end of practice, participants in the choice group agreed to a greater extent than did participants in the control condition that they had a choice as to how to perform the task. Furthermore, consistent with other studies of choice (e.g., Hooyman et al., 2014; Lemos et al., 2017; Lou et al., 2011; Murayama et al., 2017; see also; Wulf & Lewthwaite, 2016), learners' confidence differed as a result of having a choice versus no choice during practice. While there were no group differences before the practice phase, the choice group had higher confidence ratings than did the control group at the end of practice as well as before the retention test. Because the choice group achieved progressively better performance across the practice phase, the impact of choice on post-practice confidence may be direct or indirect (i.e., through performance effects on confidence). The increase in positive affect demonstrated by the choice group relative to the control group is consistent with the enhanced expectations and, in general, the positive experience associated with choice. Heightened positive affect resulting from choice corroborates previous findings (Hooyman et al., 2014). Also, in studies by Lemos et al. (2017) as well as Reeve and Tseng (2011), participants in autonomy-supportive groups reported significantly greater enjoyment, fun, curiosity, interest, and engagement than did participants in groups without possibility for choice.

Expectations of success, or rewarding experiences, whether from the anticipation of choice per se or from performance advantages, are associated with dopamine release (de la Fuente-Fernández, 2009; Lidstone, Schulzer, Dinelle, Mak, Sossi, Ruth et al., 2010), which has directly or indirectly been shown to enhance movement effectiveness and efficiency (Foreman et al., 2014; Jenkinson & Brown, 2011; Meadows, Gable, Lohse, & Miller, 2016). Phasic increases in dopamine release resulting from positive experiences strengthen neural connections (Ashby, Turner, & Horvitz, 2010) which may be a mechanism underlying motor learning (Abe et al., 2011).

The findings related to the impacts of choice on intrinsic motivation and learning have obvious implications for applied settings. Practitioners can easily take advantage of these positive effects by supporting performers' need for autonomy. Relatively small choices, such as those provided in the present study, can facilitate performance and learning (see also Iwatsuki, Navalta et al., 2019; Lewthwaite et al., 2015; Wulf & Adams, 2014). Furthermore, in one study (Wulf, Freitas, & Tandy, 2014) participants, who were able to choose the order of exercises, subsequently chose to complete more sets and repetitions than did a control group. Thus, the motivational consequences of choice (e.g., confidence, positive affect) may have additional benefits such as increasing performer engagement and interest in practicing, which may further contribute to enhanced learning.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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