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Positive feedback enhances motivation and skill learning in adolescents

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ABSTRACT

Studies have shown that feedback indicating good performance facilitates motor skill learning. The present study examined whether enhancing learners' expectancies through simple encouraging feedback would boost motivation and learning. Adolescent participants performed a linear positioning task. The goal was to move a slide to a target 60 cm to the right and include a reversal movement on the way. Veridical feedback related to spatial accuracy was provided to all participants after each of eight 10-trial practice blocks. An enhanced expectancy (EE) group was given an additional positive feedback statement after each practice block, while a control group received no such feedback. Retention (60 cm target distance) and transfer (45 cm) tests were performed without feedback on the following day. The EE group demonstrated greater movement accuracy than the control group on both tests. Moreover, self-efficacy, intrinsic motivation, positive affect, and interest in continued practice were significantly higher for the EE group after practice and before retention testing. The findings demonstrate that, in line with OPTIMAL theory (Wulf & Lewthwaite, 2016) predictions, enhancing learners' expectancies by providing positive feedback resulted in benefits for intrinsic motivation and skill learning.

1. Introduction

In the motor learning literature, feedback was long viewed as (neutral) task-related information that learners use to reduce errors in their attempts to acquire movement skills (e.g., Adams, 1971; Bilodeau & Bilodeau, 1958). That is, the main role of augmented feedback was seen as guiding learners to the movement goal by providing them with information about their performance (cf. guidance hypothesis; Salmoni, Schmidt, & Walter, 1984; Schmidt, 1991). More recently, it has become clear that, aside from its informational role, feedback has other important functions (Chiviacowsky, 2020). For instance, the effectiveness of feedback is also determined by the type of attentional focus (external versus internal) it promotes (e.g., Chua, Jimenez-Diaz, Lewthwaite, Kim, & Wulf, 2021; Wulf, Chiviacowsky, Schiller, & Ávila, 2010; Wulf, McConnel, Gärtner, & Schwarz, 2002). Moreover, feedback has been shown to influence the performer's motivational state, with consequences for learning. Initially demonstrated by Chiviacowsky and Wulf (2007), providing learners with feedback after "good" trials, compared with "poor" trials, resulted in more effective learning. In their study,

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different groups of participants were given feedback about their most accurate or least accurate trials in a given block (unbeknownst to them). Those who received feedback on more accurate trials demonstrated more effective learning. These results have been replicated in subsequent studies (e.g., Badami, VaezMousavi, Wulf, & Namazizadeh, 2012; Chiviacowsky, Wulf, Wally, & Borges, 2009; Saemi, Porter, Ghotbi-Varzaneh, Zarghami, & Maleki, 2012; Saemi, Wulf, Varzaneh, & Zarghami, 2011). Thus, feedback emphasizing successful performance, while ignoring less successful attempts, benefited retention. In contrast, feedback emphasizing errors or indicating poor performance typically has detrimental effects on motor learning, relative to positive feedback or control conditions (e.g., Abbas & North, 2018; Chiviacowsky & Harter, 2015; Chiviacowsky, Wulf, & Lewthwaite, 2012; Lewthwaite & Wulf, 2010). Feedback after relatively effective trials has been found to increase perceptions of competence (Badami, VaezMousavi, Wulf, & Namazizadeh, 2011; Saemi et al., 2011) and self-efficacy (Badami et al., 2012; Saemi et al., 2012). Potential consequences of higher self-efficacy include facilitation of performance through enhanced processing of task errors (Themanson, Pontiflex, Hillman, & McAuley, 2011).

In other studies that examined motivational impacts of feedback, social (e.g., Lewthwaite & Wulf, 2010) or temporal (e.g., Chiviacowsky & Drews, 2016) comparative information was provided. Comparative feedback serves as a potent basis for evaluating one's own competence. Learners led to believe that their performance was better than average (Ávila, Chiviacowsky, Wulf, & Lewthwaite, 2012; Lewthwaite & Wulf, 2010; Wulf, Chiviacowsky, & Lewthwaite, 2010; Wulf, Chiviacowsky, & Lewthwaite, 2012, Experiment 1) or their own past selves (Chiviacowsky & Drews, 2016; Chiviacowsky, Harter, Gonçalves, & Cardozo, 2019; Lessa, Tani, & Chiviacowsky, 2018) typically demonstrated more effective learning than those who were led to believe that their performance was not improving or worse than average, or who were not given comparative feedback. As veridical feedback about the learners' own performance was also provided in these studies, the learning benefits of this type of feedback cannot be explained from a standpoint that views feedback as neutral information. Positive comparative feedback has been found to increase perceived competence (e.g., Ávila et al., 2012; Chiviacowsky et al., 2019), reduce concerns about ability and nervousness (Lessa et al., 2018; Wulf et al., 2012, Experiment 1), and increase satisfaction with one's performance and motivation to learn (Wulf, Lewthwaite, & Hooyman, 2013).

Notably, even simple distinct positive feedback statements, shaping mindsets about one's own competence, can affect motivation (Bejjani, DePasque, & Tricomi, 2019; Cimpian, Arce, Markman, & Dweck, 2007; Vella, Braithewaite, Gardner, & Spray, 2016), as well as motor performance and learning (Chiviacowsky & Drews, 2014). For example, participants receiving non-generic or performance-related feedback statements (e.g., "Your last kicks were very good"), suggesting that the skill is learnable (incremental view of ability), outperformed participants receiving more generic or person-related feedback statements (e.g., "You are a great soccer player") inducing an entity view of ability (Chiviacowsky & Drews, 2014). In the former condition, learners tend to react to difficult situations by increasing their effort, being more focused on task learning, and seeing mistakes as a natural part of the learning process, while in the latter condition they tend to show less effort and persistence when confronted with errors, avoiding challenging situations that might demonstrate low ability (Dweck & Leggett, 1988). Thus, simple positive feedback statements, recognizing good performance, have the potential to increase intrinsic motivation and facilitate motor performance and learning.

Only two other motor learning studies used motivational feedback statements that were similar to the ones used in Chiviacowsky and Drews (2014) experiment. In one of them (Drews, Tani, Cardozo, & Chiviacowsky, 2020), positive feedback (e.g., "You did a great job on these first trials") did not affect children's learning an intrinsically motivating task of riding a pedalo relative to a control group. The high level of intrinsic motivation in both groups observed at the beginning of and across practice may have attenuated the positive feedback effect (motivational ceiling effect). In the other experiment (Beroukhim-Kay, Kim, Monterosso, Lewthwaite, & Winstein, 2022), adult participants asked to learn a pinch force tracking task were provided with five positive feedback statements during practice (e.g., "Alright! Your improvement across the past trials is reflecting your learning and getting the hang of it") and an instructional statement designed to promote an incremental view of ability ("Keep in mind that at the beginning it is common to undershoot or overshoot the target, but this is the type of task that you get better at with practice") (cf. Wulf & Lewthwaite, 2009). This group showed more effective learning compared with a control group without the motivational statements.

Motivational constructs such as expectancies (or perceptions of competence) are central determinants of behavior in a number of psychological theories, including self-efficacy theory (Bandura, 1977) and self-determination theory (Ryan & Deci, 2000). The conviction that one is doing well, or the confidence of being able to perform well in the future, appears to be a precondition for optimal performance and learning. Feedback that provides information about movement success serves to enhance performers' expectancies. In the OPTIMAL theory of motor learning (Lewthwaite & Wulf, 2017; Wulf & Lewthwaite, 2016, 2021), enhanced expectancies are one of two motivational factors that are key to optimal performance and learning. (The other motivational factor is autonomy support). Self-efficacy expectations – which are one form of expectancies (Bandura, 1977) – have been shown to be a predictor of performance (e.g., Feltz, Chow, & Hepler, 2008; Peifer, Schönfeld, Wolters, Aust, & Margraf, 2020) and learning (e.g., Chiviacowsky et al. 2012; Pascua, Wulf, & Lewthwaite, 2015). Positive expectations for future movements signal an anticipated reward associated with the upcoming experience – which in turn triggers the release of dopamine that is critical for effective performance and memory consolidation or learning (Beeler & Kisbye Dreyer, 2019; Mohebi et al. 2019; Speranza, di Porzio, Viggiano, de Donato, & Volpicelli, 2021; Wise, 2004; see also Lewthwaite & Wulf, 2017; Wulf & Lewthwaite, 2021).

In the present study, we therefore wanted to further examine whether boosting learners' expectations through simple praise or encouraging statements (e.g., Chiviacowsky & Drews, 2014; Drews et al., 2020) could be effective for enhancing motivation and learning. In addition, because most previous studies included young adults or children as participants, adolescents were recruited for the present study. To date, only a few studies have examined motor skill learning in adolescents as a function of motivational factors, including perceived relatedness (Kaefer & Chiviacowsky, 2021; 2022), social-comparative feedback (Wulf, Chiviacowsky, & Cardozo, 2014), or conceptions of ability (Drews, Chiviacowsky, & Wulf, 2013). Adolescence is characterized by important transitions and notably marked by a decline in perceived sports ability (Eccles et al. 1989; Wigfield, Eccles, Mac-Iver, Reuman, & Midgley, 1991; Wigfield & Wagner, 2005). Adolescents have also been found to show a greater reduction in learning relative to children and adults during practice with negative feedback (Zhuang, Feng, & Liao, 2017). It is therefore important to examine the effects of simple positive feedback statements on motor learning in this population.

Participants in the present study performed a linear positioning task. In addition to veridical error information, one group (enhanced expectancy) was given a positive feedback statement after each practice block, while another group (control group) received no such feedback. We hypothesized that positive feedback would result in more effective learning, as measured by delayed retention and transfer tests, and enhanced motivation. To assess the motivational impacts of positive feedback, measures of self-efficacy, intrinsic motivation (Intrinsic Motivation Inventory or IMI, McAuley, Duncan, & Tammen, 1989), affect (Feeling Scale; Hardy & Rejeski, 1989; Rejeski, Best, Griffith, & Kenney, 1987), and persistence were included. If positive feedback enhances learners' expectancies for future performance, this should be reflected in higher self-efficacy ratings relative to a control group at the end of the practice phase, and perhaps before retention testing on the following day. Furthermore, enhanced expectancies are assumed to potentially contribute to a virtuous cycle of increased motivation, as reflected in greater enjoyment or positive affect, task interest and effort, as well as interest in continued practice (Wulf & Lewthwaite, 2016). We therefore expected the enhanced expectancy group to show higher ratings on the enjoyment/interest, perceived competence, and effort/importance scales of the IMI, greater positive affect on the Feeling Scale, and increased interest in performing more practice trials, relative to the control group.

2. Methods

2.1. Participants

Thirty-four adolescents, students from a public school (18 boys, 16 girls), with a mean age of 15.2 years ($SD = 1.14$) participated in this study. Calculation of sample size was carried out using G*Power 3.1, using F tests, with an α level of 5%, effect size (f) of.50, and a power of 80% for the two groups, based on effect sizes previously reported in a similar study ($\eta_p^2 = .21$, Drews et al., 2020). This effect size is also in line with effect sizes reported in previous studies that included two groups, in which expectancies were enhanced through positive feedback (e.g., Chiviacowsky et al., 2019, $\eta_p^2 = .18$; Chiviacowsky & Drews, 2016, $\eta_p^2 = .30$). All participants were right-handed. They had no prior experience with the task and were not aware of the study purpose. Consent forms were signed by the participants as well as their parents. The Research Ethics Committee of the University approved this experiment.

2.2. Apparatus and task

A linear positioning apparatus was used. It consisted of a linear track with a slide, secured to a table top (see Chiviacowsky & Lessa, 2017). The slide could easily be moved by hand from side to side. A one-meter measuring device was attached to one side of the apparatus to determine the horizontal displacement of the slide (in mm). Participants sat in front of the apparatus, opposite to the measuring device, with their left shoulder aligned with the starting position of the slide (see Fig. 1). They were asked to use their right hand to move the slide to the target on the right, after making a small (up to 10 cm) reversal movement (i.e., back-and-forth) on the way. Participants were blindfolded by wearing opaque swimming goggles. During the practice and retention phases of the experiment, the target was 60 cm from the starting point. On the transfer test, the target distance was 45 cm.

To assess self-efficacy (Bandura, 2006), participants rated their confidence, on a scale from 1 (not confident at all) to 10 (extremely confident), that they would be able to achieve a deviation from the target that was equal to, or smaller than, 5, 4, 3, 2, or 1 cm, respectively. In addition, we used the enjoyment/interest, perceived competence, and effort/importance scales of the Intrinsic Motivation Inventory (IMI) questionnaire (McAuley et al. 1989). Each subscale consisted of three items. Examples of these items are: "I enjoyed doing this activity very much" (enjoyment/interest); "After practicing this task for a while, I felt pretty competent" (perceived competence); and "I worked hard to do this task well" (effort/importance). Participants responded to each item on a Likert scale from 1 (not at all) to 7 (very much). The Feeling Scale (Hardy & Rejeski, 1989; Rejeski et al., 1987) was used to determine participants' positive or negative affect. The scale was presented in a 11-point bipolar good/bad format, ranging from + 5 to − 5. Verbal anchors

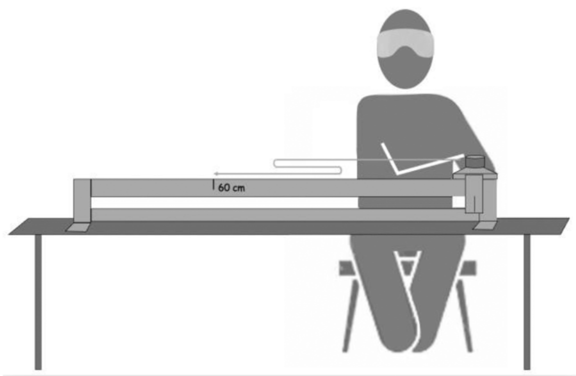

Fig. 1. Apparatus and experimental set-up.

were provided at the 0 point, and at all odd integers + 5 = very good, + 3 = good, + 1 = fairly good, 0 = neutral, − 1 = fairly bad, − 3 = bad, and − 5 = very bad. Finally, participants were asked to fill out a multi-choice question about persistence: “If you had time to complete more trials today, how many would you like to do?” Possible responses were 0, 10, 20, 30, or 40 trials.

2.3. Procedure

Participants were randomly assigned to two experimental conditions, the enhanced expectancy (EE) and control groups. Participants first received general task instructions. They were informed that the goal of the task was to move the slide from the start to the goal position (60 cm) and including a small reversal movement. They then observed a demonstration of the task. Subsequently, participants performed two pre-test trials, followed by 80 practice trials. All participants received feedback on the last trial in each 10-trial block of the practice phase (i.e., 10% feedback). They were verbally informed about the extent and direction of the deviation from the target position (e.g., −2 cm). In addition to this veridical feedback, EE group participants received a positive feedback statement after each 10-trial block (see Table 1). These statements reflected performance on the entire previous block, rather than a specific trial. The statements were given to all participants in the EE group, irrespective of their actual performance. That is, in contrast to the veridical feedback, positive feedback statements may not always have reflected the participant’s actual performance. On the retention test (60 cm target distance) and transfer test (45 cm) one day later, participants received no feedback. Before the transfer test, participants were informed that the new target distance was 45 cm. Each test consisted of 10 trials. Participants filled out the self-efficacy, IMI, and Feeling questionnaires after the pre-test and the practice phase, and before the retention test. Also, at the end of practice, they answered a question related to persistence (“If you had time to complete more trials today, how many would you like to do?”). After the transfer test, participants were debriefed, informed about the objective of the study, thanked, and released.

2.4. Data analysis

Absolute error (AE), that is, the absolute deviation (in cm) of the final slide position from the target, was used as dependent variable. AEs were average across blocks of 10 trials. One-way ANOVAs were used for the pre-test, retention, and transfer tests, while the practice data were analyzed in a 2 (groups) × 8 (blocks) ANOVA with repeated measures on blocks. Bonferroni post-hoc tests were used for follow-up analyses. Average self-efficacy and IMI scores, as well as affect and persistence scores were analyzed in one-way ANOVAs. Partial eta-squared (η_p^2) was used to determine effect size. Alpha was set at.05 for all analyses.

3. Results

3.1. Accuracy scores

3.1.1. Pre-test

There were no differences in AE between the EE (19.2 cm, SD 8.5) and control (18.3 cm, SD 12.5) groups on the pre-test, F (1, 32) = .065, $p = .801$, $\eta_p^2 = .002$ (see Fig. 2).

3.1.2. Practice

Both groups reduced their errors across the practice phase, with the EE group demonstrating smaller error scores throughout practice. The main effect of block was significant, F (7, 224) = 27.148, $p < .001$, $\eta_p^2 = .459$. Post-hoc tests indicated differences between block 1 and all other blocks, $ps < .001$; blocks 2 and 8, $p = .005$; blocks 3 and 7, $p = .001$; blocks 3 and 8, $p = .001$; blocks 4 and 8, $p = .050$; and blocks 6 and 8, $p = .003$. The main effect of group was also significant, F (1, 32) = 34.890, $p < .001$, $\eta_p^2 = .522$. The interaction of block and group was not significant, F (7, 224) = 1.399, $p = .207$, $\eta_p^2 = .042$.

3.1.3. Retention

On the no-feedback retention test one day later, the EE group (3.1 cm, SD 2.0) had smaller AEs than the control group (9.6 cm, SD 7.3). The group difference was significant, F (1, 32) = 12.496, $p = .001$, $\eta_p^2 = .281$.

Table 1
Positive feedback statements provided to the EE group after each 10-trial practice block.

Block	Feedback
1	You did a good job on these first trials.
2	Excellent! You were on target on some trials.
3	Your errors are decreasing. Congratulations!
4	You made good progress during the first half of practice.
5	You are continuing to improve.
6	The number of target hits continues to increase.
7	You are making very good progress.
8	You did an excellent job.

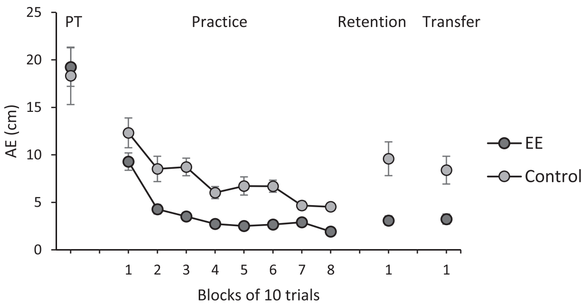

Fig. 2. Accuracy scores during pretest (PT), practice, retention, and transfer for the EE and control groups. Error bars indicate standard errors.

3.1.4. *Transfer*

Similarly, on the transfer test that included a novel target distance (45 cm), the EE group (3.2 cm, SD 2.2) had smaller errors compared with the control group (8.4 cm, SD 6.0). The difference between groups was significant, F (1, 32) = 11.007, p = .002, $\eta_p{}^2$ = .256.

3.2. *Self-efficacy*

3.2.1. *Pre-test*

The EE (4.2, SD 1.1) and control (4.3, SD 1.3) groups did not differ in self-efficacy after the pre-test (Fig. 3), F (1, 32) = .050, p = .825, $\eta_p{}^2$ = .002.

3.2.2. *After Practice*

At the end of the practice phase, the EE group (7.2, SD 1.2) had higher self-efficacy scores than the control group (5.1, SD 1.3). The group difference was significant, F (1, 32) = 25.650, p < .001, $\eta_p{}^2$ = .445.

3.2.3. *Before retention*

The EE group (7.2, SD 1.1) maintained their level of self-efficacy on Day 2. Their scores were again higher than those of control group participants (4.3, SD 1.4), F (1, 32) = 47.84, p < .001, $\eta_p{}^2$ = .599.

3.3. *Intrinsic motivation inventory*

3.3.1. *After pre-test*

After the two pre-test trials, the two groups did not differ with respect to enjoyment/interest, F (1, 32) = .158, p = .693, $\eta_p{}^2$ = .005, perceived competence, F (1, 32) = 1.116, p = .299, $\eta_p{}^2$ = .034, or effort/importance, F (1, 32) = .258, p = .615, $\eta_p{}^2$ = .008 (see Fig. 4).

3.3.2. *After practice*

At the end of the practice phase, the EE group scored higher on intrinsic motivation than the control group. There were significant group differences in enjoyment/interest, F (1, 32) = 20.947, p < .001, $\eta_p{}^2$ = .396, perceived competence, F (1, 32) = 13.397, p = .001, $\eta_p{}^2$ = .295, and effort/importance, F (1, 32) = 14.416, p = .001, $\eta_p{}^2$ = .311.

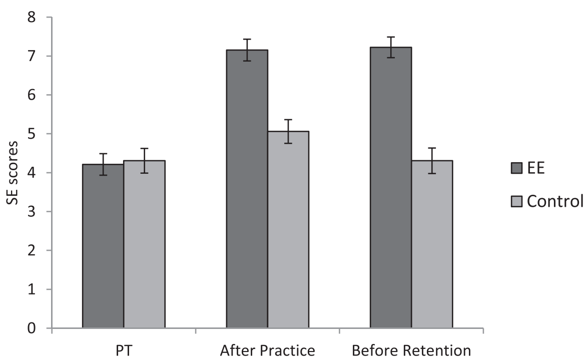

Fig. 3. Self-efficacy scores after the pre-test (PT) and practice, and before the retention test for the EE and control groups. Error bars indicate standard errors.

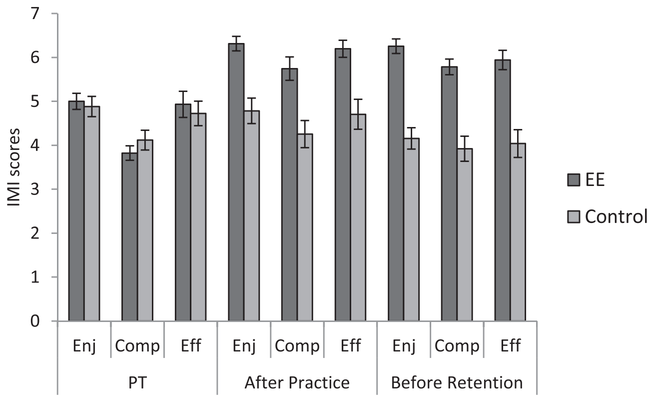

Fig. 4. Intrinsic Motivation Inventory (IMI) scores for the enjoyment, competence, and effort scales, after the pre-test (PT) and practice, and before the retention test for the EE and control groups. Error bars indicate standard errors.

3.3.3. Before retention

Similar results were found before the retention test, with higher levels of enjoyment/interest, F (1, 32) = 51.002, $p < .001$, $\eta_p^2 = .614$, perceived competence, F (1, 32) = 30.362, $p < .001$, $\eta_p^2 = .489$, and effort/importance, F (1, 32) = 24.446, $p < .001$, $\eta_p^2 = .433$, for the EE group relative to the control group.

3.4. Feelings scale

3.4.1. After pre-test

After the pre-test trials, the EE group (0.4, SD 1.5) tended to have somewhat lower affect ratings than the control group (1.1, SD 2.1). However, the group difference was not significant, F (1, 32) = 1.535, $p = .224$, $\eta_p^2 = .046$ (see Fig. 5).

3.4.2. After practice

After the practice phase, there were clear group differences. The EE group (2.9 = "good", SD 1.0) had higher ratings compared to the control group (−0.1 = "neutral", SD 2.4), F (1, 32) = 24.306, $p < .001$, $\eta_p^2 = .432$.

3.4.3. Before retention

Affect ratings at the beginning of Day 2 were similar to the end of practice. The EE group (2.9, SD 1.2) again indicated more positive affect than did the control group (−0.5, SD 2.7). The group differences were again significant, F (1, 32) = 21.987, $p < .001$, $\eta_p^2 = .407$.

3.5. Persistence

In response to the question whether they would be interested in continuing to practice if they had more time, the EE group showed greater interest in completing more practice trials (21.2 trials, SD 13,6) relative to the control group (7.1 trials, SD 9.2). This difference between groups was significant, F (1, 32) = 12.522, $p = .001$, $\eta_p^2 = .281$.

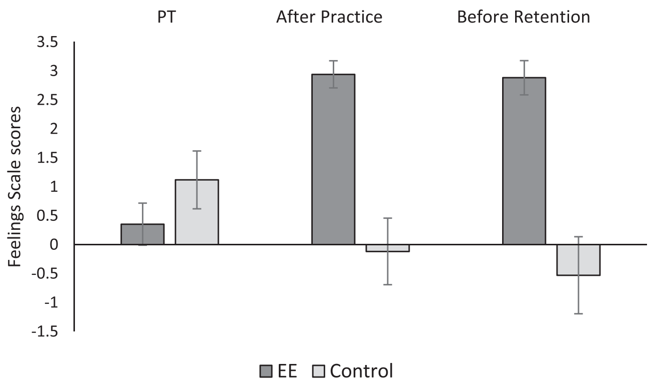

Fig. 5. Feeling Scale scores after the pre-test (PT) and practice, and before the retention test, ranging from "very good" (+5) to "very bad" (−5), for the EE and control groups. Error bars indicate standard errors.

4. Discussion

The learning of a linear positioning task was facilitated by enhancing learners' expectancies through the provision of occasional positive feedback. The EE group was given positive feedback eight times during the practice phase, in addition to eight veridical performance feedback statements. Compared with the control group that was only given veridical feedback, the EE group demonstrated greater movement accuracy throughout the practice phase, when the feedback was present. Importantly, the EE also outperformed the control group on a delayed no-feedback retention test with the same target distance. In addition, performance on the transfer test that involved a new target distance (45 cm) was facilitated by the positive feedback (EE group), demonstrating the generalizability of the learning benefits to novel situations. These findings are in line with the OPTIMAL theory (Wulf & Lewthwaite, 2016) prediction that conditions (i.e., enhanced expectancies, autonomy support, external focus of attention) that optimize performance facilitate learning.

The positive feedback in the present study was provided in the form of praise for good performance or improvement, which is different from previous studies in which performance feedback was provided on selected (i.e., relatively accurate) trials (e.g., Abbas & North, 2018; Chiviacowsky & Wulf, 2007), or in which feedback involved false comparative information suggesting to learners that they were performing better than average or their past selves (e.g., Ávila, et al., 2012; Chiviacowsky & Drews, 2016; Chiviacowsky et al., 2019; Lewthwaite & Wulf, 2010). As such, this type of feedback might be more suitable for practical settings than other types of feedback that involve deception.

Various measures in our study confirmed that the positive feedback had motivational consequences. Self-efficacy, or learners' confidence in their ability to perform the task with relatively small errors, was clearly enhanced in the EE relative to the control group. This effect was seen not only after the practice phase, but participants' self-efficacy was still higher one day later before the retention test. These findings are in line with the EE group's higher perceived competence ratings on the IMI after practice and before retention testing. EE participants also rated their interest and enjoyment higher than control group participants at both points in times. This is consistent with their affective ratings on the Feeling Scale, which were also significantly higher for the EE group after practice and before the retention test. Finally, and in line with their effort and importance ratings on the IMI, EE group participants indicated greater interest in continuing to practice than did participants in the control group. Overall, these findings highlight motivational impacts of positive feedback. They are consistent with results seen in other populations, such as children and adults, and for other motivational variables (for reviews and meta-analysis see Bacelar, Parma, Murrah, & Miller, 2022; Chiviacowsky, 2020; Simpson, Ellison, Carnegie, & Marchant, 2021; Wulf & Lewthwaite, 2016).

In the OPTIMAL theory (Lewthwaite & Wulf, 2017; Wulf & Lewthwaite, 2016, 2021), enhanced expectancies are a key motivational factor for performance and learning. In previous studies, learners' expectancies were enhanced not only through feedback indicating good performance and promoting an incremental view of ability (e.g., present study; Chiviacowsky & Drews, 2014; Chiviacowsky & Wulf, 2007; Cimpian et al., 2007), but also through monetary reward (e.g., Abe et al. 2011), visual illusions (e.g., Chauvel, Wulf, & Maquestiaux, 2015; Witt, Linkenauger, & Proffitt, 2012), liberal definitions of movement success (e.g., Chiviacowsky & Harter, 2015; Chiviacowsky et al., 2012; Palmer, Chiviacowsky, & Wulf, 2016; Trempe, Sabourin, & Proteau, 2012; Ziv, Ochayon, & Lidor, 2019), or other encouraging information designed to influence learners' expectancies (e.g., Chiviacowsky et al., 2019; Lewthwaite & Wulf, 2010). According to OPTIMAL theory predictions, "[w]hen temporally associated with skill practice, conditions that enhance expectancies for positive outcomes trigger dopaminergic responses and thereby benefit motor performance" and "[e]nhanced expectancies […] facilitate motor learning by making dopamine available for memory consolidation and neural pathway development" (Wulf & Lewthwaite, 2016). Enhanced expectancies have consistently been shown to result in both effective performance and learning. Positive experiences are rewarding, and reward is associated with dopamine release and dopamine-dependent long-term potentiation (Beeler & Kisbye Dreyer, 2019; Speranza et al., 2021). Dopamine strengthens neural connections and is believed to be a mechanism underlying motor learning (for a review, see Wise, 2004). Enhanced expectancies contribute to *goal-action coupling*, or the fluidity with which the movement goal is translated into neuromuscular activation (Lewthwaite & Wulf, 2017; Wulf & Lewthwaite, 2016, 2021). They are assumed to facilitate the functional connectivity among task-related motor networks and reduce activity in unrelated or self-related networks, similar to what is typically seen in expert performers (Giboin et al., 2019; Milton, Solodkin, Hluštík, & Small, 2007).

It should be noted that a few studies failed to find performance or learning benefits of experimental manipulations designed to enhance learners' expectancies (Ong & Hodges, 2018; Ziv & Lidor, 2021). However, this failure to replicate the results of numerous previous studies can likely be explained with the unusual specifics of the manipulations in those studies. For example, Ong and Hodges (2018) used a balance task (stabilometer) and provided participants with feedback about their performance (i.e., percentage of time the balance platform was within a certain number of degrees of horizontal) after each trial. This feedback was based on different criteria for different groups (1 versus 5 deg. of horizontal), which were not revealed to participants. Thus, learners had no basis for comparison that would have allowed them to judge the effectiveness of their performance – and that could have differentially affected their self-efficacy expectations. Not surprisingly, participants' confidence ratings simply reflected the feedback they had been given. In a study by Ziv and Lidor (2021), criteria for success were defined by different-size circles for different groups (40 cm vs. 10 cm) that placed around a golf hole during practice of a putting task. In contrast to previous studies using a similar task (e.g., Palmer et al., 2016; Ziv, Lidor, & Lavie, 2021; Ziv et al. 2019), no learning difference was found between groups with relatively easy versus difficult success criteria. However, rather than removing the circles, thereby creating equal conditions for all groups, on the retention and transfer tests, Ziv and Lidor (2021) decided to place a 25 cm circle around the target. In addition, they informed participants about the change in "task difficulty" on those tests. Thus, the retention and transfer tasks became easier for the group that had a more difficult criterion during practice, and vice versa. This unfortunate flaw in the experimental design – changed expectations in the opposite direction relative to practice – most likely canceled out any learning differences that might have been seen if expectations hadn't been altered, and learning had been measured on a "level playing field" (Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2019).

Overall, evidence from various lines of research indicates that enhancing performance expectancies facilitates learning (Bacelar et al., 2022; Wulf & Lewthwaite, 2016). The nature of the feedback used to enhance learners' expectancies for future performance in the present study, as well as the Chiviacowsky and Drews (2014); Drews et al. (2020), and Beroukhim-Kay et al. (2022) studies, makes this type of feedback more applicable to practical settings than the feedback provided in previous studies. Occasional encouraging information about their performance can evidently be sufficient to enhance learners' expectancies, task interest and engagement, enjoyment, effort, and desire for continued practice. The ensuing learning benefits may further increase learners' expectancies – potentially resulting in a virtuous cycle of positive effects for motivation, performance, and learning (see Wulf & Lewthwaite, 2016).

The linear positioning task used in the present study has a limited number of degrees of freedom. In addition, there was a spatial goal, but no timing requirement, making the task relatively "simple." It is therefore somewhat remarkable that occasional positive feedback statements were able to enhance the learning of this simple task. One might expect to see even greater benefits for more complex tasks with more challenging coordination requirements, including spatial-temporal coordination among various joints. Future studies should use more complex tasks with appropriate measures of performance, which may include biomechanical or neurophysiological measures to assess a wider range of potential benefits of enhanced expectancies.

Author statement

The manuscript represents results of original work. Each of the authors has read and concurs with the content in the final manuscript. The material within will not be submitted for publication elsewhere. If accepted, it will not be published elsewhere, including electronically in the same form, in English or in any other language, without the written consent of the copyright-holder.

The work also meets all Ethical Standards for the Reporting and Publishing of Scientific Information, has received the approval of an ethics committee, and follows the latest guidelines of Learning and Motivation (APA manual, edition VII).

CRediT authorship contribution statement

Cardozo Priscila: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft. **Martinez Victor:** Conceptualization, Data curation, Investigation, Writing – original draft. **Wulf Gabriele:** Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Kaefer Angélica:** Conceptualization, Data curation, Investigation, Methodology. **Chiviacowsky Suzete:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

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References

Abbas, Z. A., & North, J. S. (2018). Good-vs. poor-trial feedback in motor learning: The role of self-efficacy and intrinsic motivation across levels of task difficulty. *Learning and Instruction, 55*, 105–112. https://doi.org/10.1016/j.learninstruc.2017.09.009

Abe, M., Schambra, H., Wassermann, E. M., Luckenbaugh, D., Schweighofer, N., & Cohen, L. G. (2011). Reward improves long-term retention of a motor memory through induction of offline memory gains. *Current Biology, 21*(7), 557–562. https://doi.org/10.1016/j.cub.2011.02.030

Adams, J. A. (1971). A closed-loop theory of motor learning. *Journal of Motor Behavior, 3*(2), 111–150. https://doi.org/10.1016/B978-0-12-665950-4.50009-2

Ávila, L. T., Chiviacowsky, S., Wulf, G., & Lewthwaite, R. (2012). Positive social-comparative feedback enhances motor learning in children. *Psychology of Sport and Exercise, 13*(6), 849–853. https://doi.org/10.1016/j.psychsport.2012.07.001

Bacelar, M. F., Parma, J. O., Murrah, W. M., & Miller, M. W. (2022). Meta-analyzing enhanced expectancies on motor learning: Positive effects but methodological concerns. *International Review of Sport and Exercise Psychology*. https://doi.org/10.1080/1750984X.2022.2042839

Badami, R., VaezMousavi, M., Wulf, G., & Namazizadeh, M. (2011). Feedback after good versus poor trials affects intrinsic motivation. *Research Quarterly for Exercise and Sport, 82*(2), 360–364. https://doi.org/10.1080/02701367.2011.10599765

Badami, R., VaezMousavi, M., Wulf, G., & Namazizadeh, M. (2012). Feedback about more accurate versus less accurate trials: Differential effects on self-confidence and activation. *Research Quarterly for Exercise and Sport, 83*(2), 196–203. https://doi.org/10.1080/02701367.2012.10599850

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*, 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares, & T. Urdan (Eds.), *Self-efficacy beliefs of adolescents* (Vol. 5, pp. 307–337). Greenwich, CT: Information Age Publishing.

Beeler, J. A., & Kisbye Dreyer, J. (2019). Synchronicity: The role of midbrain dopamine in whole-brain coordination. *eNeuro, 6*. https://doi.org/10.1523/ENEURO.0345-18.2019

Bejjani, C., DePasque, S., & Tricomi, E. (2019). Intelligence mindset shapes neural learning signals and memory. *Biological Psychology, 156*, Article e107715. https://doi.org/10.1016/j.biopsycho.2019.06.003

Beroukhim-Kay, D., Kim, B., Monterosso, J., Lewthwaite, R., & Winstein, C. (2022). Different Patterns of Neural Activity Characterize Motor Skill Performance During Acquisition and Retention. *Frontiers in Human Neuroscience, 16*. https://doi.org/10.3389/fnhum.2022.900405

Bilodeau, E. A., & Bilodeau, I. M. (1958). Variable frequency of knowledge of results and the learning of a simple skill. *Journal of Experimental Psychology, 55*(4), 379. https://doi.org/10.1037/h0043214

Chauvel, G., Wulf, G., & Maquestiaux, F. (2015). Visual illusions can facilitate sport skill learning. *Psychonomic Bulletin & Review, 22*(3), 717–721. https://doi.org/10.3758/s13423-014-0744-9

Chiviacowsky, S. (2020). The motivational role of feedback in motor learning: evidence, interpretations, and implications. In B. Maurizio, E. Filho, & P. C. Terry (Eds.), *Advancements in Mental Skills Training (1st ed.)* (pp. 44–56). Routledge. https://doi.org/10.4324/9780429025112.

Chiviacowsky, S., & Drews, R. (2014). Effects of Generic versus Non-Generic Feedback on Motor Learning in Children. *PLoS ONE, 9*, Article e88989. https://doi.org/10.1371/journal.pone.0088989

Chiviacowsky, S., & Drews, R. (2016). Temporal-comparative feedback affects motor learning. *Journal of Motor Learning and Development, 4*, 208–218. https://doi.org/10.1123/jmld.2015-0034

Chiviacowsky, S., & Harter, N. M. (2015). Perceptions of competence and motor learning: performance criterion resulting in low success experience degrades learning. *Brazilian Journal of Motor Behavior, 9*(1), 30–40. https://doi.org/10.20338/bjmb.v9i1.82

Chiviacowsky, S., Harter, N. M., Gonçalves, G. S., & Cardozo, P. L. (2019). Temporal-comparative feedback facilitates golf putting. *Frontiers in Psychology, 9*, Article e2691. https://doi.org/10.3389/fpsyg.2018.02691

Chiviacowsky, S., & Lessa, H. T. (2017). Choices over feedback enhance motor learning in older adults. *Journal of Motor Learning and Development, 5*(2), 304–318. https://doi.org/10.1123/jmld.2016-0031

Chiviacowsky, S., & Wulf, G. (2007). Feedback after good trials enhances learning. *Research Quarterly for Exercise and Sport, 78*(2), 40–47. https://doi.org/10.1080/02701367.2007.10599402

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

Chiviacowsky, S., Wulf, G., Wally, R., & Borges, T. (2009). Knowledge of results after good trials enhances learning in older adults. *Research Quarterly for Exercise and Sport, 80*(3), 663–668. https://doi.org/10.1080/02701367.2009.10599606

Chua, L. K., Jimenez-Diaz, J., Lewthwaite, R., Kim, T., & Wulf, G. (2021). Superiority of external attentional focus for motor performance and learning: Systematic reviews and meta-analyses. *Psychological Bulletin, 147*(6), 618–645. https://doi.org/10.1037/bul0000335

Cimpian, A., Arce, H. M. C., Markman, E. M., & Dweck, C. S. (2007). Subtle linguistic cues affect children's motivation. *Psychological Science, 18*, 314–316. https://doi.org/10.1111/j.1467-9280.2007.01896.x

Drews, R., Chiviacowsky, S., & Wulf, G. (2013). Children's motor skill learning is influenced by their conceptions of ability. *Journal of Motor Learning and Development, 1*(2), 38–44. https://doi.org/10.1123/jmld.1.2.38

Drews, R., Tani, G., Cardozo, P., & Chiviacowsky, S. (2020). Positive feedback praising good performance does not alter the learning of an intrinsically motivating task in 10-year-old children. *European Journal of Human Movement, 45*. https://doi.org/10.21134/eurjhm.2020.45.5

Dweck, C. S., & Leggett, E. L. (1988). A social-cognitive approach to motivation and personality. *Psychological Review, 95*, 256–273. https://doi.org/10.1037/0033-295X.95.2.256

Eccles, J. S., Wigfield, A., Flanagan, C. A., Miller, C., Reuman, D. A., & Yee, D. (1989). Self-concepts, domain values, and self-esteem: Relations and changes at early adolescence. *Journal of Personality, 57*(2), 283–310.

Feltz, D. L., Chow, G. M., & Hepler, T. J. (2008). Path analysis of self-efficacy and diving performance revisited. *Journal of Sport and Exercise Psychology, 30*(3), 401–411. https://doi.org/10.1123/jsep.30.3.401

Giboin, L. S., Loewe, K., Hassa, T., Kramer, A., Dettmers, C., Spiteri, S., … Schoenfeld, M. A. (2019). Cortical, subcortical and spinal neural correlates of slackline training-induced balance performance improvements. *NeuroImage, 202*, Article 116061. https://doi.org/10.1016/j.neuroimage.2019.116061

Hardy, C. J., & Rejeski, W. J. (1989). Not what, but how one feels: the Measurement of affect during exercise. *Journal of Sport and Exercise Psychology, 11*(3), 304–317. https://doi.org/10.1123/jsep.11.3.304

Kaefer, A., & Chiviacowsky, S. (2021). Relatedness support enhances motivation, positive affect, and motor learning in adolescents. *Human Movement Science, 79*, Article 102864. https://doi.org/10.1016/j.humov.2021.102864

Kaefer, A., & Chiviacowsky, S. (2022). Cooperation enhances motor learning. *Human Movement Science, 85*, Article 102978. https://doi.org/10.1016/j.humov.2022.102978

Lessa, H. T., Tani, G., & Chiviacowsky, S. (2018). Benefits of enhanced expectancies through temporal-comparative feedback for motor learning in older adults. *International Journal of Sport Psychology, 49*(6), 521–530. https://doi.org/10.7352/IJSP.2018.49.521

Lewthwaite, R., & Wulf, G. (2010). Social-comparative feedback affects motor skill learning. *Quarterly Journal of Experimental Psychology, 63*(4), 738–749. https://doi.org/10.1080/17470210903111839

Lewthwaite, R., & Wulf, G. (2017). Optimizing motivation and attention for motor performance and learning. *Current Opinion in Psychology, 16*, 38–42. https://doi.org/10.1016/j.copsyc.2017.04.005

McAuley, E., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the Intrinsic Motivation Inventory in a competitive sport setting: A confirmatory factor analysis. *Research Quarterly for Exercise and Sport, 60*(1), 48–58. https://doi.org/10.1080/02701367.1989.10607413

Milton, J., Solodkin, A., Hluštík, P., & Small, S. L. (2007). The mind of expert motor performance is cool and focused. *NeuroImage, 35*(2), 804–813. https://doi.org/10.1016/j.neuroimage.2007.01.003

Mohebi, A., Pettibone, J. R., Hamid, A. A., Wong, J. T., Vinson, L. T., Patriarchi, T., Tian, L., Kennedy, R. T., & Berke, J. D. (2019). Dissociable dopamine dynamics for learning and motivation. *Nature, 570*, 65–70. https://doi.org/10.1038/s41586-019-1235-y

Ong, N. T., & Hodges, N. J. (2018). Balancing our perceptions of the efficacy of success based feedback manipulations on motor learning. *Journal of Motor Behavior, 50*(6), 614–630. https://doi.org/10.1080/00222895.2017.1383227

Palmer, K., Chiviacowsky, S., & Wulf, G. (2016). Enhanced expectancies facilitate golf putting. *Psychology of Sport and Exercise, 22*, 229–232. https://doi.org/10.1016/j.psychsport.2015.08.009

Pascua, L. A., Wulf, G., & Lewthwaite, R. (2015). Additive benefits of external focus and enhanced performance expectancy for motor learning. *Journal of Sports Sciences, 33*(1), 58–66. https://doi.org/10.1080/02640414.2014.922693

Peifer, C., Schönfeld, P., Wolters, G., Aust, F., & Margraf, J. (2020). Well Done! Effects of Positive Feedback on Perceived Self-Efficacy, Flow and Performance in a Mental Arithmetic Task (Article) *Frontiers in Psychology, 11*, Article 1008. https://doi.org/10.3389/fpsyg.2020.01008.

Rejeski, W. J., Best, D. L., Griffith, P., & Kenney, E. (1987). Sex-role orientation and responses of men to exercise stress. *Research Quarterly for Exercise and Sport, 58*(3), 260–264. https://doi.org/10.1080/02701367.1987.10605459

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American psychologist, 55*(1), 68.

Saemi, E., Porter, J. M., Ghotbi-Varzaneh, A., Zarghami, M., & Maleki, F. (2012). Knowledge of results after relatively good trials enhances self-efficacy and motor learning. *Psychology of Sport and Exercise, 13*(4), 378–382. https://doi.org/10.1016/j.psychsport.2011.12.008

Saemi, E., Wulf, G., Varzaneh, A. G., & Zarghami, M. (2011). Feedback after good versus poor trials enhances motor learning in children. *Brazilian Journal of Physical Education and Sport, 25*, 673–681. https://doi.org/10.1590/S1807-55092011000400011

Salmoni, A. W., Schmidt, R. A., & Walter, C. B. (1984). Knowledge of results and motor learning: A review and critical reappraisal. *Psychological Bulletin, 95*(3), 355–386. https://doi.org/10.1037/0033-2909.95.3.355

Schmidt, R. A. (1991). Frequent augmented feedback can degrade learning: evidence and interpretations. *In tutorials in motor neuroscience* (pp. 59–75). Dordrecht: Springer,.

Schmidt, R. A., Lee, T. D., Winstein, C. J., Wulf, G., & Zelaznik, H. N. (2019). *Motor control and learning* (6th edition). Champaign, IL: Human Kinetics.

Simpson, T., Ellison, P., Carnegie, E., & Marchant, D. (2021). A systematic review of motivational and attentional variables on children's fundamental movement skill development: The OPTIMAL theory. *International Review of Sport and Exercise Psychology, 14*(1), 312–358.

Speranza, L., di Porzio, U., Viggiano, D., de Donato, A., & Volpicelli, F. (2021). Dopamine: The neuromodulator of long-term synaptic plasticity, reward and movement control. *Cells, 10*, 735. https://doi.org/10.3390/cells10040735

Themanson, J. R., Pontiflex, M. B., Hillman, C. H., & McAuley, E. (2011). The relation of self-efficacy and error-related self-regulation. *International Journal of Psychophysiology, 80*, 1–10. https://doi.org/10.1016/j.ijpsycho.2011.01.005

Trempe, M., Sabourin, M., & Proteau, L. (2012). Success modulates consolidation of a visuomotor adaptation task. *Journal of Experimental Psychology: Learning Memory and Cognition, 38*(1), 52–60. https://doi.org/10.1037/a0024883

Vella, S. A., Braithewaite, R. E., Gardner, L. A., & Spray, C. M. (2016). A systematic review and meta-analysis of implicit theory research in sport, physical activity, and physical education. *International Review of Sport and Exercise Psychology, 9*, 191–214. https://doi.org/10.1080/1750984X.2016.1160418

Wigfield, A., Eccles, J. S., Mac Iver, D., Reuman, D. A., & Midgley, C. (1991). Transitions during early adolescence: Changes in children's domain-specific self-perceptions and general self-esteem across the transition to junior high school. *Developmental Psychology, 27*(4), 552.

Wigfield, A., & Wagner, A. L. (2005). Competence, Motivation, and Identity Development during Adolescence. In A. J. Elliot, & C. S. Dweck (Eds.), *Handbook of competence and motivation* (pp. 222–239). Guilford Publications.

Wise, R. A. (2004). Dopamine, learning and motivation. *Nature Reviews Neuroscience, 5*(6), 483–494.

Witt, J. K., Linkenauger, S. A., & Proffitt, D. R. (2012). Get me out of this slump! Visual illusions improve sports performance. *Psychological Science, 23*(4), 397–399. https://doi.org/10.1177/095679761142881

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. https://doi.org/10.1016/j.humov.2014.06.004

Wulf, G., Chiviacowsky, S., & Lewthwaite, R. (2012). Altering mindset can enhance motor learning in older adults. *Psychology and Aging, 27*(1), 14–21. https://doi.org/10.1037/a0025718

Wulf, G., Chiviacowsky, S., Schiller, E., & Ávila, L. T. G. (2010). Frequent external-focus feedback enhances motor learning. *Frontiers in Psychology*, 1–7, 1 (Article 190).

Wulf, G., & Lewthwaite, R. (2009). Conceptions of ability affect motor learning. *Journal of Motor Behavior, 41*(5), 461–467. https://doi.org/10.3200/35-08-083

Wulf, G., & Lewthwaite, R. (2016). Optimizing performance through intrinsic motivation and attention for learning: The OPTIMAL theory of motor learning. *Psychonomic Bulletin & Review, 23*(5), 1382–1414. https://doi.org/10.3758/s13423-015-0999-9

Wulf, G., & Lewthwaite, R. (2021). Translating thoughts into action: Optimizing motor performance and learning through brief motivational and attentional influences. *Current Directions in Psychological Science, 30*(6), 535–541. https://doi.org/10.1177/09637214211046199

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*(1), 20–30. https://doi.org/10.1123/jmld.1.1.20

Wulf, G., McConnel, N., Gärtner, M., & Schwarz, A. (2002). Enhancing the learning of sport skills through external-focus feedback. *Journal of Motor Behavior, 34*(2), 171–182. https://doi.org/10.1080/00222890209601939

Zhuang, Y., Feng, W., & Liao, Y. (2017). Want more? Learn less: Motivation affects adolescents learning from negative feedback. *Frontiers in Psychology, 8*, 76. https://doi.org/10.3389/fpsyg.2017.00076

Ziv, G., & Lidor, R. (2021). Different task success criteria affect expectancies of success but do not improve golf putting performance. *Psychology of Sport and Exercise, 54*, Article 101887. https://doi.org/10.1016/j.psychsport.2021.101887

Ziv, G., Lidor, R., & Lavie, M. (2021). Enhanced expectancies in golf putting – a replication study with increased ecological validity. *International Journal of Sport and Exercise Psychology, 19*, 1–12. https://doi.org/10.1080/1612197X.2019.1637362

Ziv, G., Ochayon, M., & Lidor, R. (2019). Enhanced or diminished expectancies in golf putting–Which actually affects performance? *Psychology of Sport and Exercise, 40*, 82–86. https://doi.org/10.1016/j.psychsport.2018.10.003