

## Autonomy support enhances performance expectancies, positive affect, and motor learning



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### ABSTRACT

**Objectives:** According to the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016), autonomy support contributes to successful performance and learning in part by enhancing learners' expectancies. The present study was designed to test expectancy-related predictions. Specifically, we examined the effects of practice with autonomy support on learners' self-efficacy, positive affect, and thoughts during practice.

**Design:** Experimental study with two groups. Movement form was assessed in two different experimental phases, supplemented by questionnaire data.

**Method:** Ten-year old children were shown a sequence of 5 ballet positions they were asked to learn: Preparatory position, *demi pli e*, *tendu* with arms and legs in second position, *pass e* with arms in first position, and *lev e* with feet in first position. In the autonomy-support (AS) group, participants were able to choose video demonstrations throughout practice, while control (C) group participants were provided with demonstrations based on their yoked counterparts' choices. One day after practice, participants performed in a retention test.

**Results:** The AS group demonstrated greater improvements in movement form during practice and enhanced learning relative to the C group. Furthermore, AS participants had higher self-efficacy and greater positive affect than the C group. Also, AS participants reported having more positive thoughts during practice relative to C group participants, who reported more negative and self-related thoughts.

**Conclusions:** The present findings are in line with OPTIMAL theory predictions. They highlight the motivational underpinnings of the learning benefits that are seen when learners are given choices.

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Learner autonomy is important for successful skill learning, and it is therefore a key factor in the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016). Practice conditions that satisfy learners' need for autonomy (Deci & Ryan, 2000, 2008) – including the provision of choices – have reliably been found to result in more effective motor skill learning compared with conditions that do not provide autonomy support (for reviews, see Lewthwaite & Wulf, 2012; Sanli, Patterson, Bray, & Lee, 2013). In most studies examining the effects of so-called self-controlled practice, performers' choices were relevant to task performance. As such they have included the delivery of feedback (e.g., Chiviawsky & Wulf,

2002; Janelle, Barba, Frehlich, Tennant, & Cauraugh, 1997; Patterson & Carter, 2010), augmented task information (Patterson & Lee, 2010), use of assistive devices (Chiviawsky, Wulf, Lewthwaite, & Campos, 2012; Hartman, 2007; Wulf & Toole, 1999), or demonstrations of the goal movement (e.g., Bund & Wiemeyer, 2004; Wulf, Raupach, & Pfeiffer, 2005). Relative to control groups, in which participants were yoked (in terms of feedback delivery, etc.) to participants in self-control groups, learning was typically enhanced in the latter groups.

More recent studies have shown that even choices that are more or less incidental to the task can benefit skill learning. For instance, given a choice regarding the order of different balance tasks to be performed, learners' retention performance was superior to that of learners without such choice (Wulf & Adams, 2014). Choice of task order has also been found to increase force production in skilled

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athletes (Halperin, Chapman, Martin, Lewthwaite, & Wulf, 2016). In other studies, allowing participants to choose the color of a ball to be putted (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015; Experiment 1) or thrown (Wulf, Chiviacowsky, & Cardozo, 2014) led to more effective task learning than yoked conditions. Perhaps most compelling, the learning of a balance task was enhanced when participants were given a choice related to one of two tasks they would practice afterwards, and when they were asked their opinion as to which of two prints of paintings should be hung in the laboratory (Lewthwaite et al., 2015; Experiment 2). Relative to yoked participants who were simply informed of the second task or the print to be hung, the former group demonstrated more effective retention performance on the balance task.

Overall, supporting learners' need for autonomy has been found to enhance learning in numerous studies. Independent of which factor the learner is given control over – or whether or not this factor is directly related to the task to be learned – the learning benefits appear to be very robust. In the literature, various explanations for this effect have been suggested, most of which are related to deeper information processing (e.g., Chen & Singer, 1992; Chiviacowsky & Wulf, 2005; McCombs, 1989; Watkins, 1984) resulting from “self-control.” However, findings showing that even incidental choices (e.g., Lewthwaite et al., 2015), or autonomy-supportive as opposed to controlling language (Hooymann, Wulf, & Lewthwaite, 2014), have beneficial effects on learning suggest that information processing is not the root cause of this effect. According to the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016), learner autonomy primarily impacts learners' motivational state. The sense that one is in a situation in which one has control enhances expectations for future success (e.g., self-efficacy). Self-efficacy, or the anticipation of positive experience, aligns thoughts, attention, motivation, and neuromuscular activity to the performer's goals. Thus, autonomy support contributes to what Wulf and Lewthwaite (2016) called *goal-action coupling*, that is, the establishment of effective neural connections that facilitate performance and lead to more effective learning.

The objective of the present study was to further examine the underlying mechanisms of the effects of autonomy support on motor learning. One specific purpose was to explore whether autonomy support enhances expectancies for future performance, or self-efficacy. Only a few previous studies have assessed and demonstrated increased self-efficacy as a result of providing learners choices (Chiviacowsky, 2014; Hooymann et al., 2014; Wulf, Chiviacowsky, & Drews, 2015; Wulf et al., 2014). We hypothesized that self-efficacy would be higher in the choice group. Furthermore, we wanted to assess positive affect as a function of autonomy support. We hypothesized that positive affect would be heightened as a result of choice. While positive affect may simply be a correlate of enhanced expectancies, it has been associated with dopamine release and found to improve cognitive performance in persons with Parkinson's disease (Ridderinkhof et al., 2012). Dopamine also contributes to the consolidation of motor memories when present during and after motor practice (e.g., Floel et al., 2008; Kawashima et al., 2012). Autonomy support is assumed to facilitate motor learning as it signals the rewarding circumstance of control and thus makes dopamine available for neural pathway development and memory consolidation (Murayama, Izuma, Aoki, & Matsumoto, 2017; Wulf & Lewthwaite, 2016). Therefore, we measured the extent of “happiness” the participants experienced during practice. We also determined its correlation with self-efficacy. Finally, we hoped to gain further insight into learners' thoughts and perhaps affective responses by asking them about their thoughts while practicing the ballet sequence. In line with the OPTIMAL theory (Wulf & Lewthwaite, 2016), we assumed that, by enhancing expectancies for success, autonomy support might facilitate a

beneficial focus on the task, as opposed to a self-focus that would more likely result from a lack of autonomy support.

In summary, in the present study 10-year old children were asked to learn a series of ballet positions. In the autonomy-supportive condition, participants were given the opportunity to request video demonstrations of the sequence during practice (choice group). In the control group, participants were shown the video whenever their (yoked) counterpart in the choice group had asked for it. Aside from learning, as measured by an assessment of movement form on a delayed retention test, we were interested in the effects, if any, of autonomy support on self-efficacy, positive affect, and learners' thoughts during practice.

## 1. Methods

### 1.1. Participants

Twenty-four girls, with an average age of 10.58 years ( $SD = 0.5$ ) and without mental or physical disabilities, participated in the study. They were recruited from a southern Brazilian city. Calculation of the sample size was carried out using G\*Power 3.1, with an  $\alpha$  level of 5%, effect size ( $f$ ) of 0.62, and a power of 80%, 2 groups, based on effect sizes reported in previous work using similar designs (e.g.,  $\eta_p^2 = 0.78$  in Chiviacowsky, 2014;  $\eta_p^2 = 0.25$  in Lewthwaite et al., 2015). All participants were naive as to the purpose of the experiment and none of them had experience with classical ballet. The children gave their assent, and informed consent was obtained from their parents or guardians. The study was approved by the university's institutional review board.

### 1.2. Apparatus and task

The task involved learning the movement forms associated with five classical ballet positions: Preparatory position, *demi plié*, *tendu* in second position of arms and legs, *passé* with arms in first position, and *elevé* with feet in first position. The experiment was conducted in a gymnastics hall. Photos of a ballet dancer performing the sequence of positions were used in the initial instruction of the task (see Fig. 1). A laptop computer was used for the video demonstrations. A video camera facing the participant was set up at a distance of 4 m to record performances for later analysis.

### 1.3. Procedure

Participants were randomly assigned to the choice or control groups, with an equal number of participants in each group. Before the beginning of practice, each participant was shown photos of the 5 sequential positions. In addition, the experimenter gave them a verbal description of the task, in which she highlighted five aspects of each position (arms, legs, feet positions, hip alignment, and trunk axis). Participants then performed the first trial. Each trial consisted of the participant's performing each of the five sequential positions. After the first trial, choice group participants were informed that they would be able to ask for video demonstrations of the entire sequence of five positions before any of the remaining practice trials. Control group participants were told that the experimenter would occasionally show them a video demonstration of the task. Each participant in the control group was yoked to a participant in the choice group and also received a demonstration of all five positions before the same trials on which their counterpart had requested one. The practice phase consisted of 50 trials. A retention test was performed one day later. It consisted of 10 trials without reminders or demonstrations.



Fig. 1. Sequence of 5 ballet positions to be learned.

#### 1.4. Measures

Performance was assessed by movement form. Form was rated independently by two judges, blinded to participants' experimental condition and the study purpose. The judges were experienced dance professors, with 20 and 42 years of experience, respectively. For each ballet position, 5 different qualitative aspects of movement form were assessed (e.g., positions of arms, upper body, hip alignment). Judges awarded 1 point for each correct aspect, and 0 points for incorrect ones. Thus, there was a maximum score of 25 points for each trial.

Participants in both groups completed a 5-item self-efficacy questionnaire before the beginning of practice and after practice on Day 1, and before the beginning of the retention test on Day 2. They were asked to rate how confident they were, on a scale from 1 ("not at all") to 10 ("very"), that they would be able to properly perform at least 1, 2, 3, 4, or all 5 positions, respectively, at the end of practice (before practice), the next day (after practice), or on the retention test (before the retention test). Responses to the 5 items were averaged to yield a self-efficacy rating for each time point. Positive affect was measured at the end of the practice phase. Participants were asked to indicate their degree of happiness by putting a tick mark on a 200 mm line with endpoints labeled "not at all happy" and "very happy." Aside from the endpoints, the line had no tick marks. Lastly, at the end of the practice phase participants were also asked to answer an open-ended question: "What were you thinking about while practicing the classical ballet task?"

#### 1.5. Data analysis

The intra-class correlation of judges' ratings was high (ICC = 0.982,  $p < 0.001$ ). Therefore, the scores of both raters were averaged. The average practice data were analyzed in a 2 (groups)  $\times$  5 (blocks of 10 trials) analysis of variance (ANOVA), with repeated measures on the last factor. A one-way ANOVA was used for the retention test to assess differential effects of choice on learning.

Self-efficacy ratings were averaged across the 5 items (1, 2, 3, 4, or 5 positions) and analyzed in a 2 (groups)  $\times$  2 (time: before practice, after practice) ANOVA for the practice phase, and in a one-way ANOVA for the retention test. Positive affect at the end of practice was determined by measuring the distance (mm) between the left endpoint and the participant's tick mark, and analyzed in a one-way ANOVA. We also examined correlations between self-efficacy and positive affect at the end of practice, and between these variables and learning.

## 2. Results

### 2.1. Number of demonstrations

Participants in the choice group requested demonstrations on 17.2% of the trials, on average. Yet, there was a reduction in requests across practice blocks. The relative frequency of video demonstrations for both groups was 35, 15, 14, 9.2, and 12.5% for Blocks 1–5, respectively.

### 2.2. Movement form

Movement quality generally improved during the practice phase (see Fig. 2). Yet, the choice group showed a greater increase in form scores relative to the control group. The main effects of block,  $F(4, 88) = 76.90$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.78$ , and group,  $F(1, 22) = 18.06$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.45$ , were significant. Also, the interaction of group and block,  $F(4, 88) = 39.05$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.64$ , was significant. Bonferroni post-hoc tests revealed that the choice group outperformed the control group on block 2 ( $p < 0.05$ ), 3, 4, and 5 ( $ps < 0.01$ ).

On the retention test, choice participants clearly outperformed the control group. The group main effect was significant,  $F(1, 22) = 88.16$ ,  $p < 0.01$ ,  $\eta_p^2 = 0.80$ .

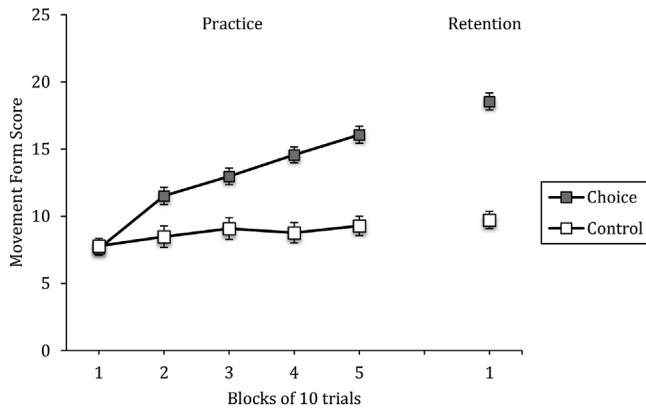


Fig. 2. Movement form scores of the choice and control groups during practice and retention. Error bars indicate standard errors.

### 2.3. Self-efficacy

Self-efficacy ratings before the beginning of practice were relatively similar for the choice (4.4) and control (5.3) groups, but the choice group had higher self-efficacy (6.3) than the control group (4.7) at the end of practice (see Fig. 3). While the main effects of time,  $F(1, 22) = 3.28, p = 0.084$ , and group,  $F(1, 22) < 1$ , failed to reach significance, the interaction effect was significant,  $F(1, 22) = 11.29, p = 0.003, \eta_p^2 = 0.34$ . Follow-up tests indicated that the two groups did not differ before practice,  $p = 0.28$ , but differed after practice,  $p = 0.029$ . Before the retention test on Day 2, self-efficacy was higher in the choice (8.0) relative to the control group (4.9),  $F(1, 22) = 15.44, p < 0.01, \eta_p^2 = 0.41$ .

### 2.4. Positive affect

At the end of practice, choice group participants demonstrated greater positive affect (185.41 mm) compared with participants in the control group (107.83 mm). The difference between groups was significant,  $F(1, 22) = 25.95, p < 0.01, \eta_p^2 = 0.54$ .

### 2.5. Relationships among variables

Positive affect was significantly correlated with self-efficacy in the same post-practice timeframe ( $r = 0.42, p < 0.05$ ), more strongly with self-efficacy measured prior to the retention phase ( $r = 0.65, p < 0.01$ ), and with learning ( $r = 0.80, p < 0.001$ ). Self-efficacy prior to the retention phase was also correlated with

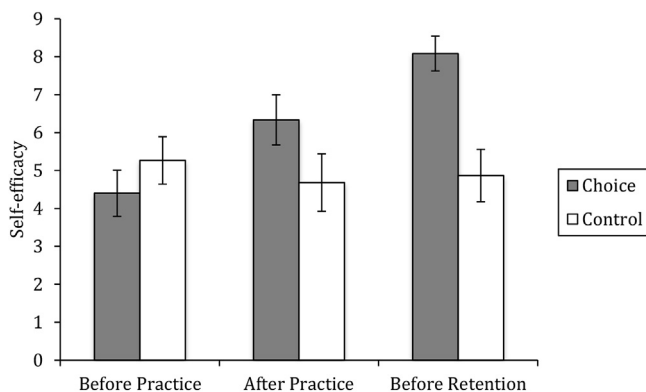


Fig. 3. Self-efficacy ratings of the choice and control groups before practice, after practice, and before retention. Error bars indicate standard errors.

subsequent performance (learning) ( $r = 0.60, p < 0.01$ ).

### 2.6. Thoughts during practice

At the end of the practice phase, participants of both groups were asked “What were you thinking about today while practicing the ballet positions?”. Their responses are listed in Table 1. The coder was a research assistant who was blind to the purpose of the experiment. Of the 12 choice group participants, 9 gave answers that suggested a task focus. Some responses (participants 4, 7, 9, and 10) were related to improving their task performance or correcting mistakes (e.g., “About trying to do the steps”, “That I would do it right”). Other responses (participants 1, 3, 5, 11, and 12) were related to the video demonstration and task performance evaluation (e.g., “About the ballerina in the video”, “Whether I was doing it right, like the dancer I saw in the video, because she is very beautiful”). The responses of 2 participants (participants 2 and 8) indicated non-task foci (e.g., “I was thinking whether I passed a test I took before”), and 1 participant (participant 6) reported a self-related focus (“Whether I would be able to do it”).

In the control group, few participants (participants 1, 3, and 5) reported task-related foci (e.g., “Whether the teacher was thinking I was doing it right or not”). Several participants (participants 2, 7, 8, 10, and 12) reported non task-related thoughts (e.g., “That ballet is boring, and that I wanted to finish my homework”, “How much longer it [practice] would take”), or had self-related thoughts (participants 4, 6, 9, and 11) (e.g., “I was embarrassed because I dance very badly and made mistakes all the time”, “That I was tired”).

The two groups also seemed to differ in terms of their affective responses to the different practice conditions. Both groups reported positive (e.g., “That I would do it right [“get the hang of it”]), uncertain/neutral (e.g., “Whether the teacher was thinking I was doing it right or not”), or negative thoughts (e.g., “I was embarrassed because I dance very badly and made mistakes all the time”). However, participants in the choice group reported mostly positive (participants 1, 2, 3, 7, 10, 11, and 12) or neutral thoughts (participants 4, 5, 6, 8, and 9), whereas the majority of control group participants reported negative thoughts (participants 2, 4, 5, 6, 7, 8, 9, and 11).

## 3. Discussion

In line with numerous previous studies, providing learners with a choice – in this case, when to view video demonstrations of ballet positions – thereby supporting their need for autonomy and signaling the opportunity for intrinsic reward, led to more effective learning than did not giving them a choice (control group). Group differences in movement quality increased over the practice phase, and the choice group had significantly higher form scores than the control group by the end of practice. Importantly, the choice group demonstrated more effective learning (i.e., retention performance). Furthermore, as predicted, the autonomy support experienced by choice group participants enhanced their performance expectancies. Their self-efficacy ratings were higher than those of control group participants at the end of practice and before the retention test. Positive affect, as measured by degree of happiness, was correlated with self-efficacy and learning, and was higher in the choice group relative to the control group at the end of practice. Finally, participants’ self-reported thoughts during the practice phase seemed to be more positive in the choice group and revealed fewer self-related concerns compared with the control group.

The findings of the present study are consistent with predictions of the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016). The theory posits that the perception of autonomy has an



**Table 1**

Responses to the question, “What were you thinking about today while practicing the ballet positions?”, posed at the end of practice (translated from Portuguese).

Choice group	Control group
1 I was very curious, because I was dancing ballet, something I don't know how to do very well.	1 I was wondering whether I was doing it right, because I don't know how to dance ballet, and no one ever taught me it at school.
2 That I was in an auditorium full of people watching me.	2 How much longer it would take (practice).
3 Whether I was dancing well, and what the teacher was thinking about it.	3 Whether the teacher was thinking I was doing it right or not.
4 About trying to do the steps.	4 I was embarrassed because I dance very badly and made mistakes all the time.
5 About the ballerina in the video.	5 I was thinking about the ballerina video to remember what the steps were, but I couldn't remember anything.
6 Whether I would be able to do it.	6 That I was tired.
7 I was wondering what position I could be doing wrong. The last time I was doing it right.	7 Thinking about rest and doing something else, because I did not like to do ballet very much.
8 I was thinking whether I passed a test I took before.	8 That I would like to try it again another day, to practice at home first.
9 About not making mistakes and focusing more.	9 That ballet is boring, and that I wanted to finish my homework.
10 That I would do it right (get the hang of it).	10 That ballet is very nice, but I would have to practice much more. I don't think I liked the ballerina in the video.
11 Whether I was doing it right, like the dancer I saw in the video, because she is very beautiful.	11 That I was tired.
12 Whether I would succeed in becoming a ballerina.	12 That it was cool.

impact on learners' motivational state, which in turn affects learning. Self-efficacy and positive affect measures indicated that motivation differed as a function of autonomy support (choice group) or lack thereof (control group). Enhanced expectancies and positive affect are likely co-effects of the same intrinsically rewarding positive experiences, including satisfaction of fundamental needs for autonomy and competence (successful performance) (Murayama et al., 2017; Wulf & Lewthwaite, 2016). Similar results were seen in a study by Hooyman et al. (2014), in which learners who were given a sense of choice through autonomy-supportive instructional language had higher positive affect and greater confidence in their ability to perform the task well (self-efficacy), compared with learners who received controlling instructions.

Autonomy support presumably influences motor learning in various ways. According to the OPTIMAL theory (Wulf & Lewthwaite, 2016), rewarding autonomy support indirectly facilitates *goal-action coupling* by enhancing learners' expectancies (e.g., self-efficacy). Linking performers' goals to their movement actions readies the motor system for task execution. Optimal motivational (and attentional focus) conditions – including autonomy support or other conditions that enhance performance expectancies – are assumed to facilitate the development of functional connectivity across brain regions, and structural neural connections more locally, that support effective and efficient motor performance and learning. Functional connectivity refers to temporal linkages between spatially distinct neural networks relevant to task performance (e.g., Di & Biswal, 2015; Friston, 2011) that are also associated with higher skill levels (e.g., Kim et al., 2014). The presence of dopamine, which is associated with positive motivation (e.g., enhanced expectancies, positive affect), is important for the occurrence of neuroplastic changes, including memory consolidation (e.g., Sugawara, Tanaka, Okazaki, Watanabe, & Sadato, 2012; Kawashima et al., 2012; Wise, 2004).

Aside from its indirect influence on learning (i.e., by enhancing learners' performance expectancies), autonomy support likely also has a more direct impact on performance and learning. Conditions that meet people's psychological and biological need for autonomy (Deci & Ryan, 2000, 2008; Leotti, Iyengar, & Ochsner, 2010) reduce stress that would be experienced in controlling conditions (Reeve & Tseng, 2011). Lack of control over and uncertainty about when needed information will be provided, such as the skill demonstrations in the present study, may lead to worries, anxiousness, and perhaps irritation. Indeed, several of the responses given by

participants in the control group seemed to reflect their concerns about performing the positions correctly (e.g., Participants 1, 3, 4, 5 in Table 1), more so than was the case in the choice group. Similarly, in a previous study involving the learning of a balance task (Chiviacowsky et al., 2012), participants who were not able to decide when to use a balance pole reported being more nervous, compared with participants who had control over the use of the balance pole. Psychological stress and subsequent attempts at controlling emotional reactions may reduce working memory capacity and take attention away from the task (e.g., Nieuwenhuys & Oudejans, 2012; Qin, Hermans, van Marle, Luo, & Fernández, 2009).

In the Chiviacowsky et al. (2012) study, there was also evidence that lack of autonomy tended to promote a self-focus. Participants indicated that they were more concerned about the position of their body parts, suggesting that they adopted a relatively ineffective internal focus, or self-focus (Wulf & Lewthwaite, 2010; Wulf, 2013), to a greater extent than did learners in autonomy-supportive practice condition. Self-related processing is one of several functions of the brain's default mode network (e.g., Buckner, Andrews-Hanna, & Schacter, 2008). The default mode network is active during mind wandering, thinking about the past, or planning for the future. It is spontaneously active when a person is not engaged in a task (Raichle, 2015). Even though activity of the default mode network is negatively correlated with activity in other networks, such as task-positive or attentional networks, it does not always deactivate when they are active (Raichle, 2015). Learners who were stymied in their effort to learn the task by not being able to access necessary or desired (video) information were presumably also impeded in their ability to switch from the default mode network to motor networks essential for effective task performance. The thoughts several control group participants reported having during the practice phase – including being tired, ballet being boring, and wanting to do homework – seem to support this interpretation (Participants 2, 6, 7, 9, 11 in Table 1). In contrast, no participant in the choice group mentioned task-unrelated thoughts. Rather all participants indicated that they focused on the task, tried to do it right, and avoid errors.

Overall, the present findings are consistent with various propositions put forward in the OPTIMAL theory (Wulf & Lewthwaite, 2016). They demonstrate that the learning advantages seen under autonomy-supportive, or self-controlled, practice conditions are motivational in nature. Learners' self-efficacy and positive affect were increased by the choice provided to them. These results are in line with the prediction that autonomy support exerts its influence

on learning primarily by enhancing expectancies – thereby effectively coupling performers' goals with their movement actions. Learner autonomy also seems to reduce stress and associated off-task and self-focused attention, further contributing to goal-action coupling.

We hypothesize that optimal motivational conditions are rewarding and thus make dopamine available for the development of neural connections that support successful performance and learning. Of course, what is considered rewarding for one individual may not serve that purpose for another (Schultz, 2013), but the range of beneficial choices would appear to be greater than clearly task-relevant ones, as the meta-analysis of Patall and colleagues (Patall, Cooper, & Robinson, 2008) indicates.

Rewarding conditions may also be preconditions for effective processing of error information or feedback. In a study by Legault and Inzlicht (2013), autonomy was associated with greater sensitivity to task errors than controlling conditions, in addition to enhanced performance. Similarly, Grand et al. (2015) found enhanced processing of information (EEG-derived feedback-related negativity), increased intrinsic motivation, and more effective motor learning under autonomy-supportive practice conditions (self-controlled feedback) relative to a yoked control condition. Aside from a possible increased working-memory capacity for processing information due to a reduced need for self-regulatory activity, autonomy seems to promote awareness of deviations from the movement goal and keep attention directed at the task goal (Legault & Inzlicht, 2013). Thus, differences in information processing seen between conditions that do or do not support learners' need for autonomy (e.g., Carter & Ste-Marie, 2016) are a consequence of the motivational impact of those conditions. A challenge for future studies will be to provide further evidence for autonomy-support related predictions including the elicitation of dopaminergic responses and neuroplastic changes such as structural (e.g., Lakhani et al., 2016; Taubert et al., 2010) and functional connectivity (e.g., Kim, Han, Kim, & Han, 2015; Milton, Solodkin, Hluštík, & Small, 2007; see Wulf & Lewthwaite, 2016). Pragmatically, though, this study extends evidence of the impacts of autonomy support on the learning of movement form.

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