7 Autonomy Support in Motor Performance and Learning

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Over the past two decades, researchers have directly examined the effects of several motivational factors on motor performance and learning (for reviews, see Chiviacowsky, 2020; Lewthwaite & Wulf, 2012). For instance, experiments have shown the relevance of personal capability mindsets (Chiviacowsky & Wulf, 2007; Heidrich & Chiviacowsky, 2015), the value of social relatedness (Gonzalez & Chiviacowsky, 2018), and the importance of supporting autonomy (Lewthwaite et al., 2015) for the acquisition of motor skills. The conceptualization of competence, relatedness, and autonomy as psychological human needs from self-determination theory (SDT) (Deci & Ryan, 2000; Ryan & Deci, 2000), and more recently the OPTIMAL theory of motor learning (Wulf & Lewthwaite, 2016), have provided important frameworks for contemplating motivational variables in this field of research. SDT is a broad theory that explains motivational phenomena and understanding of factors that facilitate or undermine motivation, while OPTIMAL theory more specifically proposes that motivational factors, including autonomy support, facilitate motor learning by contributing to the fluidity with which movement plans are translated into action; that is, goal-action coupling.

Autonomy is a heavily investigated factor of motor learning that concerns the need to feel in control of one's actions, instead of feeling controlled or pressured (Ryan, 1995). As with competence and relatedness, autonomy is as fundamental condition for human psychological well-being, growth, and integrity; it is a need that must be fulfilled for high-quality motivation to develop, while its suppression is also thought to be harmful to an individual (Ryan & Deci, 2000). Many studies have shown that autonomy increases intrinsic motivation (for reviews, see Patall et al., 2008; Vansteenkiste et al., 2020); motivated learners show, in turn, higher activation in major dopaminergic pathways or reward brain systems that support memory and learning (Di Domenico & Ryan, 2017; Wise, 2004). The act of choosing is rewarding; it positively changes the perception of outcomes, involves multiple motivational consequences and psychological processes, and is supported by several distinct brain areas (Blain & Sharot, 2021; Legault & Inzlicht, 2013; Leotti & Delgado, 2011; Murayama et al., 2016). Even if illusory, a perceived sense of control results in positive outcomes, such as enhanced persistence in the presence of difficulties when individuals are outperformed or when rewards fade (Studer et al., 2020).

The effects of autonomy support in motor performance and learning have been observed over the years through different lines of research that use a great variety of tasks – mostly closed self-paced tasks. Examples vary from simple tasks such as timing key-presses (Chiviacowsky & Wulf, 2002), to more complex skills such as basketball free-throw shots (Aiken et al., 2012) or ballet sequences (Lemos et al., 2017). Environmental conditions are stable and predictable for performing self-paced tasks, with the best performances associated with automatic optimal functioning (Singer, 2002) and with many other factors, including the individual's perceptions of control, influencing its performance and learning. Autonomy support, in fact, enhances motivation, positive affect, task focus, and performance and learning of self-paced tasks (e.g., Chiviacowsky, 2014; Grand et al., 2015; Lemos et al., 2017). It allows learners to adapt their practice to satisfy their performance needs or preferences (Chiviacowsky & Wulf, 2002). Autonomy frustration, on the other hand, results in negative outcomes – for example self-evaluative concerns and nervousness or stress, which undermine performance and learning (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012; Hooyman et al., 2014; Reeve & Tseng, 2011).

In the present chapter, a brief overview of different lines of investigation are presented, which observe the impact of autonomy support on motor performance and learning. Underlying mechanisms explaining the observed effects are discussed. The importance of extending research for a deeper understanding of the relationship between autonomy support, motivational outcomes, and motor performance and learning, in different contexts and populations, is highlighted. Lastly, a set of practical recommendations on how to apply autonomy supportive interventions in multiple motor performance and learning contexts is suggested.

Choosing Feedback

Feedback – information about one's performance by which learners can confirm, adjust, or reorganize not only performance, knowledge, and strategies, but also conceptions or views about one's self, abilities, and skills (Chiviacowsky, 2020) – is a key motivational factor for learning. Considering its relevance, it is not a surprise that the first (e.g., Janelle et al., 1997) and the great majority of studies observing autonomy support and its underlying mechanisms on motor learning, utilized choices of feedback. Participants who are allowed to choose feedback are usually compared to participants who are not given a choice (control or "yoked" groups) and demonstrate enhanced motivation, motor performance, and learning. These effects have been observed in a variety of motor tasks in distinct populations such as young adults (Janelle et al., 1997), children (Chiviacowsky, Wulf, Medeiros, Kaefer, & Tani, 2008), older adults (Chiviacowsky & Lessa, 2017), individuals with disabilities (Hemayattalab et al., 2013), and those with different personality traits (Kaefer et al., 2014) or distinct physical activity levels (Fairbrother et al., 2012). Notably, this research has revealed a clear preference of learners for choosing feedback mainly to confirm good performance (Chiviacowsky & Wulf, 2002; Fairbrother et al., 2012), showing that this strategy impacts learning not only by increasing sense of agency (Chiviacowsky, 2014), but also by protecting perceptions of competence (Chiviacowsky, Wulf, & Lewthwaite, 2012). More recently, studies looking at neural mechanisms [Electroencephalogram (EEG) activity] underlying the choices of feedback effects on learning have corroborating previous findings, observing that choice participants not only ask for feedback after more successful trials, but also show higher attention while processing the feedback and increased motivation relative to yoked groups (e.g., Grand et al., 2015; Kim et al., 2019). Together, these outcomes and others show that supporting autonomy through choices over feedback satisfies both autonomy and competence needs, increasing motivation and facilitating learning.

Deciding When to Observe the Performance of a Model

The observation of actions of others provides learners with information about the form of movements and also about strategies to accomplish a determined task. Both behavioral (Hodges, 2017) and neural (Ramsey et al., 2021) research have observed benefits in motor performance and learning through action observation. Practice conditions allowing participants to decide when to observe a model's action have resulted in enhanced learning relative to conditions where specific times for model observation were externally imposed. For instance, positive learning effects have been observed in young adults deciding when to observe a video model performing the forehand top-spin stroke in table tennis (Bund & Wiemeyer, 2004) or basketball jump shots (Wulf et al., 2005), and also in children deciding when to observe the performance of a model while learning a sequence from classical ballet (Lemos et al., 2017). Autonomous participants have demonstrated not only a higher quality of movement, but also higher levels of positive affect, self-efficacy, and positive thoughts relative to yoked participants (Lemos et al., 2017). Other positive outcomes include, for example, more favorable perceptions of learning in young adults deciding between different models when learning a baseball pitch (Ghorbani et al., 2020). As with choices of feedback, the positive effects of supporting learners' autonomy through decisions about when to observe a model are robust; they have been replicated in several kinds of tasks and different populations, and were noticed not to vary regarding frequency of observations (St. Germain et al., 2019).

Controlling the Amount and the Pacing of Practice

The degree of control provided to learners regarding the manner in which a practice is organized — including the amount and the pacing of practice — plays an important role in motor performance and learning. In one experiment, young adults practicing dart throwing were allowed to control the number of trials during a determined session; they were compared with a yoked group practicing with a matched schedule, but who were not given a choice (Post et al., 2011). Those participants demonstrated increased learning relative to the group who were not allowed to control when they ceased the practice. Such effects were generalized to the learning of basketball set shots in the same population (Post et al., 2014), and also in older adults learning a sequential cup-stacking task (Lessa & Chiviacowsky, 2015). Results of questionnaires revealed that participants' reasons for stopping practice after a certain number of trials included mainly competence-related factors, such as satisfaction with performance and fear of worsening performance if the practice continues, but also fatigue (Lessa & Chiviacowsky, 2015; Post et al., 2011). Learners controlling the pacing of practice, such as choosing how much time to spend between trials (time to prepare for the next trial and time to process feedback after the trial was completed), also showed better outcomes than a yoked group using the same intertrial interval but without choice (Aiken et al., 2020). Together, such studies show that identical amounts of practice or intertrial intervals do not always result in similar learning, with opportunities to control these practice aspects positively impacting the outcomes.

Adopting a Preferred Order of Tasks, Devices, or Limbs

Supporting autonomy by permitting learners to adopt a preferred order of tasks, devices, or which limb to perform with first in a determined practice session, is another strategy observed to benefit learning (Keetch & Lee, 2007; Wu & Magill, 2011; Ziv & Lidor, 2021). In one study (Wulf et al., 2015), participants throwing beach-tennis balls overhand at a target could adopt a preferred order of trial blocks in which they could use either their non-dominant or dominant arm, while another group had to perform in the same order as the former; the autonomous group learned the task better. Superior learning was also found in participants adopting a preferred order of different suturing skills (Safir et al., 2013), timing key-pressing tasks (Wu & Magill, 2011), choice reaction-time tasks (Ziv & Lidor, 2021), and golf practice devices (An et al., 2020), relative to yoked participants. Along with movement effectiveness, movement efficiency has also been enhanced by this autonomy-supportive practice strategy. For instance, maximum force productions were increased in kickboxers provided with freedom to adopt a preferred order of punch practices (Halperin et al., 2017), and also in non-athletes practicing with a hand-grip dynamometer while choosing the order of hands (e.g., dominant before non-dominant, or vice versa) (Iwatsuki et al., 2017). This autonomy supportive strategy was observed to enhance perceived choice, confidence, self-efficacy, and positive affect (An et al., 2020; Wulf et al., 2015).

Adjusting Task Difficulty or Challenge Levels

Allowing learners to freely transit over different levels of difficulty during practice is another autonomy-supportive strategy observed to enhance skill learning, relative to imposed conditions that do not consider the learners' capacities or preferences. Positive effects on learning were observed in individuals controlling task difficulty by adjusting racquet widths while practicing a computer task (Andrieux et al., 2012; Andrieux et al., 2016), distances in golf putting (Jaquess et al., 2020), and also difficulty levels of a computer game involving combined speed-accuracy tasks (Leiker et al., 2016; Leiker et al., 2019). Participants practicing in the above-mentioned conditions showed increased intrinsic motivation and learning compared to individuals who were not allowed any choice; they also showed a competence-protective behavior, in that when the difficulty was too great, they reduced it, and thus increased their engagement. Yoked participants, on the other hand, showed lower levels of engagement with the externally imposed task challenges (Jaquess et al., 2020; Pathania et al., 2019). These findings are in line with studies observing increased perceptions of competence and learning in individuals practicing relatively less-difficult tasks, manipulated through the use of different criteria of task success that included autonomy-supportive contexts of practice (Chiviacowsky, Wulf, & Lewthwaite, 2012) or did not (e.g., Chiviacowsky & Harter, 2015; Ziv et al., 2019). Together, they show that allowing learners to actively adjust task difficulty helps to maintain an optimal balance between challenge and success, increasing motivation and learning.

Judging the Use of Assistive Devices

The use of assistive devices is common in many different practical settings, as they can be used in various ways – one of which is preserving learners of potentially dangerous situations when performing and learning more challenging motor skills. Examples of such devices are training wheels on learning bicycles, ski poles, and canes and walkers in rehabilitation settings. The benefits of learning when allowing individuals to judge their need for using assistive devices have been observed in several experiments. The learning of slalom-type movements on a ski-simulator was enhanced in adult participants deciding when to use ski poles relative to yoked participants (Wulf & Toole, 1999). Similar results were found in young adults (Hartman, 2007) and in individuals with Parkinson's disease (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012) choosing when to use a balance pole while learning the task of balancing in a stabilometer. Questionnaire results indicate that these participants were less nervous, less concerned about body movements, and more motivated to learn the task, relative to yoked participants (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012). Higher levels of positive affect were also found in post-stroke adults who had suffered unilateral cerebrovascular accidents, judging the need to use a support bar while walking over a certain distance, overcoming obstacles, as fast as possible (Yussef & Chiviacowsky, 2018). Such findings show that granting learners decisions about the use of assistive devices benefits the learning process in different populations and contexts, from sport skills to rehabilitation settings.

Choosing Over Small Task-Irrelevant Aspects

Offering instructionally task-irrelevant choices has been observed across many domains to produce positive effects on intrinsic motivation; effects even stronger than those observed in instructionally task-relevant choices (Patall et al., 2008). Motor learning experiments have also shown that small and less-important choices can add benefits to the learning process. For instance, Lewthwaite et al. (2015) observed enhanced learning in a golf-putting task in young adults choosing between the colors of golf balls in each upcoming block of trials, relative to yoked participants. The researchers also observed learning advantages in a balance task in participants asked about their preferences regarding two aspects: a task to be performed the next day and a painting to hang on a wall, relative to participants only informed about the experimenters' decisions. Similar results were found in other experiments manipulating incidental choices, such as mat color in young adults (Wulf et al., 2018), and balls with different designs in children (Abdollahipour et al., 2017). In another experiment (Grand et al., 2017), the effects of a task-irrelevant choice (beanbag color) on adults' motor learning were not found; however, EEG measures revealed predictive positive relationships between motivation and motor performance. This suggests that some factors may attenuate the effects of task-irrelevant choices on motor learning. Examples could include experimental conditions failing to produce differences in perceptions of autonomy between groups (Grand et al., 2017), or frustrating the participants' competence (Chiviacowsky, Wulf, & Lewthwaite, 2012) and relatedness (Gonzalez & Chiviacowsky, 2018) needs, or even the use of intrinsically motivating tasks that create a ceiling motivational effect that is difficult to overcome using other motivational variables (Drews et al., 2020). Notwithstanding, the effects of choices over less task-relevant aspects on performance and learning reinforce that the underlying mechanisms of autonomy-support effects have motivational roots.

Organizing Team Tactics

Many learning contexts involve individuals collaboratively sharing the learning of a task toward a common goal, as a team. Examples of skills are the swimming relay, baton-passing in athletics, *pas de deux* (dance duet) in classical ballet, the tango or the waltz in ballroom dancing, musicians playing as a band, and even more simple tasks, such as balancing together on a seesaw. Experiments testing the effects of autonomy support on team-based motor learning are, however, still very scarce. In one experiment by Chiviacowsky et al. (2020), pairs of children collaboratively sharing the learning of a sequential motor task — speed-cup-stacking — were provided or were not provided with the freedom to organize a team tactic. Before each block of practice, every pair of participants in the autonomous condition were able to decide which participant would perform the first (up-stacking) or the second (down-stacking) phase of the task, while in the control condition the order of participants within each pair was yoked to the order of a counterpart pair from the former group. The results showed better learning for children in the autonomous condition: they needed less time to complete the task during the retention and transfer tests. The findings demonstrate that the benefits of autonomy support observed at an individual level can extend to team motor learning, and indicates the importance of extending research on autonomy support in multiple team, or other shared (e.g., Karlinsky et al., 2019), learning contexts.

Receiving Autonomous Instructional Language

Instructional messages can be communicated using language in different ways and with distinct tones of voice, supporting an individual's sense of agency or, in contrast, thwarting autonomy by its use in a more pressuring or controlling way. In three different experiments, Weinstein et al. (2020) observed that both semantics (i.e., words) and prosody (i.e., tone of voice) can independently communicate messages in controlling or in autonomy-supportive ways; that controlling tones of voice are perceived as pressuring, evoking resistant or defiant reactions; and, when used in combination (as is typical), they result in the stronger defiance. One motor learning experiment by Hooyman et al. (2014) observed the effects of different instructional language on the learning of a cricket bowling action. Groups of participants received instructions designed to provide the same technical information about how to perform the task, but it differed in terms of degree of perceived autonomy. The group instructed with autonomous-instructional messages demonstrated both higher learning and better levels of perceived choice, self-efficacy, and positive affect relative to the group where language instructions were controlled. While studies observing the impact that tone of voice has on motor learning are still lacking, the existing findings are promising – showing that the use of both autonomous language and tone of voice can be important supportive strategies to optimize motor performance and learning.

Conclusions and New Research Directions

In the present chapter, we reviewed several research lines investigating the effects of autonomy support in motor performance and learning. As observed, using autonomous language and granting individuals' decisions, ranging from simple choices such as equipment color (Lewthwaite et al., 2015) to more complex judgments such as feedback delivery (Janelle et al., 1997), task difficulty (Andrieux et al., 2012), or team tactics (Chiviacowsky et al., 2020), results in many positive outcomes in distinct tasks and populations. Examples are increased intrinsic motivation, self-efficacy, task focus, positive affect, and motor performance and learning (Chiviacowsky, 2014; Grand et al., 2015; Lemos et al., 2017). Nevertheless, research on autonomy support in the field is relatively recent and is yet to address new questions, not only looking at the generalization of findings to different populations and settings (e.g., sport, dance, physical education, music, martial arts, rehabilitation, or medical and other technical skills), but also to further explore the relation between autonomy support, motivation, and motor performance and learning.

For example, research has shown a learner's preference for feedback to confirm successful performance (Chiviacowsky & Wulf, 2002; Grand et al., 2015), and that protecting perceptions of competence is not only important but also a condition of autonomy support benefits on learning (Chiviacowsky, Wulf, & Lewthwaite, 2012). Preferences while choosing over different kinds of instructional assistance have been identified to vary across performers and to change during practice (Laughlin et al., 2015). Older adults seem to lack sufficient confidence to feel responsible for feedback delivery during the entire practice session; however, allowing these adults the autonomy to decide "if" and "when" they want to choose over feedback during practice results in higher learning (Chiviacowsky & Lessa, 2017). Choices concerning feedback benefit children's learning, but children showing a lower interest in this relevant information demonstrate inferior outcomes (Chiviacowsky, Wulf, Medeiros, Kaefer, & Wally, 2008). Such types of observations help to unravel how different variables – such as perceptions of competence, individual differences, and age, mediate or moderate autonomy support effects. How individuals perceive and deal with autonomy in different contexts, what motivates them to use the freedom as they do, and how learning conditions involving more or less intrinsically motivating tasks or success and failures, impact choices and consequent outcomes, are examples of questions deserving further research. They would not only advance knowledge on underlying mechanisms explaining autonomy-support effects, but also inform how to adapt and optimize autonomy-supportive strategies to a wide range of motor performance or learning circumstances.

Practical Recommendations

Considering the contribution to the learning of different motivational strategies supporting psychological needs (e.g., Reeve & Cheon, 2021), and that any of the strategies described in the present chapter can be easily implemented by professionals from multiple contexts teaching closed self-paced or other tasks, we list the following set of recommendations for autonomy supportive intervention in motor performance and learning:

a. Start by adopting autonomous (e.g., "you might", "you could") instead of pressuring or controlling (e.g., "you must", "you have to") language or tone of voice while communicating your planned activities.
b. When possible, ensure that different kinds or colors of equipment are available for choice.
c. Before the beginning of a session or sessions of practice, if applicable, let the performers decide a preferred order of tasks or exercises.
d. After demonstrating a new task, inform the learners that more demonstrations can be provided during practice by request.
e. After the learners have practiced for a while, acknowledge improvements with positive feedback and inform them that you can provide more feedback when needed or desired (note that learning is optimized when feedback highlights the more positive aspects).
f. Help the performers to freely adjust a preferred level of difficulty on the proposed task, granting challenges with experiences of success.
g. If the task involves the initial use of an assistive device or physical aid, ask the learners to judge when it would start to be (comfortably and safely) less needed.
h. Inform the learners that the quantity of practice is a very important factor for learning, but let them practice as much as they want and at their own pace, considering time availability and safety issues.
i. While teaching teams or individuals collaboratively learning a task, allow discussion and free exploration of different efficient tactics.
j. Lastly, make sure the practice takes place in an optimally challenging, caring, and enjoyable context. Allowing choices while using a pressuring tone of voice, or choices that exceed the learner's cognitive capacity and generate anxiety, are just a few examples of adverse concomitant practice conditions (potentially frustrating the individual's relatedness and competence needs) that would certainly undermine autonomy support benefits in learning.

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