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Self-controlled practice benefits motor learning in older adults

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ABSTRACT

Providing learners with the chance to choose over certain aspects of practice has been consistently shown to facilitate the acquisition of motor skills in several populations. However, studies investigating the effects of providing autonomy support during the learning process of older adults remain scarce. The objective of the present study was to investigate the effects of self-controlled amount of practice on the learning of a sequential motor task in older adults. Participants in the self-control group were able to choose when to stop practicing a speed cup stacking task, while the number of practice trials for a yoked group was pre-determined, mirroring the self-control group. The opportunity to choose when stop practicing facilitated motor performance and learning compared to the yoked condition. The findings suggest that letting older adult learners choose the amount of practice, supporting their autonomy needs, has a positive influence on motor learning.

1. Introduction

Autonomy is considered as a term referring to an individual's independence or freedom to determine one's own actions. According to the fundamental psychological needs framework of Deci and Ryan (2008), the satisfaction or support of autonomy, competence and social relatedness are key aspects for human psychological well-being, and for optimal functioning and learning. Indeed, the

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ability to exercise control over the environment has been considered as satisfying not only a basic psychological need (Deci & Ryan, 2000), but also a biological necessity (Leotti & Delgado, 2011; Leotti, Iyvengar, & Ochsner, 2010). Studies have demonstrating that humans (Tiger, Hanley, & Hernandez, 2006), as well as animals (Catania, 1975; Catania & Sagvolden, 1980; Voss & Homzie, 1970), prefer having the option to choose, even when having choices can result in greater work or effort, suggesting the existence of an inherent reward with the exercise of control (Leotti & Delgado, 2011). The benefits of autonomous regulation when compared to controlled regulation have been observed regarding affective experiences, persistence, quality of relationships, and general well-being, across a broad range of domains (Deci & Ryan, 2000, 2008). Individuals provided with autonomy have demonstrated superior performance and learning when compared with individuals not allowed to choose (Cordova & Lepper, 1996; Hackman & Oldham, 1976; Tafarodi, Milne, & Smith, 1999).

In the motor learning field, providing autonomy support has consistently shown to benefit young adults' learning, while controlling different kinds of variables during practice, as for example the amount of practice (Post, Fairbrother, & Barros, 2011; Post, Fairbrother, Barros, & Kulpa, 2014), the order of trials during multi-task practice (Wu & Magill, 2011), model observation (Wulf, Raupach, & Pfeiffer, 2005); task difficulty (Andrieux, Danna, & Thon, 2012), use of assistive devices (Hartman, 2007; Wulf, Clauss, Shea, & Whitacre, 2001; Wulf & Toole, 1999), and the provision of augmented feedback (Ali, Fawver, Kim, Fairbrother, & Janelle, 2012; Chiviacowsky, 2014; Chiviacowsky & Wulf, 2002; Huet, Camachon, Fernandez, Jacobs, & Montagne, 2009; Patterson & Carter, 2010). In addition, providing learners with the chance to choose over certain aspects of practice has been shown to facilitate the acquisition of motor skills in several populations, including children (Chiviacowsky, Wulf, Medeiros, Kaefer, & Tani, 2008; Ste-Marie, Vertes, Law, & Rymal, 2013), individuals presenting different levels of physical activity (Fairbrother, Laughlin, & Nguyen, 2012) or personality traits (Kaefer, Chiviacowsky, Meira, & Tani, 2014), as well as individuals with intellectual or motor disabilities (Chiviacowsky, Wulf, Lewthwaite, & Campos, 2012; Chiviacowsky, Wulf, Machado, & Rydberg, 2012).

Research investigating the effects of providing autonomy support during the learning process of older adults are, however, still scarce. In one study, the benefits of the self-controlled use of a physical assistance device while learning a balance task were found in older adults presenting Parkinson Disease (Chiviacowsky, Wulf, Lewthwaite, et al., 2012). Even so, results regarding another important variable, self-controlled feedback, were much less conclusive regarding the benefits of autonomy support for the older adult population. An experiment by Carter and Patterson (2012) suggested that the choices provided during self-controlled practice are not as beneficial for older adults as they are for younger individuals. In their experiment, while self-controlled young participants outperformed a yoked group in the learning of a discrete motor task, differences in older adults' learning were not found when comparing the same self and yoked feedback schedules conditions. In fact, age-related differences between young and older adults have been found both in terms of cognitive performance and the motor learning process. Cognitive aging has been associated with loss of memory, less control of memory retrieval processes, slower neural processing speed, and worse capacity to focus on relevant sources than younger adults (Gopie, Craik, & Hasher, 2011; Henninger, Madden, & Huettel, 2010; Ren, Wu, Chan, & Yan, 2013; Smyth & Shanks, 2011). Along the same lines, reduced motor learning rates were found with aging, in different practice contexts (Coats, Wilson, Snapp-Childs, Fath, & Bingham, 2014; Van Dijk & Hermens, 2006; Wishart, Lee, Cunningham, & Murdoch, 2002).

However, research has, as yet, failed to address the effects of providing autonomy support on the learning of older adults in other contexts of practice compared to the use of physical assistance devices or feedback schedules. Amount of practice has long been considered an important motor learning factor (Schmidt & Lee, 1988). Recently, it was demonstrated that allowing autonomy regarding amount of practice benefits young adults' learning (Post et al., 2011, 2014). In these two studies, participants who had the opportunity to control the number of trials during practice showed better performance in the learning tests than participants not allowed to choose when they would stop practice. These results indicate that identical amounts of practice may not always result in similar learning, with other factors, such as the provision of autonomy support for learners, playing important roles in the learning process. The objective of the present study was, therefore, to examine the effects of self-controlled amount of practice on the learning of a motor skill in older adults. Given the lack of studies investigating autonomy support over amount of practice in older adults, the cognitive and motor learning differences (Coats et al., 2014; Gopie et al., 2011; Henninger et al., 2010; Ren et al., 2013; Smyth & Shanks, 2011; Van Dijk & Hermens, 2006; Wishart et al., 2002) observed between young and older adults, including the effects of self-controlled practice on learning (see Carter & Patterson, 2012), and the fact that the capacity for self-directed control is widely accepted to be a predictor of outcomes over the lifespan (Boltz, Resnick, Capezuti, & Shuluk, 2014; Gibson, 1995; Smith, Thelen, Titzer, & McLin, 1999; Thelen, 1995), it was deemed important to conduct such research.

In the present experiment, two groups of participants practiced a sequential motor task (speed cup stacking). While participants of the self-controlled group (self) were able to decide when to stop practice, participants of the other group (yoked) received an externally determined (mirrored to the self-controlled group) amount of practice. Considering the advantageous effects which providing individuals with autonomy support has on learning (Deci & Ryan, 2000, 2008), and taking into account previous findings demonstrating the benefits of self-controlled amount of practice for motor learning in young adults (Post et al., 2011, 2014), it was hypothesized that older adult participants of the self group would demonstrate superior motor learning results, presenting faster task times on the speed cup-stacking task, when compared with participants in the yoked control group.

2. Methods

2.1. Participants

Thirty-six older adults (34 women and 2 men) with a mean age of 68.66 ± 6.06 years (self-control group: mean = 68.44, SD = 6.06; yoked group: mean = 68.88, SD = 6.22) participated in this experiment. Participants were recruited from a physical activity group that was part of an association of retired people in the southern Brazil. The participants were physically active and healthy, and gave their voluntary participation by an informed consent. They were not aware of the specific purpose of the study and had no prior experience with the experimental task. The study was approved by the University's institutional review board.

2.2. Apparatus and task

The task involved a speed cup-stacking task, similar to the study of Granados and Wulf (2007). Specific cups were used, with three holes in the top to allow air to escape quickly during movement. The cups were stacked upside down into each other on a table. At the beginning of each trial, the cups were positioned in front of participants with one three-cup tower on the left, one six-cup tower in the middle and one three-cup tower on the right of the participants. The task consisted of two phases: "up-stacking" and "down-stacking". The participants used both hands to build a $3 \times 6 \times 3$ cup stack (Fig. 1). In other words, they built a three-cup pyramid on their left, a six-cup pyramid in the middle and one three-cup pyramid on their right. Following this "up-stacking" phase, the participants began the "down-stacking" phase, which consisted of dismantling the pyramids and placing the cups in the original arrangement, with three towers positioned as they were at the beginning of the task. Participants were instructed to perform both stacking phases, during practice and retention, always from left to right, keeping the same order throughout the phases. They were also informed that if any error occurred while performing the task, they should fix these errors and continue until the cups are placed in the appropriate arrangements. For the transfer phase, 10 cups were positioned in front of the participants, forming only one 10-cup tower (Fig. 1). They were asked to build only one pyramid, with four, three, two and one cups, respectively, at the four different levels. They were also asked to disassemble the pyramid, forming only one tower with the cups stacked one inside the other, positioning them back in their initial places. Task times, that is, the movement times to perform each trial of the task ("up-stacking" and "down-stacking") were measured using a stopwatch.

2.3. Procedure

After completing the consent form, participants were randomly assigned to either the self-control or yoked group, and matched according to sex and age. They received general instructions regarding the

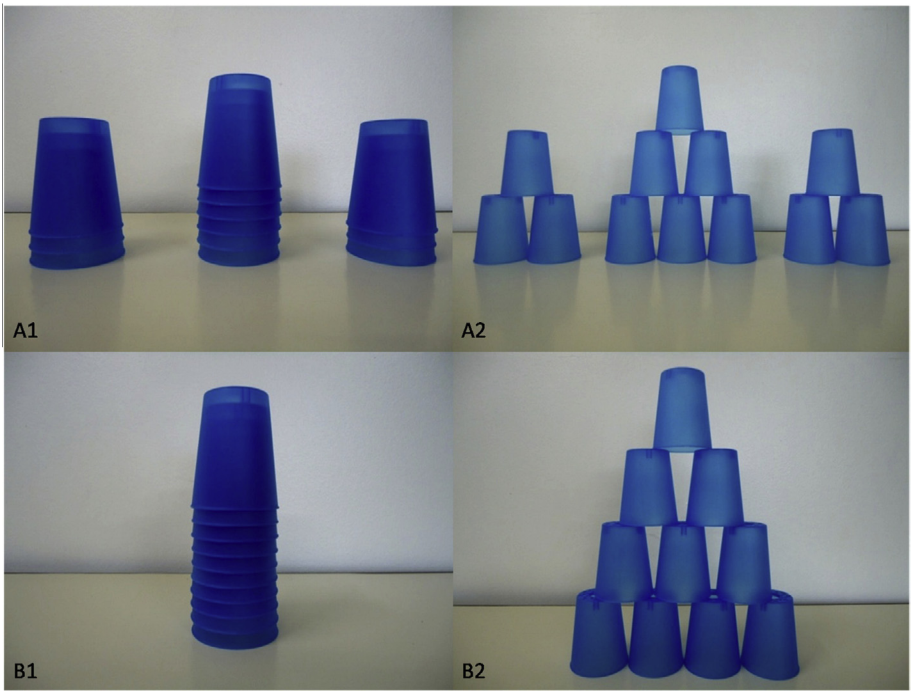

Fig. 1. Schematic of the cup set and cup stack. (A1) Cups in initial position during practice and retention. (A2) 3 × 6 × 3 pyramids in practice and retention. (B1) Cups in initial position during transfer. (B2) Ten cups pyramid in transfer.

task and observed one video demonstration of the cups up-stack and down-stack movements. They were also asked to perform the task as quickly as possible. In addition, participants from the self-control group received the instruction that they would be able to perform as many trials as they wanted during the practice phase. The yoked group participants were told that the experimenter would choose how many times the task would be performed, and that they would be told when to stop practicing. Participants in the yoked group were each yoked to a participant in the self-control group, regarding sex, age, and number of trials performed by the respective pair. In addition, the experimenter asked all participants to place both hands on a marking in front of the instrument before the beginning of each trial, returning them to the same point at the end of the trial. Task times taken to complete each trial ("up-stacking" and "down-stacking") were measured using a stopwatch. The use of a stopwatch involves measurements including the experimenter's reaction times at the beginning and end of each trial. However, it has been considered an efficient procedure in motor learning experiments with this kind of tasks, having already being used in previous studies (e.g., Granados & Wulf, 2007). Task time was counted from the moment participants' hands left the initial position; counting stopped when the hands were returned to the initial position. All participants received feedback after each trial of practice, consisting of the time taken to perform the "up-stacking" and "down-stacking" phases. Retention and transfer tests were performed 48 h after the practice phase, each consisting of five trials, without feedback. Similar to the study by Post et al. (2011), after the tests, participants from the self-controlled group were asked to report their reason why they stopped practicing. In addition, participants from both groups were asked to recall the total number of trials they completed during practice.

2.4. Data analysis

Only performance on the first and last five trials of the practice phase was analyzed, since participants from the self-control group chose different amounts of practice, similar to the studies with young adults (Post et al., 2011, 2014). Similar to the study by Granados and Wulf (2007), the number of errors of each participant during the practice phase was not examined. Task times were analyzed using a 2 (group) × 2 (practice blocks) × 5 (trials) analysis of variance (ANOVA), with repeated measures on the last two factors. Separate two-way ANOVAs 2 (group) × 5 (trials) analysis of variance (ANOVA), were used for the retention and transfer tests. In order to compare the total number of completed and recalled trials a 2 (group) × 2 (trial type) analysis of variance (ANOVA), with repeated measures on the last factor was used. Alpha was set at .05 for all analysis.

3. Results

3.1. Trials completed

The number of trials completed during the acquisition phase by each participant ranged from 10 to 21 (*M* = 13.83; SD = 3.53). A total of 28 participants (14 from the self-control group and 14 from the yoked group) completed between 10 and 15 trials; 6 participants (3 from the self-control group and 3 from the yoked group) completed between 16 and 20 trials, while 2 participants (1 from the self-control group and 1 from the yoked group) completed 21 trials.

3.2. Reasons for stopping practice

A total of 12 participants from the self-control group indicated they were satisfied with their performance (4 participants performed 15 trials, while the other 8 participants completed 10, 11, 12, 13, 17, 18, 20 and 21 trials). Two participants declared that they stopped because of tiredness (after completing 10 and 12 trials, respectively). The remaining 4 participants stopped practice because of other specific reasons: fear of worsening performance (after completing 10 trials), hurry (10 trials), personal goal achievement (15 trials), and best time performance since the beginning of practice (10 trials).

3.3. Task time

Both groups reduced their task times across trials during the blocks of practice (Fig. 2, left and middle), with the self-control group tending to demonstrate lower task times than the yoked group. Analysis of the first trial showed similarity between the groups at the beginning of practice, $F(1,34) < 1$. However, the main effects of block, $F(1,34) = 168.44$, $p < .001$, $\eta_p^2 = .83$; trial,

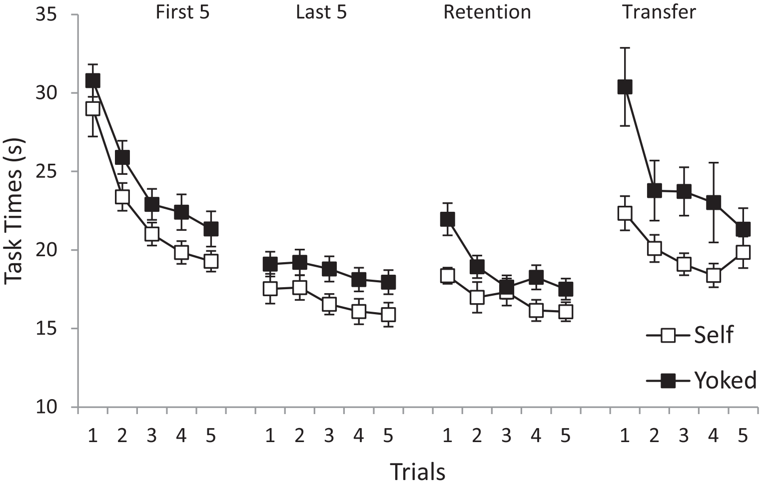

Fig. 2. Task times (s) of the self and yoked groups in practice (first and last 5 trials), retention and transfer.

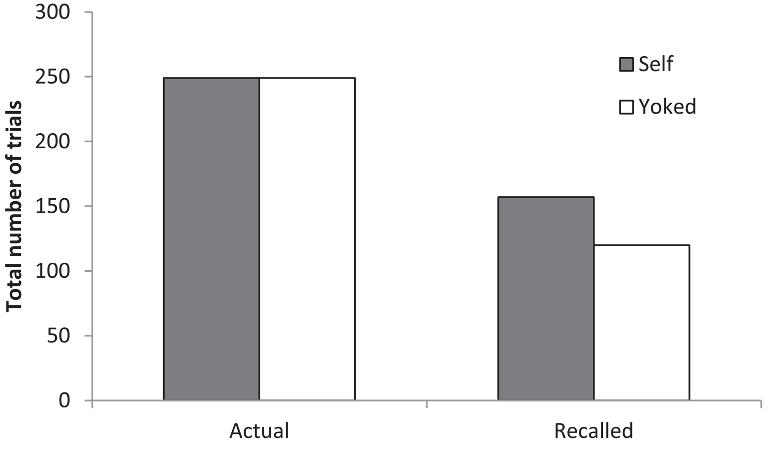

Fig. 3. Actual and recalled number of trials completed by the self and yoked groups.

$F(4,136) = 46.16$, $p < .001$, $\eta_p^2 = .57$, and group, $F(1,34) = 4.78$, $p < .05$, $\eta_p^2 = .12$, were significant. No interactions were observed between group × block, $F(1,34) < 1$; group × trial, $F(4,136) < 1$; or group × block × trial, $F(4,136) < 1$, while an interaction was found between blocks × trial $F(4,136) = 27.48$, $p < .01$, $\eta_p^2 = .45$, indicating generally greater reduction in task time in block 1, compared with block 2 of practice. In addition, in order to check inter-group variability we collapsed trials of each block to yield a single value (SD) per block for each subject. A 2 (group) × 2 (practice block) analysis of variance, with repeated measures on the last factor, showed great similarity between groups, $F(1,34) < 1$, as well as no interaction between group × block $F(1,34) = 1.04$, $p < .05$.

The analysis of the retention test revealed significant differences between groups, $F(1,34) = 4.87$, $p < .05$, $\eta_p^2 = .12$ (Fig. 2, middle), with participants of the self-control group presenting faster task times compared to yoked participants. The main effect of trial, $F(4,136) = 9.46$, $p < .01$, $\eta_p^2 = .22$, was also significant, showing performance improvement across the retention phase. No interaction was observed between group × trial, $F(4,136) = 1.91$, $p > .05$.

In the transfer test, during which the participants had to built only one pyramid with 10 cups, significant differences were also found between the self-control and yoked groups (Fig. 2, right), $F(1,34) = 5.97$, $p < .05$, $\eta_p^2 = .15$. Similar to the retention phase, the self-control group demonstrated faster task times compared to the yoked group. The main effects of trial, $F(4,136) = 8.24$, $p < .01$, $\eta_p^2 = .19$, were significant, demonstrating improvement across the transfer phase. No interaction was found regarding group × trial, $F(4,136) = 2.02$, $p > .05$.

3.4. Recall of number of trials completed

Participants from the self-control group, and consequently, from the yoked group, completed 249 total trials, with the number of each participant's trials ranging from 10 to 21 ($M = 13.83$). Both groups tended largely to underestimate the number of trials completed, with participants recalling 157 trials and 120 of the completed trials in the self-control and yoked groups respectively. Significant differences were found between trial type (actual and recalled trials), $F(1,34) = 89.70$, $p < .001$, $\eta_p^2 = .72$, but not between the groups, $F(1,34) = 1.85$, $p > .05$, or in the interaction between groups and trial type, $F(1,34) = 2.51$, $p > .05$ (see Fig. 3).

4. Discussion

The benefits of autonomy support on the learning of motor skills have been consistently shown in young adults while controlling different kinds of variables during practice (for a review see Sanli, Patterson, Bray, & Lee, 2013). Nevertheless, results of studies providing autonomy to typical older adults are less conclusive regarding its benefits for motor learning, or even inexistent regarding several motor learning factors.

The present study examined the effects of self-controlled amount of practice on older adults' motor learning. Differences in cognitive performance and motor learning were previously observed between younger and older adults (Carter & Patterson, 2012; Coats et al., 2014; Gopie et al., 2011; Ren et al., 2013). In this way, the effects of self-controlled amount of practice in older adult population remained unclear. Our results showed more effective learning of a sequential motor task, speed cup stacking, when the participants were able to choose how many trials they completed during practice, compared to the yoked control participants, who were not allowed to choose. These findings are consistent and extend recent research showing that the benefits of self-control of amount of practice for motor learning found in young adults (Post et al., 2011, 2014) can be generalized to the older adult population. Self-controlled participants in the present study not only showed better learning, but also higher performance during practice, outperforming yoked participants in both experimental phases. These findings can indicate great suitability of self-control over the amount of practice for older adults' motor learning.

Another interesting finding is that self and yoked older adult participants did not significantly differ regarding the comparison of the number of trials recalled, with both similarly underestimating the actual number of trials completed. A previous study showed significant advantages for self-controlled young adult participants compared to the yoked group in recalling the actual number of completed trials (Post et al., 2011). The authors considered more accuracy regarding the number of trials recalled as an indicator of deeper information processing during the learning process. The present study' finding relating to lack of difference between the self and yoked groups regarding trials recalled could indicate that informational reasons (deeper information processing) might not be the best explanation for the learning differences. One line of investigation in the motor learning literature points to the role of motivational factors to explain the benefits of self-controlled practice (for a review se Lewthwaite & Wulf, 2012). Autonomy supporting practice conditions have been demonstrated to result in increases in individuals' motivation and motor learning, even when the choices provided are not directly related to information about the task to be learned (Lewthwaite, Chiviacowsky, Drews, & Wulf, 2015; Wulf, Chiviacowsky, & Cardozo, 2014), as in the current study. So, motivational instead of informational reasons, could better explain the benefits of providing autonomy through self-controlled amount of practice in older adults' learning.

It is also worthy noting that 83.33% (15 subjects) of the self-controlled participants' main reasons for stopping practice in the present study (satisfaction with performance, fear of worsening performance, personal goal achievement, and best time performance since the beginning of practice) were linked with perceptions of competence, another important motivation source (Deci & Ryan, 2000, 2008). Competence, together with the needs for autonomy and social relatedness, is considered a basic psychological need (Deci & Ryan, 2000). An individual's belief, regarding her or his competence to produce a desired result, also known as self-efficacy (Bandura, 1977), has already been shown to impact performance in various domains (Bandura, 1993; Feltz, Chow, & Hepler, 2008). Previous motor learning studies have also demonstrated the importance of learners' perceived competence during self-controlled practice showing, for example, the learners' preference to ask for (self group), or receive (yoked group), feedback after good instead of after bad trials (Chiviacowsky & Wulf, 2002; Patterson & Carter, 2010; Patterson, Carter, & Sanli, 2011), and the importance of being able to confirm good performance when requesting feedback after a determined trial (Chiviacowsky & Wulf, 2005; Chiviacowsky, Wulf, & Lewthwaite, 2012). More recent findings directly suggest that the autonomy provided by self-controlled practice increases learners' perceptions of competence (Chiviacowsky, 2014; Wulf et al., 2014). Considering the different amount of practice performed by self-controlled participants in the present study (ranging from 10 to 21 trials), it is possible that their yoked counterparts, not allowed to choose regarding this aspect, were stymied in their attempts to feeling competent during practice, receiving less, or more, than optimal amounts of practice according to their needs or preferences, thus resulting in degraded learning.

In conclusion, the present study demonstrates that self-controlled amount of practice can positively impact motor learning in older adults. Learning was enhanced when learners were given control over the trials to complete, compared with participants without the chance to choose this important aspect of practice. Given the worldwide phenomenon of aging populations and the importance of regular exercise training in preventing chronic diseases associated with age-related physiological declines (Ciolac, 2013), it would be fruitful if professionals involved in contexts of teaching and learning of motor skills in older adults use such arrangements, in order to optimize their learning. The benefits of kinds of practice supporting individual's psychological needs may play an important role in promoting higher engagement in physical activity, contributing to the improvement of health and quality of life in this population. We suggest that future studies examine the effects of the provision of autonomy support, through self-controlled amount of practice, on the learning of different tasks in older adults. Moreover, the use of specific motivational questionnaires could shed further light on the reasons behind the benefits of self-controlled practice in this population.

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