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Motor learning benefits of self-controlled practice in persons with Parkinson's disease

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ABSTRACT

The present study examined the effectiveness of a training method to enhance balance in people with PD, which could potentially reduce their risk for falls. Specifically, we investigated whether the benefits of the self-controlled use of a physical assistance device for the learning of a balance task, found previously in healthy adults, would generalize to adults with PD. Twenty-eight individuals with PD were randomly assigned to one of two groups, a self-control and a yoked (control) group. The task required participants to stand on a balance platform (stabilometer), trying to keep the platform as close to horizontal as possible during each 30-s trial. In the self-control group, participants had a choice, on each of 10 practice trials, to use or not to use a balance pole. Participants in the yoked group received the same balance pole on the schedule used by their counterparts in the self-control group, but did not have a choice. Learning was assessed one day later by a retention test. The self-control group demonstrated more effective learning of the task than the yoked group. Questionnaire results indicated that self-control participants were more motivated to learn the task, were less nervous, and less concerned about their body movements relative to yoked participants. Possible reasons for the learning benefits of self-controlled practice, including a basic psychological need for autonomy, are discussed.

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1. Introduction

Parkinson's disease (PD) is a well-known progressive neurological condition that is associated with disordered motor control [1]. People with PD show atypical behaviors such as postural instability, tremor at rest, rigidity, and bradykinesia [2]. Postural instability, considered a primary risk factor for falls in persons with PD [3], is related to increased latencies in response to perturbation, ankle muscle weakness, degraded perception of stability limits and disequilibrium [4]. About two thirds of individuals with PD report falling within the past 12 months [5]. At the very least, falling can have a detrimental effect on people's confidence and, more generally, their quality of life [6]. Thus, developing training methods that effectively improve balance and have the potential to reduce the risk of falling is an important endeavor [7].

Recent intervention studies aiming at challenging impaired systems in PD have shown encouraging results [8], indicating a

potential for reversing or delaying disease progression in this population. Even though people with PD demonstrate slower learning rates than controls, their capability to learn motor skills is relatively preserved. For example, a reduction in postural instability in persons with PD was observed when they were given instructions that promoted an external focus of attention [9], similar to findings with unimpaired participants (for a review, see Wulf [10]). In another study [11], participants with PD demonstrated more effective learning of a linear-positioning task with a reduced frequency of feedback compared to those who were given feedback after every trial, similar to what previous studies have shown for adults without neurological disorders [12].

A practice method that has consistently been shown to have positive effects on the learning of motor skills in unimpaired participants is self-controlled practice. In self-controlled practice conditions, learners are given control over a certain aspect of the practice conditions. Their learning is typically compared with participants in a control condition who are yoked to each self-control participant. Studies have demonstrated more effective learning under self-controlled practice conditions, relative to yoked conditions, when participants could decide when to receive feedback about their performance [13], when to watch a video model of a skilled performer [14], or when to use a physical assistance device while learning a balance task [15,16]. For

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example, in one study [16], learning to produce slalom-type ski movements on a ski-simulator was enhanced when (unimpaired) performers were allowed to decide, before each practice trial, when to use ski poles that have been shown to facilitate learning [17]. In a subsequent study with young healthy adults, the learning of another balance task (stabilometer) was enhanced by the self-controlled use of a balance pole [15] – even though it provided no actual advantage for the learning of this task, as shown in a pilot study. This finding, in particular, underscores the powerful role of self-control in the learning process.

The potential benefits of self-controlled practice have yet to be examined in persons with PD. Given the motor impairments in this population and, more specifically, their challenged postural stability, we deemed it important to investigate whether balance learning could be facilitated by granting participants control over the use of an assistive device (i.e., balance pole), relative to not having control (yoked group). Following a practice phase under different conditions (self-control versus yoked), learning was assessed by a delayed retention test without the assistive device. In addition to examining effects on learning, we used a customized questionnaire to assess potential influences on participants' motivation, nervousness, and attentional focus as a function of practice conditions. As self-controlled practice presumably satisfies people's basic psychological need for autonomy [18], we hypothesized that participants would be more motivated to learn the task and perhaps show greater enjoyment of practicing. Also, we speculated that an increased sense of control or autonomy might reduce participants' level of anxiety and nervousness, particularly when first acquiring the skill. Finally, under the assumption that self-controlled practice would enhance the learning of the task, we assumed that performers would be less inclined to consciously control their body movements (i.e., adopting an internal focus of attention), and perhaps direct more attention to the movements of the balance platform (i.e., external focus) [10].

2. Method

2.1. Participants

Twenty-eight individuals with PD (18 men and 10 women), who were classified in Stages II and III on the Hoehn and Yahr scale [19], with an age range of 46–88 years (mean age of the self-control group: 67.92; yoked group: 66.57) participated in the study. During the experiment, participants were medicated for PD according to their own optimized schedule. Table 1 shows the participants' characteristics. The study was approved by the university's ethics committee, and informed consent was obtained from the participants. They were naïve as to the purpose of the experiment, and the task was unfamiliar to them.

2.2. Apparatus and task

The apparatus and task were similar to those used in previous studies [7,15]. Participants were asked to balance on a stabilometer. The apparatus consisted of a 130 cm × 140 cm wooden platform, with a maximum deviation of 18° to either side. The participant's task was to try to keep the platform in a horizontal position, or as close to horizontal as possible, during each 30-s trial. Above the stabilometer, a safety harness was suspended from the ceiling. Participants wore the harness to prevent them from falling in case they lost their balance. A millisecond timer measured time in balance (i.e., platform position within 5° from horizontal). A balance pole, 180 cm in length and 450 g in weight, was used as a physical assistive device (that was provided at participants' request in the self-control condition, or on matching trials in the yoked control condition).

2.3. Procedure

Participants were quasi-randomly assigned to either the self-control or the yoked group. More specifically, they were assigned to groups based on gender (five women in each group), and clinical stage (six Hoehn and Yahr Stage II, and eight Stage III participants per group). Participants were informed that the goal of the task was to keep the platform horizontal and that they would be given feedback about their time in balance (within ±5°) after each practice trial. Furthermore, all participants were told that using the balance pole typically facilitated the performance and learning of this task, and that they would be asked to perform the task without the pole on the following day. Participants in the self-control group were informed that they could request the pole on any trial during the practice phase. Participants in the yoked group were provided the pole on the same trials as their counterparts in the self-control group. They were told that they would sometimes be able to practice with the pole and sometimes they would not. Thus, the frequency and timing of the use of the assistive device (balance pole) were identical for the self-control and yoked groups,

Table 1
Participants' characteristics and medications.

Patients	Age (years)	Gender	Hoehn and Yahr stage	Disease duration (years)	Predominant symptoms	Medications
Self-control group						
1	65	F	2	5	T,	SL
2	68	M	2	3	T, B, R	P
3	77	M	3	5	B	P, M, S
4	51	M	3	6	T, B	P, S
5	55	F	2	4	B, R	P, M, S
6	68	M	3	10	T, B	P, M, S
7	65	M	3	5	B	P
8	75	F	2	2	T	P
9	75	M	2	4	B	P
10	68	F	3	7	T, B	P, M
11	69	M	3	5	R	P, S
12	75	M	2	4	B	P
13	65	F	3	4	T, B	P, M
14	75	M	3	6	T, B, R	P, M, CL
Yoked group						
15	67	M	3	4	T, R	CL
16	75	M	3	4	R	CL, M
17	46	F	3	10	T, R	P, M
18	73	M	2	4	T, R	P, S
19	74	M	2	2	T, R	P, S
20	58	F	3	1	T	CL, M
21	54	M	2	5	T, B, R	CL, S
22	71	F	3	6	B, R	P, M
23	51	M	3	13	B, R	P, A
24	88	F	3	8	T, B, R	P, S, M
25	75	M	2	1	T	M, CL
26	75	M	3	5	T, B	P
27	66	M	2	4	T, B, R	P, M
28	59	F	2	4	T, B	CL

Abbreviations: T, resting tremor; R, rigidity; B, bradykinesia; P, prolopa; M, mantidan; S, sifrol; CL, carbidopa + levodopa; A, artani.

Table 2

Results of the questionnaires completed at the end of each day (means and standard deviations). Responses for each question ranged from 1 ("not at all") to 10 ("very"). Significant group differences on each day are indicated by *. A marginally significant difference ($p = .08$) is indicated by (*).

Questions	Self-control		Yoked	
	Day 1	Day 2	Day 1	Day 2
Motivation				
How motivated were you to learn this task?	8.5 (0.85)*	9.1 (0.91)	7.6 (1.33)*	8.9 (0.91)
How much did you enjoy practicing this task?	8.4 (1.39)	8.9 (1.38)	8.5 (1.60)	9.1 (0.86)
Nervousness				
How nervous were you before the start of each trial?	0.9 (1.77)*	1.1 (1.95) (*)	3.6 (3.10)*	3.1 (3.65) (*)
How nervous were you while balancing on the platform?	1.9 (2.81)	0.8 (1.74)*	2.9 (2.89)	3.6 (2.95)*
Attentional focus				
How concerned were you about the position of your body (feet, knees, hip, head)	5.5 (3.47)	3.7 (3.49)*	6.1 (2.34)	6.3 (2.40)*
How concerned were you about the position of the platform	5.8 (3.27)	4.1 (3.82)	5.4 (2.92)	5.6 (2.02)

with the only difference between conditions being participants' freedom of choice (or not).

Each of the 10 trials in the practice phase had a duration of 30 s, with a 90-s rest interval between trials. Feedback about time in balance (in seconds) was provided after each practice trial. A retention test with no feedback or pole use was conducted 24 h later to assess learning effects as a function of practice conditions. It consisted of five 30-s trials with 90-s breaks between trials. All participants completed a customized questionnaire (see Table 2) at the end of practice on Day 1 and after the retention test on Day 2.

2.4. Data analysis

Time in balance for the practice phase was analyzed in a 2 (groups) × 10 (trials) analysis of variance (ANOVA) with repeated measures on the last factor. The retention data were analyzed in a 2 (groups) × 5 (trials) repeated-measures ANOVA. To determine whether using the balance pole had an influence on performance, time in balance was averaged across practice trial with and without the pole and analyzed in a 2 (groups) × trial type (pole, no pole) ANOVA with repeated measures on the last factor. Separate one-way ANOVAs were used to analyze the questionnaire responses.

3. Results

3.1. Balance

3.1.1. Practice phase

Participants in the self-control group asked for the balance pole on 41% of the trials, on average, ranging from 30% to 70% (SD: 13.5%). Across practice, pole use remained relatively constant, but was somewhat lower at the beginning and end of the practice phase. More specifically, on Trials 1–10 the pole was used by 14%, 36%, 50%, 50%, 50%, 43%, 50%, 43%, 50%, and 29% of participants, respectively. Both groups increased their time in balance across practice trials, with the self-control group tending to remain in balance longer than the yoked group (see Fig. 1, left). The main effects of trial, $F(9, 234) = 16.11, p < .001, \eta^2 = .39$, was significant. The main effect of group, $F(1, 26) = 2.21, p = .15$, and the interaction of group and trial, $F(9, 234) = 1.07, p > .05$, were not significant.

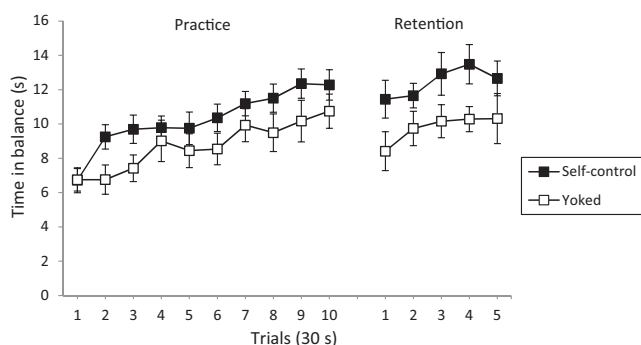


Fig. 1. Time in balance for the self-control and yoked groups during practice and retention.

Time in balance was significantly different for trials with pole use versus without pole use, $F(1, 26) = 4.36, p < .05, \eta^2 = .14$. The average time in balance for trials with versus without pole was 10.23 versus 9.86 s for the self-control group, and 9.23 versus 8.46 s for the yoked group, respectively. There was no interaction of group and trial type, $F(1, 26) < 1$, or difference between groups, $F(1, 26) = 1.47, p > .05$. Thus, the balance performance was enhanced on trials on which the pole was used.

3.1.2. Retention phase

Both groups continued to increase their time in balance across retention trials (see Fig. 1, right). The self-control group was overall more effective than the yoked group. Time in balance was significantly longer for the self-control group, $F(1, 26) = 4.25, p < .05, \eta^2 = .14$. The main effect of trial was also significant, $F(4, 104) = 3.07, p < .05, \eta^2 = .11$. There was no interaction of group and trial, $F(4, 104) < 1$. Thus, the participant's opportunity to control the use of the balance pole resulted in more effective learning than the externally controlled use of the assistive device.

3.2. Questionnaire results

After the practice phase on Day 1, the groups differed in terms of how motivated they were to learn the task, with the self-control participants rating their motivation significantly higher, $F(1, 27) = 4.81, p < .05, \eta^2 = .16$ (see Table 2). Group differences in questionnaire responses were not significant on Day 2 following the retention phase (i.e., when the self-control manipulation was removed), $F(1, 27) < 1$. Both groups seemed to enjoy practicing the task, and there were no significant group differences on either Day 1 or 2, $F_s(1, 27) < 1$. Self-control participants were also less nervous before the beginning of a trial on Day 1, compared with the yoked group participants. The group difference was significant, with $F(1, 27) = 8.07, p < .01, \eta^2 = 0.24$. The groups did not differ significantly on Day 2, $F(1, 27) = 3.26, p > .05$. There were no significant group differences in nervousness while balancing on either Day 1, $F(1, 27) < 1$, but significant differences were found on Day 2, $F(1, 27) = 9.23, p < .01, \eta^2 = .26$. Finally, even though there were no group differences in terms of body-position related concerns on Day 1, $F(1, 27) < 1$, the self-control group participants indicated less concern on Day 2, $F(1, 27) = 5.43, p < .05, \eta^2 = .17$. Even though the self-control group appeared to pay somewhat more attention to the position of the platform, the group differences were not significant on Day 1, $F(1, 27) < 1$, or Day 2, $F(1, 27) = 1.68, p > .05$.

4. Discussion

Participants with PD showed more effective learning of a challenging balance task when they were able to control the use of an ostensibly helpful assistive device (balance pole) compared

with yoked control participants. This result is in line with the findings of previous studies with healthy participants [15,16]. Participants in the present study chose to use the balance pole on 41% of the practice trials. This is similar to the frequency found by Hartman (2007) (i.e., 38%) in his study with unimpaired young adults [15]. The learning advantage of self-controlled practice was associated with participants' increased motivation to learn the task, reduced nervousness, and less concern about body movements (see below).

It is interesting that, in contrast to Hartman's [15] pilot study, in which the pole did not aid balance learning, participants in the present study generally showed improved balance performance on trials on which they used the pole (both groups). We suspect that this discrepancy is the result of a placebo effect. Participants were told that the pole facilitated learning of the task (in order to motivate them to make use of it). It is well known that persons with PD are particularly susceptible to placebos, presumably due to the mediating effects of dopamine release in the striatum [20].

Importantly, the self-controlled use of the balance pole clearly enhanced balance learning. In fact, the retention performance of the self-control group was at the same level as that of unimpaired (control) participants of the same age in another recent study [21]. Several accounts have been put forward to explain the learning benefits of self-controlled learning. For example, it has been suggested that self-control promotes deeper processing of relevant information, makes performers take charge of their own learning process, might be more tailored to the learners' specific needs, or facilitates learners' testing of different movement strategies [22]. It is also possible that yoked participants had difficulty responding to a change in context, or were stymied in their attempts to try new strategies given the seemingly random presentation of the pole. The role of another factor – autonomy – has been largely neglected in the motor learning literature. Autonomy is considered to be a fundamental psychological need, and its satisfaction is critical for optimal functioning and psychological well-being [18]. The importance of autonomy has been demonstrated in studies showing increases in intrinsic motivation, perceived competence, depth of engagement in learning and amount learned in a fixed time period as a result of practice with higher levels of autonomy [23]. With respect to health-related behavior, granting patients autonomy regarding medication use and diabetes self-management, for example, has been found to be related to increased medication adherence, physiological outcome measures, as well as quality of life [24]. Also, an autonomy-supportive intervention has been shown to facilitate long-term tobacco abstinence [25]. Situations that provide autonomy are generally assumed to lead to more effective outcomes because they increase individuals' intrinsic motivation [18].

Motivation can be diversely disordered in individuals with PD with symptoms ranging from apathy [26] to addictive behavior [27]. The questionnaire results of the present study support the notion that self-controlled practice increased participants' intrinsic motivation. In fact, recent studies have shown links between motivation and motor learning [28]. The present findings add to the converging evidence that motivation has a direct influence on the learning of motor skills. The mechanism of this motor learning effect may involve the same dopamine system affected in PD [29].

It is also interesting to note that self-control participants were less nervous before a trial than yoked participants, particularly during practice, and while balancing on the retention test. Having the opportunity to choose the "physical assistance" device whenever they felt they needed it, may have alleviated possible concerns related to their ability and task performance. Nervousness, or anxiety, is known to have detrimental effects on motor performance [30] and has been shown to affect balance in people with PD in the same way as healthy individuals [31]. Thus, having

control over the use of an assistive device may have indirectly benefited learning by reducing performers' anxiety.

Finally, self-control participants reported less concern regarding their body position than did yoked participants. Numerous studies have shown that attention directed at one's body movements (a so-called internal focus) is detrimental to motor performance and learning [10]. Yet, unless given instructions that prevent an internal focus (i.e., those that induce an external focus on the movement outcome, such as the platform movements), motor learners typically tend to focus on their movements. In contrast, skilled performers pay less attention to the execution of their movements [32]. Thus, the fact that self-control participants, in contrast to their yoked counterparts, indicated directing less attention to their body movements on Day 2 is in line with their enhanced performance and presumably increased sense of mastery of the task.

The present results demonstrate that self-controlled practice has positive effects on motor learning in people with PD. These findings have important implications for applied settings, such as physical activity classes or physical therapy. The control of practice conditions, including the use of physical assistive devices, is typically seen as the prerogative of instructors or clinicians, while patients normally assume a relatively passive role [22]. The present results demonstrate motor performance and learning can be effectively facilitated by relinquishing some of that control, and respecting people's need for autonomy – independent of whether or not they have certain impairments.

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Conflict of interest statement

None of the authors has any conflict of interest.

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