**All's well that ends well: an early-phase study testing lower end-session exercise
intensity to promote physical activity in patients with Parkinson's disease**

Running head: PHYSICAL ACTIVITY AND EFFORT INTENSITY

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Declaration of Competing Interest

The authors declare no conflict of interests.

Consent to participate

All the participants agreed to participate and signed a written informed consent.

Consent for publication

All the authors listed in the by-line have agreed to the by-line order and to the submission of the manuscript in this form.

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45 Data availability statement

46 The data that support the findings of this study are available at

47 <https://zenodo.org/deposit/4742001>

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Abstract

Decreasing the intensity of exercise at the end of a session has been associated with greater post-exercise pleasure and enjoyment. Here, we investigated whether this manipulation can enhance affective attitudes toward physical activity (PA) and promotes PA in patients with Parkinson's disease (PD). Seven patients (72.9 ± 5.6 years, 3 women) were included in an eight-week within-subject study consisting of weekly exercise sessions. The first four weeks were used as a control condition. In the last four weeks, ten minutes of lower-intensity exercise were added at the end of each session (experimental condition). Results of the linear mixed-effects models showed that the addition of lower-intensity exercise increased the explicit affective attitudes toward PA ($b = 1.00$, 95% Confidence Interval = .36 to 1.64, $p = .022$). We found no evidence of an effect on implicit affective attitudes ($p = .564$), accelerometer-based PA ($p = .417$) and self-reported PA ($p = .122$) measures of PA. Although not significant, self-reported physical activity per day was 36 minutes longer in the intervention than in the control condition. These findings suggest that consistently reducing the intensity of an exercise at the end of the sessions enhances explicit affective attitudes toward PA in patients with PD.

Keywords: Parkinson's disease, Physical activity, Effort; Affects, Peak-end rule

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Highlights

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- A free and easily-implemented intervention could improve explicit affective attitudes toward physical activity in patients with Parkinson's disease.

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- We found no statistical evidence of an effect of lower end-session exercise intensity on implicit attitudes toward physical activity or on the engagement in physical activity.

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- Although not significant, physical activity per day was 36 minutes longer in the intervention than in the control condition.

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1. Introduction

Parkinson disease (PD) is the second most common neurodegenerative disorder worldwide affecting 2-3% of the population aged 65 years or older (Connolly and Lang, 2014; Poewe et al., 2017). This chronic disorder is characterized by motor and non-motor symptoms including tremor, rigidity, slowness of movement, cognitive impairment, mood and affective disorders, as well as depressive symptoms (Chaudhuri et al., 2006; Obeso et al., 2017). Accumulating evidence suggests that patients with PD can benefit from physical activity (PA) (Chen et al., 2005; Speelman et al., 2011). For example, PA can improve motor performance (Goodwin et al., 2008), cognitive function (Murray et al., 2014), quality of life (van Uem et al., 2018), and depressive symptoms (van Uem et al., 2018). Despite such benefits, many patients with PD do not engage in the recommended levels of PA and are typically less active than the general population (Cavanaugh et al., 2015; Pradhan and Kelly, 2019). Developing interventions promoting PA in this population is thus warranted.

1.1. The theory of effort minimization in PA

Interventions promoting PA in patients with PD are mostly grounded in the dominant socio-cognitive theories (Krishnamurthi et al., 2020), which contend that goals are proximal determinants of behaviors (Bandura, 1997; Carver and Scheier, 1998). From this perspective, changing conscious goals can lead to substantial changes in behavior (Brand and Cheval, 2019; Sheeran et al., 2013). Although interventions focusing on conscious goals have proven to be effective to change PA behavior (Hillsdon et al., 2005), meta-analyses also indicate that these interventions are more effective in changing intentions than actual behavior (Rhodes et al., 2020). An automatic attraction toward effort minimization has recently been proposed to

account for the difficulties of the dominant socio-cognitive theories to explain failures in turning intentions to be physically active into behavior (Cheval and Boisgontier, 2021).

Based on a neuropsychological approach to physical effort (Bernacer et al., 2019; Klein-Flügge et al., 2016) anchored in an evolutionary perspective (Cheval et al., 2018a; Lieberman, 2015), the theory of effort minimization in PA (TEMPA; Cheval and Boisgontier, 2021) argues that humans have evolved an automatic attraction toward physical effort minimization, which restrains the engagement in physical activity. In line with TEMPA, results suggested that avoiding stimuli related to effort minimization requires higher inhibitory control than approaching these stimuli (Cheval et al., 2021; Cheval et al., 2020; Cheval et al., 2018b). Other results showed that the ability to overcome the automatic attraction to effort minimization is essential to the engagement in PA (Bernacer et al., 2019; Cheval et al., 2015; Cheval et al., 2018b).

In line with the dual-processes models of PA (Brand and Ekkekakis, 2018; Cheval et al., 2018a; Conroy and Berry, 2017), TEMPA argues that the affective evaluation of PA is instrumental to the regulation of this behavior. Specifically, positive affective evaluations (e.g., pleasure) experienced during PA are believed to favor initiation and continuation of PA behaviors. Conversely, negative affective evaluations (e.g., displeasure) experienced during PA are believed to hinder initiation and continuation of PA behaviors. In line with these theories, studies showed that affective responses to exercise predict future engagement in PA (Rhodes et al., 2019; Williams and Bohlen, 2019).

According to TEMPA, the lack of engagement in PA results from an inability to overcome the perception of physical effort, an inability that might be particularly pronounced among patients with PD. For example, behavioral apathy, which is often observed in patients with PD, may reflect an inability to accurately perceive physical effort or an altered sensitivity to this effort (Bonnelle et al., 2016). TEMPA posits that the affective value of PA moderates the

perception of effort. Higher positive affective evaluations may reduce the perception of effort associated to a given behavior and, in turn, favor the initiation and continuation of PA behavior. In sum, developing positive affective evaluation of PA through the reduction of the perception of effort may promote PA (Cheval and Boisgontier, 2021).

1.2. The peak-end rule in exercise

Interventions that manipulate the affective evaluation of exercise to promote PA are rare (Conroy and Kim, 2020; Williams et al., 2019), but recent studies have developed such interventions drawing on the peak-end rule (Hargreaves and Stych, 2013; Hutchinson et al., 2020; Zenko et al., 2016). This rule is based on two mechanisms underlying the affective evaluation of physical activity. The first mechanism refers to the link between effort intensity and affective evaluation. Higher intensity (i.e., above the ventilatory threshold) reduces pleasure and increases displeasure (Ekkekakis et al., 2011). The second mechanism postulates that the global evaluation of an experience mainly depends on the affects experienced during the most intense affective moment of the experience (i.e., “peak”) and at the end of the experience (i.e., “end”) (Fredrickson, 2000; Kahneman et al., 1993). Combining these two mechanisms, studies have investigated how the dynamic of effort intensity during an exercise session impacts the global affective evaluation of the session. The hypothesis is that lower effort intensity at the end of the session results in a more positive affective remembered experience, which favors a more positive global affective evaluation of the session (i.e., generalization of a specific experience to PA in general).

To the best of our knowledge, only two studies have directly manipulated the dynamics of effort intensity during exercise (Hutchinson et al., 2020; Zenko et al., 2016). In these studies, healthy adults were randomly assigned to perform a 15-min exercise session on a recumbent bike (Zenko et al., 2016) or a resistance training (Hutchinson et al., 2020) in an increasing or decreasing-intensity condition. Results showed that the decreasing-intensity condition was

associated with greater post-exercise pleasure, enjoyment, remembered pleasure (i.e., affective memories of the session), and forecasted pleasure (i.e., anticipation of the affect in a future session). In sum, these studies showed that manipulating the dynamic of effort intensity influences the affective evaluation of an exercise session. Yet, these studies focused on the affective evaluation of a single exercise session rather than toward PA in general and did not measure subsequent PA. Accordingly, whether the manipulation of effort can generalize to the affective evaluation of PA and impact subsequent PA behavior remain unknown. Finally, these studies did not examine whether the effect could be observed at the implicit level.

The aim of the present study was to assess whether manipulating the intensity of effort at the end exercise sessions of an intervention enhances affective evaluation of PA and promotes daily-life PA behaviors in patients with PD. Based on TEMPA (Cheval and Boisgontier, 2021) and on the peak-end rule (Fredrickson, 2000; Kahneman et al., 1993), we hypothesized that four weekly sessions ending with a 10-min bout of light-intensity exercise would result in more positive explicit and implicit affective evaluations of PA compared with four sessions without the final 10-min bout (H1). We also hypothesized that self-reported and accelerometer-based daily-life PA would be higher during the four weeks with than without the final 10-min light-intensity bout (H2).

2. Methods

Study preregistration, material, and data can be found at <https://zenodo.org/deposit/4742001>

2.1. Participants

Participants were recruited through the exercise program of a Swiss private clinic in January 2021. To be included in the study, participants should be 18 years of age or older, clinically diagnosed with PD, and able to give informed consent. Participants were excluded if they had contraindications to PA, dementia (Mini Mental State Examination score ≤ 24 ; (Folstein et al.,

1975) or motor dependence (stage 5 on the Hoehn and Yahr scale; (Hoehn and Yahr, 1998).
Given the small number of patients in the department, we initially aimed to recruit as many
patients as possible (i.e., $N = 20$) (Figure 1). As such, the sample size was limited by resources
constraints (Lakens, 2021).

2.2. Procedure

In a within-subjects design, participants were first invited to a clinical visit to provide
written informed consent and filled in a questionnaire about their age, sex, height, and weight,
motivation toward PA (i.e., intention, attitudes, and self-efficacy), and usual physical activity.
They also performed a task measuring implicit affective attitudes toward PA (Rebar et al.,
2015). Participants then completed a four-week exercise program (i.e., control condition) and
four additional weeks in which a ten-min exercise bout of light intensity was added (i.e.,
experimental condition). Implicit and explicit affective attitudes were assessed at baseline, at
the end of the control condition, and at the end of the experimental condition. Self-reported and
accelerometer-based measures of PA were performed on a daily-basis across the eight weeks.

2.3. Exercise sessions

Each exercise session started with a 15-min warm-up period including light-intensity
exercises mobilizing articulations, cardiovascular and muscular systems, gait, and balance.
Then, three 10-min bouts of circuit training were performed. Each round was composed of six
1-min bouts of exercise followed by a 30-sec rest period. The circuit included muscle,
cardiovascular and balance work at a moderate intensity. Participants were asked to rate their
effort on a visual analog scale (CR10 scale; Borg, 1998) twice during each 10-min bout (see
Table S1 for more details) and to maintain it between 3 (moderate) and 5 (strong) out of 10.
During the last 4 weeks of the 8-weeks program, a ten-min exercise bout was added. In this
fourth 10-min bout, participants were asked to perform the exercises at an intensity between 1
(very weak) and 2 (weak) out of 10.

2.4. Measures

2.4.1. Usual PA

Usual physical activity was assessed at baseline using an adapted version of the “Saltin-Grimby PA level scale” (Grimby et al., 2015): “Before the onset of PD, how much did you move and exert yourself physically during leisure time? If your activity varied greatly between, for example, the summer and winter, try to estimate an average”. Respondents could choose between four options used to create four self-reported PA groups: (1) physically inactive; (2) light PA; (3) regular PA and physical training; and (4) regular hard physical training for competition and sports.

2.4.2. Affective attitudes toward PA

These variables were assessed at baseline, at the end of the control condition (i.e., four weeks after the start of the study), and at the end of the experimental condition (i.e., eight weeks after the start of the study).

Affective attitudes toward PA were assessed using two items (Rhodes and Courneya, 2003). The stem prior to each item was “Would you say that being physically activity is something ...”. Participants answered on a seven-point bipolar scale from 1 (*unpleasant*) to 7 (*pleasant*) and from 1 (*boring*) to 7 (*fun*). Items were averaged to create an overall measure of affective attitudes toward PA (correlation between items = .93, .73, and .88 at baseline, at the end of the control condition, and at the end of the experimental condition, respectively).

Implicit attitudes toward PA were assessed using an Implicit Association Test (Greenwald et al., 1998), a response-time categorization task that assesses the relative strength of automatic affective associations between PA and sedentary behavior (see Supplemental Material 1 for more details). For each participant, a D-score was calculated on -2 to +2 range to assess negative or positive implicit attitudes toward PA (vs. sedentary behaviors).

2.4.3. PA behavior

These variables were assessed daily across the eight weeks.

Self-reported PA. Self-reported PA during commuting and leisure time was assessed using an adapted version the International PA Questionnaire (IPAQ; Craig et al., 2003). Each week, participants received a notebook and were invited to provide a daily report of the time spent in moderate-to-vigorous PA, walking, and sitting. The time spent in walking and moderate-to-vigorous PA was used as an outcome.

Accelerometer-based measure of PA. Following recommendations in patients with PD (Mantri et al., 2019), a three-axis accelerometer (Actigraph GT3X+; Pensacola, USA) was used to assess PA. Participants were given the accelerometer and related indications on the first exercise session. They were asked to return the accelerometer on the next exercise session, one week later. At the end of each exercise session, participants were given a new accelerometer. One-minute epochs were used for data analyses and non-wear time was defined as ≥ 59 consecutive minutes of zero counts. Daily data were included if the wear time was ≥ 10 waking hours per day (Evanson and Terry, 2009). Data were included if ≥ 4 days met the aforementioned conditions (Matthews et al., 2002). The time spent in moderate-to-vigorous PA determined through previously validated cut-points (Freedson et al., 1998) in bouts lasting at least 10 min was used as an outcome.

2.4.4. Other measures

Additional measures are described in Supplemental Material 2.

2.5. Statistical analyses

To examine the effect of the intervention (i.e., control vs. experimental condition) on the affective evaluation of PA and daily-life physical activity, linear mixed-effects models (MEMs) were used. MEMs are well-suited to investigate longitudinal data as they allow to handle missing data and to account for the nested structure of the data (i.e., multiple observations from the same individuals over time). Moreover, statistical assumptions associated

with MEM can be met even in small data paradigm (Baayen et al., 2008; Boisgontier and Cheval, 2016). Restricted maximum likelihood (REML) was used as it provides less biased estimates of variance components compared with full maximum likelihood (Luke, 2017) particularly in small sample size (McNeish and Stapleton, 2016). Finally, to reduce the inflated type-I error rate that results from underestimated fixed-effects standard errors in small sample size (McNeish and Stapleton, 2016), Kenward-Roger's approximations for degrees of freedom were used to calculate p -values (Kenward and Roger, 1997). An estimate of the effect size was reported using the marginal pseudo R^2 computed using the MuMIn package (Barton, 2018). Statistical assumptions associated with MEM (normality of the residuals, homogeneity of variance, linearity, multicollinearity, and undue influence) were checked and met for all models. The analyses were conducted in R with the lme4 and lmerTest packages (R core team 2019; Bates et al., 2014; Kuznetsova et al., 2015). To reduce convergence issues, each model was first optimized using the default BOBYQA optimizer (Powell, 2009), followed by the Nelder-Mead optimizer (Nelder and Mead, 1965), the nlmb optimizer from the optimx package (Nash and Varadhan, 2011), and then the L-BFGS-B optimizer (see Cheval et al., 2021; Cheval et al., 2020; Frossard and Renaud, 2019, for similar procedure).

To examine the evolution of affective explicit and implicit attitudes as a function of condition, we used a linear MEM that included condition (baseline vs. control vs. experimental conditions) as a fixed factor. The MEM specified participants as a random factor and included random effects for the conditions. The models were adjusted for usual physical activity but not for age, sex, or body mass index because of the low number of participants.

To examine the evolution of self-reported and accelerometer-based measures of PA as a function of condition, we used a linear MEM that included the condition (i.e., control condition vs. experimental conditions) as a fixed factor and specified the same random structure as the one for the models testing the evolution of affective attitudes. The models were adjusted

for usual PA and for the day of the week (i.e., Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, Sunday).

3. Results

After the descriptive statistics, the results are reported in two sections: the first describes results of analyses on explicit and implicit affective attitudes, and the second describes results of analyses on self-reported and accelerometer-based measures of physical activity. The effect of the intervention on the evaluation of the exercise sessions are presented in Supplemental material 3.

3.1. Descriptive statistics

Table 1 summarizes the characteristics of the participants stratified by condition (i.e., baseline vs. control vs. experimental). The final sample included 7 patients with PD (72.9 ± 5.6 years, 3 women, 22.8 ± 2.9 body mass index) (Figure 1). Most patients did regular PA before the onset of their disease (two participants were in the stage 3 “*regular PA*” and five were in the stage 2 “*some PA*” of the Saltin-Grimby questionnaire). Descriptive statistics stratified by week are provided in Supplemental Table S2.

3.2. Effect of the intervention on the affective attitudes toward physical activity

3.2.1. Explicit attitudes

Explicit affective attitudes toward PA were significantly more positive after the four weeks of the experimental condition than after the four weeks of the control conditions ($b = 1.00$, 95% Confidence Interval [95%CI] = .36 to 1.64, $p = .022$). No significant difference was observed between baseline and the control ($b = .64$, 95%CI = -0.15 to 1.43, $p = .163$) or experimental condition ($b = .36$, 95%CI = -0.10 to .82, $p = .182$). The variables under consideration explained 36.6% of the variance in the explicit affective attitudes toward PA (Table 2). As illustrated in Figure 2A, the evolution of the explicit attitudes seems to follow a quadratic pattern in which these attitudes first decreased from baseline to the end of the control

condition and increased from the end of control condition to the end of the experimental condition. To formally test this evolution, an additional model using polynomial contrasts was conducted. This model included a linear (-1 for baseline, 0 for the control condition, and +1 for the experimental condition) and a quadratic (1 for baseline, -2 for the control condition, and +1 for the experimental condition) orthogonal contrasts. Results revealed a significant effect of the quadratic contrast only ($p = .014$). In other words, this model confirms that explicit affective attitudes followed the aforementioned quadratic pattern.

3.2.2. *Implicit attitudes*

No significant difference in implicit affective attitudes was observed between the control condition and baseline ($b = -.16$, 95%CI = $-.33$ to $.01$, $p = .163$), between the control condition and the experimental condition ($b = .19$, 95%CI = $-.41$ to $.79$, $p = .564$), or between baseline and the experimental condition ($b = .37$, 95%CI = $-.20$ to $.96$, $p = .272$) (Table 2; Figure 2B). A model testing the pattern of evolution of the implicit attitudes using the aforementioned polynomial contrasts showed that neither the linear ($p = .366$) nor the quadratic ($p = .747$) contrasts were significant, thereby confirming that attitudes did not significantly change as a function of condition.

3.3. Effect of the intervention on daily-life physical activity

3.3.1. *Self-reported measure*

No significant difference PA was observed in self-reported moderate-to-vigorous between the four weeks of the control condition and the four weeks of the experimental condition ($b = 36.6$ min per day, 95%CI = -3.2 to 76.2 ; $p = .122$) (Table 3; Figure 3A).

3.3.2. *Accelerometer-based measure*

No significant differences were observed in accelerometer-based moderate-to-vigorous PA between the four weeks of the control condition and the four weeks of the experimental condition ($b = 2.3$ min per day, 95%CI = -2.6 to 7.11 , $p = .417$). Participants who usually

performed some PA before the onset of PD exhibited a lower level of accelerometer-based moderate-to-vigorous PA compared with participants who usually performed regular PA ($b = -31.9$ min per day, 95%CI = -47.6 to -16.3, $p = .028$) (Table 3; Figure 3B).

4. Discussion

4.1. Main findings

The present study investigated whether manipulating the intensity of the effort at the end of an exercise session enhances affective attitudes toward PA and promotes daily-life PA behaviors in patients with PD. The findings revealed that adding a 10-min period of lower physical effort intensity at the end of a weekly exercise session over four weeks improved explicit affective attitudes toward physical activity. It is worth noting that, all other things being equal, the experimental condition is more demanding than the control condition both in term of time duration and total effort to be invested. Consequently, the observation that the experimental condition improves the affective attitudes is consistent with the notion that humans have a bounded rationality (Simon, 1990) and use affective heuristics (or biases) to evaluate a given experience (Finucane et al., 2000). No significant effects of the intervention were found on the other outcomes (i.e., implicit attitudes and physical activity), although results are in the expected direction for self-reported physical activity (see below).

4.2. Comparison with other studies

Our results are in line with previous studies testing the peak-end rules hypothesis in PA (Hargreaves and Stych, 2013; Hutchinson et al., 2020; Zenko et al., 2016). However, whereas prior studies examined the effect on the affective evaluation of a single exercise session, the present study assessed the effect on the affective evaluation of PA in general. Hence, our study provides preliminary evidence that interventions based on the peak-end rule can enhance the affective determinants of PA (Rhodes et al., 2019; Stevens et al., 2020; Williams and Bohlen, 2019).

In line with a previous study exploring the peak-end rule in PA (Hargreaves and Stych, 2013), we did not observe that the intervention was associated with a significant higher level of self-reported moderate-to-vigorous PA. Nevertheless, although non-significant, participants self-reported an additional 36 min per day of daily-life moderate-to-vigorous physical activity over the four weeks of the experimental condition compared with the control condition. This result is promising but needs to be considered in light of the study design, which cannot determine if the effect observed is explained by the intervention or by the effect of time (i.e., the participation in an exercise program). The latter seems to be supported by the evolution of PA across the eight weeks (Figure S1).

We did not found evidence of an effect of the effort manipulation neither on the implicit affective attitudes nor on the accelerometer-based measure of physical activity. Comparisons with previous literature testing the manipulation of effort intensity is not straightforward given that, to the best of our knowledge, no study has assessed implicit attitudes and an accelerometer-based measure of daily-life PA following such manipulations. The differences between implicit and explicit measure of affective evaluation of PA could be explained by the fact that the automatic processes could be less malleable than the controlled processes (Joy-Gaba and Nosek, 2010). For example, in line with this suggestion, studies showed that explicit attitudes are more readily to change with relatively few exposures to counter-attitudinal examples, while implicit associations required more exposures to evolve (Rydell and McConnell, 2006; Rydell et al., 2007). Consequently, longer interventions would have been necessary to modify implicit affective associations with physical activity.

The difference in the effect size observed between self-reported and accelerometer-based measure of PA (i.e., ~36 min vs. ~2min per day) may be explained by at least two features. First, these measures did not assess the same type of physical activity. The questionnaire measured the time spent walking and in moderate-to-vigorous physical activity, irrespective of

their duration, while the accelerometer-based measure only included moderate-to-vigorous PA behaviors that last a minimum of 10 min. Second, it has been shown that self-reported measures of PA often overestimate PA levels, in comparison with accelerometer-based measures (Prince et al., 2008; Skender et al., 2016), especially in patients with PD (Mantri et al., 2019).

4.3. Strengths and weaknesses

Among the strengths of the present study are the application of the peak-end rule principle in physical activity, a clinical sample of patients with PD, a longitudinal design (i.e., repeated measurements over eight weeks), the measure of both explicit and implicit affective attitudes toward physical activity, and the use of both self-reported and accelerometer-based measures of daily-life PA. This study also has some limitations. First, our study relied on a small sample size ($N = 7$), which can bias the effects (Brysbaert, 2019), although we used a statistical approach adapted to small samples of participants (Luke, 2017; McNeish and Stapleton, 2016). Second, this work was an early-phase study aiming to test the potential impact of an intervention anchored in the peak-end rule principle but was not a formal randomized controlled trial. Specifically, our study was drawn on a within-subject design in which all patients first performed the four weeks of the traditional exercise rehabilitation program and then performed the four weeks of the experimental program. Accordingly, we cannot rule out the possibility that the effects observed were due to an effect of time rather than to the intervention. Finally, patients with PD receiving levodopa therapy often demonstrate random fluctuations in their motor performance, called the “on-off” phenomenon (Nutt et al., 1984). These fluctuations are likely to affect patients daily-life PA and should therefore be monitored and accounted for in future research.

5. Conclusion

In this study, we tested a manipulation that simply consists of adding a “better (less intensive) end” with all other things being equal. Our findings provide preliminary evidence

396 that an intervention manipulating the effort intensity at the end an exercise session may be
397 effective to enhance explicit evaluation of PA. If these results are confirmed by a randomized
398 controlled trial, this free and easily-deliverable intervention could be rapidly implemented on a
399 large scale to promote physical activity among patients with PD and other diseases.

References

- Baayen, R.H., Davidson, D.J., Bates, D.M., 2008. Mixed-effects modeling with crossed random effects for subjects and items. *J Mem Lang* 59:390-412.
- Bandura, A., 1997. *Self-efficacy: The exercise of control* (1st edition). Worth Publishers, New York.
- Barton, K., 2018. MuMIn: Multi-model inference. R package version 1.42.1. <https://CRAN.R-project.org/package=MuMIn>.
- Bates, D., Mächler, M., Bolker, B., Walker, S., 2014. Fitting linear mixed-effects models using lme4. *J Stat Softw* 67:1-48.
- Bernacer, J., Martinez-Valbuena, I., Martinez, M., Pujol, N., Luis, E.O., Ramirez-Castillo, D., Pastor, M.A., 2019. An amygdala-cingulate network underpins changes in effort-based decision making after a fitness program. *NeuroImage* 203:116181.
- Blanton, H., Jaccard, J., Burrows, C.N., 2015. Implications of the implicit association test D-transformation for psychological assessment. *Assessment* 22:429-40.
- Boisgontier, M.P., Cheval, B., 2016. The anova to mixed model transition. *Neurosci Biobehav Rev* 68:1004-05.
- Bonnelle, V., Manohar, S., Behrens, T., Husain, M., 2016. Individual differences in premotor brain systems underlie behavioral apathy. *Cereb Cortex* 26:807-19.
- Borg, G., 1998. Borg's perceived exertion and pain scales. *Human kinetics*.
- Brand, R., Cheval, B., 2019. Theories to explain exercise motivation and physical inactivity: Ways of expanding our current theoretical perspective. *Front Psychol* 10:1147.
- Brand, R., Ekkekakis, P., 2018. Affective–Reflective Theory of physical inactivity and exercise. *Ger J Exerc Sport Res* 48:48-58.
- Brysbaert, M., 2019. How many participants do we have to include in properly powered experiments? A tutorial of power analysis with reference tables. *J Cogn* 2:16.

- 425 Carver, C.S., Scheier, M.F., 1998. On the self-regulation of behavior. Cambridge University
426 Press, New York.
- 427 Cavanaugh, J.T., Ellis, T.D., Earhart, G.M., Ford, M.P., Foreman, K.B., Dibble, L.E., 2015.
428 Toward understanding ambulatory activity decline in Parkinson disease. *Phys Ther*
429 95:1142-50.
- 430 Chaudhuri, K.R., Healy, D.G., Schapira, A.H., 2006. Non-motor symptoms of Parkinson's
431 disease: diagnosis and management. *Lancet Neurol* 5:235-45.
- 432 Chen, H., Zhang, S., Schwarzschild, M., Hernan, M., Ascherio, A., 2005. Physical activity and
433 the risk of Parkinson disease. *Neurology* 64:664-69.
- 434 Cheval, B., Boisgontier, M.P., 2021. The theory of effort minimization in physical activity
435 (TEMPA). *Exerc Sport Sci Rev*.
- 436 Cheval, B., Cabral, D.A.R., Daou, M., Bacelar, M., Parma, J.O., Forestier, C., Orsholits, D.,
437 Maltagliati, S., Sander, D., et al., 2021. Inhibitory control elicited by physical activity and
438 inactivity stimuli: an EEG study. *Motiv Sci*.
- 439 Cheval, B., Chalabaev, A., Quested, E., Courvoisier, D.S., Sarrazin, P., 2017a. How perceived
440 autonomy support and controlling coach behaviors are related to well-and ill-being in elite
441 soccer players: A within-person changes and between-person differences analysis. *Psychol*
442 *Sport Exerc* 28:68-77.
- 443 Cheval, B., Daou, M., Cabral, D.A.R., Bacelar, M., Parma, J.O., Forestier, C., Orsholits, D.,
444 Sander, D., Boisgontier, M.P., et al., 2020. Higher inhibitory control is required to escape
445 the innate attraction to effort minimization. *Psychol Sport Exerc* 51:101781.
- 446 Cheval, B., Radel, R., Neva, J.L., Boyd, L.A., Swinnen, S.P., Sander, D., Boisgontier, M.P.,
447 2018a. Behavioral and neural evidence of the rewarding value of exercise behaviors: a
448 systematic review. *Sports Med* 48:1389-404.

- 449 Cheval, B., Sarrazin, P., Boisgontier, M.P., Radel, R., 2017b. Temptations toward behaviors
450 minimizing energetic costs (BMEC) automatically activate physical activity goals in
451 successful exercisers. *Psychol Sport Exerc* 30:110-17.
- 452 Cheval, B., Sarrazin, P., Isoard-Gautheur, S., Radel, R., Friese, M., 2015. Reflective and
453 impulsive processes explain (in)effectiveness of messages promoting physical activity: a
454 randomized controlled trial. *Health Psychol* 34:10-19.
- 455 Cheval, B., Tipura, E., Burra, N., Frossard, J., Chanal, J., Orsholits, D., Radel, R., Boisgontier,
456 M.P., 2018b. Avoiding sedentary behaviors requires more cortical resources than avoiding
457 physical activity: an EEG study. *Neuropsychologia* 119:68-80.
- 458 Chevance, G., Héraud, N., Guerrieri, A., Rebar, A., Boiché, J., 2017. Measuring implicit
459 attitudes toward physical activity and sedentary behaviors: Test-retest reliability of three
460 scoring algorithms of the Implicit Association Test and Single Category-Implicit
461 Association Test. *Psychol Sport Exerc* 31:70-78.
- 462 Connolly, B.S., Lang, A.E., 2014. Pharmacological treatment of Parkinson disease: a review.
463 *JAMA* 311:1670-83.
- 464 Conroy, D.E., Berry, T.R., 2017. Automatic affective evaluations of physical activity. *Exerc*
465 *Sport Sci Rev* 45:230-37.
- 466 Conroy, D.E., Hyde, A.L., Doerksen, S.E., Ribeiro, N.F., 2010. Implicit attitudes and explicit
467 motivation prospectively predict physical activity. *Ann Behav Med* 39:112-18.
- 468 Conroy, D.E., Kim, I., 2020. Heartphone: Mobile evaluative conditioning to enhance affective
469 processes and promote physical activity. *Health Psychol*.
- 470 Craig, C.L., Marshall, A.L., Sjorstrom, M., Bauman, A.E., Booth, M.L., Ainsworth, B.E., Pratt,
471 M., Ekelund, U., Yngve, A., et al., 2003. International physical activity questionnaire: 12-
472 country reliability and validity. *Med Sci Sports Exerc* 35:1381-95.

- 473 Ekkekakis, P., Parfitt, G., Petruzzello, S.J., 2011. The pleasure and displeasure people feel when
474 they exercise at different intensities. *Sports Med* 41:641-71.
- 475 Evenson, K.R., Terry, J.W., 2009. Assessment of differing definitions of accelerometer
476 nonwear time. *Res Q Exerc Sport* 80:355-62.
- 477 Finucane, M.L., Alhakami, A., Slovic, P., Johnson, S.M., 2000. The affect heuristic in
478 judgments of risks and benefits. *J Behav Decis Mak* 13:1-17.
- 479 Folstein, M.F., Folstein, S.E., McHugh, P.R., 1975. "Mini-mental state": a practical method for
480 grading the cognitive state of patients for the clinician. *J Psychiatr Res* 12:189-98.
- 481 Fredrickson, B.L., 2000. Extracting meaning from past affective experiences: The importance
482 of peaks, ends, and specific emotions. *Cogn Emot* 14:577-606.
- 483 Freedson, P.S., Melanson, E., Sirard, J., 1998. Calibration of the computer science and
484 applications, inc. accelerometer. *Med Sci Sports Exerc* 30:777-81.
- 485 Frossard, J., Renaud, O., 2019. The correlation structure of mixed effects models with crossed
486 random effects in controlled experiments. *arXiv*.
- 487 Goodwin, V.A., Richards, S.H., Taylor, R.S., Taylor, A.H., Campbell, J.L., 2008. The
488 effectiveness of exercise interventions for people with Parkinson's disease: A systematic
489 review and meta-analysis. *Mov Disord* 23:631-40.
- 490 Greenwald, A.G., McGhee, D.E., Schwartz, J.L., 1998. Measuring individual differences in
491 implicit cognition: the implicit association test. *J Pers Soc Psychol* 74:1464-80.
- 492 Greenwald, A.G., Nosek, B.A., Banaji, M.R., 2003. Understanding and using the implicit
493 association test: I. An improved scoring algorithm. *J Pers Soc Psychol* 85:197-216.
- 494 Grimby, G., Börjesson, M., Jonsdottir, I., Schnohr, P., Thelle, D., Saltin, B., 2015. The "Saltin–
495 Grimby physical activity level scale" and its application to health research. *Scand J Med
496 Sci Spor* 25:119-25.

- 497 Hargreaves, E.A., Stych, K., 2013. Exploring the peak and end rule of past affective episodes
498 within the exercise context. *Psychol Sport Exerc* 14:169-78.
- 499 Hillsdon, M., Foster, C., Thorogood, M., 2005. Interventions for promoting physical activity.
500 *Cochrane Database Syst Rev* 1:CD003180.
- 501 Hoehn, M.M., Yahr, M.D., 1998. Parkinsonism: onset, progression, and mortality. *Neurology*
502 50:318-18.
- 503 Hutchinson, J.C., Zenko, Z., Santich, S., Dalton, P.C., 2020. Increasing the pleasure and
504 enjoyment of exercise: a novel resistance-training protocol. *J Sport Exerc Psychol* 42:143-
505 52.
- 506 Hyde, A.L., Elavsky, S., Doerksen, S.E., Conroy, D.E., 2012. The stability of automatic
507 evaluations of physical activity and their relations with physical activity. *J Sport Exerc*
508 *Psychol* 34:715-36.
- 509 Joy-Gaba, J.A., Nosek, B.A., 2010. The surprisingly limited malleability of implicit racial
510 evaluations. *Social Psychology* 41:137-46.
- 511 Kahneman, D., Fredrickson, B.L., Schreiber, C.A., Redelmeier, D.A., 1993. When more pain
512 is preferred to less: Adding a better end. *Psychol Sci* 4:401-05.
- 513 Kenward, M.G., Roger, J.H., 1997. Small sample inference for fixed effects from restricted
514 maximum likelihood. *Biometrics*:983-97.
- 515 Klein-Flügge, M.C., Kennerley, S.W., Friston, K., Bestmann, S., 2016. Neural signatures of
516 value comparison in human cingulate cortex during decisions requiring an effort-reward
517 trade-off. *J Neurosci* 36:10002-15.
- 518 Krishnamurthi, N., Fleury, J., Belyea, M., Shill, H.A., Abbas, J.J., 2020. ReadySteady
519 intervention to promote physical activity in older adults with Parkinson's disease: Study
520 design and methods. *Contemp Clin Trials Commun* 17:100513.

- 521 Kuznetsova, A., Brockhoff, P.B., Christensen, R.H.B., 2015. lmerTest Package: tests in linear
522 mixed effects models. *J Stat Softw* 82:1-26.
- 523 Lakens, D., 2021. Sample Size Justification. *PsyArXiv*.
- 524 Lieberman, D.E., 2015. Is exercise really medicine? An evolutionary perspective. *Curr Sports*
525 *Med Rep* 14:313-19.
- 526 Luke, S.G., 2017. Evaluating significance in linear mixed-effects models in R. *Behav Res*
527 *Methods* 49:1494-502.
- 528 Mantri, S., Wood, S., Duda, J.E., Morley, J.F., 2019. Comparing self-reported and objective
529 monitoring of physical activity in Parkinson disease. *Parkinsonism Relat Disord* 67:56-59.
- 530 Matthews, C.E., Ainsworth, B.E., Thompson, R.W., Bassett Jr, D.R., 2002. Sources of variance
531 in daily physical activity levels as measured by an accelerometer. *Med Sci Sports Exerc*
532 34:1376-81.
- 533 McNeish, D.M., Stapleton, L.M., 2016. The effect of small sample size on two-level model
534 estimates: A review and illustration. *Educ Psychol Rev* 28:295-314.
- 535 Murray, D.K., Sacheli, M.A., Eng, J.J., Stoessl, A.J., 2014. The effects of exercise on cognition
536 in Parkinson's disease: a systematic review. *Transl Neurodegener* 3:1-13.
- 537 Nash, J.C., Varadhan, R., 2011. Unifying optimization algorithms to aid software system users:
538 *optimx* for R. *J Stat Softw* 43:1-14.
- 539 Nelder, J.A., Mead, R., 1965. A simplex method for function minimization. *Comput J* 7:308-
540 13.
- 541 Nutt, J.G., Woodward, W.R., Hammerstad, J.P., Carter, J.H., Anderson, J.L., 1984. The "on-
542 off" phenomenon in Parkinson's disease: relation to levodopa absorption and transport. *N*
543 *Engl J Med* 310:483-88.

- 544 Obeso, J., Stamelou, M., Goetz, C., Poewe, W., Lang, A., Weintraub, D., Burn, D., Halliday,
545 G.M., Bezard, E., et al., 2017. Past, present, and future of Parkinson's disease: a special
546 essay on the 200th anniversary of the shaking palsy. *Mov Disord* 32:1264-310.
- 547 Poewe, W., Seppi, K., Tanner, C.M., Halliday, G.M., Brundin, P., Volkmann, J., Schrag, A.-
548 E., Lang, A.E., 2017. Parkinson disease. *Nat Rev Dis Primers* 3:1-21.
- 549 Powell, M.J., 2009. The BOBYQA algorithm for bound constrained optimization without
550 derivatives. Cambridge NA Report NA2009/06, University of Cambridge, Cambridge:26-
551 46.
- 552 Pradhan, S., Kelly, V.E., 2019. Quantifying physical activity in early Parkinson disease using
553 a commercial activity monitor. *Parkinsonism & related disorders* 66:171-75.
- 554 Prince, S.A., Adamo, K.B., Hamel, M.E., Hardt, J., Gorber, S.C., Tremblay, M., 2008. A
555 comparison of direct versus self-report measures for assessing physical activity in adults: a
556 systematic review. *Int J Behav Nutr Phys Act* 5:56.
- 557 R Core Team. 2019. R: A language and environment for statistical computing. Vienna, Austria.
558 <https://www.R-project.org/>.
- 559 Rebar, A.L., Ram, N., Conroy, D.E., 2015. Using the EZ-diffusion model to score a single-
560 category implicit association test of physical activity. *Psychol Sport Exerc* 16:96-105.
- 561 Rhodes, R.E., Boudreau, P., Josefsson, K.W., Ivarsson, A., 2020. Mediators of physical activity
562 behaviour change interventions among adults: a systematic review and meta-analysis.
563 *Health Psychol Rev*:1-15.
- 564 Rhodes, R.E., Courneya, K.S., 2003. Investigating multiple components of attitude, subjective
565 norm, and perceived control: An examination of the theory of planned behaviour in the
566 exercise domain. *Brit J Soc Psychol* 42:129-46.
- 567 Rhodes, R.E., McEwan, D., Rebar, A.L., 2019. Theories of physical activity behaviour change:
568 A history and synthesis of approaches. *Psychol Sport Exerc* 42:100-09.

- 569 Rydell, R.J., McConnell, A.R., 2006. Understanding implicit and explicit attitude change: a
570 systems of reasoning analysis. *J Pers Soc Psychol* 91:995-1008.
- 571 Rydell, R.J., McConnell, A.R., Strain, L.M., Claypool, H.M., Hugenberg, K., 2007. Implicit
572 and explicit attitudes respond differently to increasing amounts of counterattitudinal
573 information. *Eur J Soc Psychol* 37:867-78.
- 574 Sheeran, P., Gollwitzer, P.M., Bargh, J.A., 2013. Nonconscious processes and health. *Health*
575 *Psychol* 32:460-73.
- 576 Simon, H., 1990. Reason in human affairs. Stanford University Press.
- 577 Skender, S., Ose, J., Chang-Claude, J., Paskow, M., Brühmann, B., Siegel, E.M., Steindorf, K.,
578 Ulrich, C.M., 2016. Accelerometry and physical activity questionnaires-a systematic
579 review. *BMC Public Health* 16:1-10.
- 580 Speelman, A.D., Van De Warrenburg, B.P., Van Nimwegen, M., Petzinger, G.M., Munneke,
581 M., Bloem, B.R., 2011. How might physical activity benefit patients with Parkinson
582 disease? *Nature Reviews Neurology* 7:528.
- 583 Stevens, C.J., Baldwin, A.S., Bryan, A.D., Conner, M., Rhodes, R.E., Williams, D.M., 2020.
584 Affective Determinants of Physical Activity: A Conceptual Framework and Narrative
585 Review. *Front Psychol* 11:3366.
- 586 van Uem, J.M., Cerff, B., Kampmeyer, M., Prinzen, J., Zuidema, M., Hobert, M.A., Gräber, S.,
587 Berg, D., Maetzler, W., et al., 2018. The association between objectively measured physical
588 activity, depression, cognition, and health-related quality of life in Parkinson's disease.
589 *Parkinsonism Relat Disord* 48:74-81.
- 590 Williams, D.M., Bohlen, L.C., 2019. Motivation for exercise: reflective desire versus hedonic
591 dread, in: Anshel, M.H., Petruzzello, S.J., Labbé, E.E. (Eds.), *APA Handbook of Sport and*
592 *Exercise Psychology*. American Psychological Association, Washington, DC, pp. 363-85.

- 593 Williams, D.M., Rhodes, R.E., Conner, M.T., 2019. Conceptualizing and intervening on
594 affective determinants of health behaviour. *Psychol Health* 34:1267-81.
- 595 Zenko, Z., Ekkekakis, P., Ariely, D., 2016. Can you have your vigorous exercise and enjoy it
596 too? Ramping intensity down increases postexercise, remembered, and forecasted pleasure.
597 *J Sport Exerc Psychol* 38:149-59.
- 598

599 **Table 1**600 *Descriptive statistics across the conditions*

N = 7	Baseline			Conditions Control			Experimental		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Demographics									
Age (years)	72.9	5.6	63-78						
Gender (number; % women)	3	42.8%							
Body mass index (Kg/M ²)	22.8	2.9	17-26						
Usual level of PA (number; %)									
Some physical activity	5	71.4%							
Regular physical activity	2	28.6%							
Stage of motor dependence (number; %)									
Stage 3	7	100%							
Affective attitudes toward PA									
Explicit attitudes	5.9	1.1	4.5-7	5.2	0.6	4.5-6	6.2	0.9	5-7
Implicit attitudes	.58	1.0	-.6-1.56	.89	.99	-.68-1.65	.81	.71	-.56-1.62
PA behaviors (min per day)									
Self-reported measure				148.6	80.1	57-262	199.3	111.4	5-359
Accelerometer-based measure				18.5	18.9	3-52	20.9	23.2	5-64
Evaluation of each exercise session									
Perceived effort				3.8	0.7	3-6	3.6	0.5	3-5
Affective evaluation				6.7	1.5	0-10	6.8	2.3	0-10

601 *Notes.* PA = physical activity; SD = standard deviation; IAT = implicit association test. D-

602 score ranges from -2 to +2, indicating unfavorable and favorable implicit attitudes toward

603 physical activity (vs. sedentary behaviors), respectively.

604 **Table 2**605 *Results of the mixed models predicting affective attitudes toward physical activity*

	Explicit attitudes (Likert scale from 1 to 7)		Implicit attitudes (D score from -2 to +2)	
	b (CI)	p	b (CI)	p
Fixed Effects				
Intercept	5.84 (5.03;6.64)	<.001	-.01 (-1.00;0.97)	.979
Condition (ref. control condition)				
Experimental condition	1.00 (.36;1.64)	.022	.19 (-.41;.79)	.564
Baseline condition	.64 (-.15;1.43)	.163	-.16 (-.33;.01)	.163
Covariates				
Usual level of physical activity (ref. regular)				
Some light physical activity	-.87 (-1.74;.01)	.210	0.86 (.25;.1.47)	.109
Random Effects				
Participants				
Intercept	0.312		1.489	
Condition baseline	.832		0.014	
Condition experimental	.439		0.568	
Corr. (Intercept, Condition baseline)	-.58		-.48	
Corr. (Intercept, Condition experimental)	-.42		-.97	
Corr. (Condition baseline; Condition experimental)	.98		.26	
Residual	.155		.115	
R ²	.366		.128	

606 *Notes.* CI=confidence interval at 95%. D-score ranges from -2 to +2, indicating unfavorable

607 and favorable implicit attitudes toward physical activity (vs. sedentary behaviors), respectively.

608 Explicit attitudes range from 1 to 7, indicating unfavorable and favorable explicit attitudes

609 toward physical activity, respectively.

610 **Table 3**611 *Results of the mixed models predicting daily-life physical activity*

	Self-reported (in min per day)		Direct (in min per day)	
	b (CI)	p	b (CI)	p
Fixed Effects				
Intercept	190.8 (79.3;302.2)	.025	40.7 (26.7;54.7)	.003
Condition (ref. control condition)				
Experimental condition	36.5 (-3.22;76.2)	.122	2.3 (-2.6;7.11)	.417
Covariates				
Day (ref. Sunday)				
Monday	16.3 (-11.2;43.9)	.245	3.7 (-3.9;11.2)	.342
Tuesday	27.3 (-.3;54.8)	.053	-2.3 (-9.8;5.1)	.539
Wednesday	26.3 (-1.3;53.8)	.063	1.8 (-5.6;9.2)	.638
Thursday	10.4 (-17.3;38.0)	.459	-5.0 (-12.4;2.4)	.186
Friday	24.7 (-2.8;52.3)	.080	.63 (-6.9;8.1)	.870
Saturday	-2.7 (-30.3;24.8)	.848	-2.9 (-10.4;4.6)	.456
Usual level of physical activity (ref. regular)				
Some light physical activity	-59.6 (-185.9;66.7)	.467	-31.9 (-47.6;-16.3)	.028
Random Effects				
Participants				
Intercept	6806		72.95	
Condition experimental	2466		10.13	
Corr. (Intercept, Condition experimental)	.50		1.00	
Residual	5333		284.89	
R ²	.072		.354	

612 *Notes.* CI=confidence interval at 95%. Self-reported physical activity was assessed using an
613 adapted version of the International Physical Activity Questionnaire and was expressed in
614 minutes per day. Accelerometer-based measure of physical activity was expressed in minutes
615 per day. The parameter for the correlation between random intercept and random slope is
616 estimated at 1.00 in the model, which is explain by the low number of participants included in
617 the models.

618 **Figure 1**619 *Flow Chart*

620

Figure 2

Affective attitudes. A. Explicit attitudes toward physical activity. B. Implicit attitudes toward physical activity

Note. Dots represent the observations for each participant. Grey lines represent each participants evolution of the attitudes across conditions. The black line represents the averaged evolution of the attitudes across conditions. For the implicit attitudes, we used a D-score that ranges from -2 to +2, indicating unfavorable and favorable implicit attitudes toward physical activity (vs. sedentary behaviors), respectively. For the explicit attitudes, we used a scale ranging from 1 to 7, indicating unfavorable and favorable explicit attitudes toward physical activity, respectively.

Figure 3

Daily life physical activity. A. Self-reported measure of physical activity. B. Accelerometer-based measure of physical activity

Note. Dots represent the observations for each participant. Grey lines represent each participants evolution of the attitudes across conditions. The black line represents the averaged evolution of the physical activity across conditions.

640 **Supplemental Table S1**641 *Detailed description of each exercise session*

Exercises	Instructions	Scheme and material	Situational variables
Warm-up Cardiovascular / joint / muscles 15min	<p>- Turing in circle in the room (one way and then the other): unroll the step, one foot in front of the other, big steps/high steps (5min).</p> <p>- Range of motion: head forward/backward; turn arms one way, then the other; turn wrists one way, then the other; turn pelvis one way, then the other; same for knees and ankles (5min).</p>		Range of motion: walking (if feasible) or static (if too difficult to walk).
1.Motor course	The participant takes a racket in one hand and puts a ball on it.		If too easy: take a lighter ball.

	The goal is to go over the blocks and back again.	Racket + ball (heavy) + round blocks (≥ 5)	For lower intensity (i.e., experimental condition): Without the block or the racket, just the ball in the hand.
2. Kneeling up/down	Start standing, then go down on your knees one knee at a time, then go back up by unfolding one knee at a time, and so on.	Use a chair if necessary	If too easy: do not use your hand to get up. If too hard: help yourself by leaning on a chair. For low intensity (i.e., experimental condition): only sitting/standing on the chair.
3. Elastic unilateral row	In front of the espalier, knees slightly bent, pelvis in retroversion, bring the shoulder then the elbow backwards; the 2 arms at the same time.	Elastic band + espalier	If too easy: shorten the elastic band (take the elastic higher) or take a stronger elastic. For low intensity (i.e., experimental condition): Take a

	<p>Caution: remain quite straight and do not release the arm towards the front too quickly.</p>		<p>less resistant elastic band or use the bars</p> <p>to do the exercise: hang backwards with the arms, then scapular retropulsion to come back against the bar.</p>
<p>4. Cushion balance + squat</p>	<p>Standing with both feet on an air cushion, perform squats while holding on to the bar.</p> <p>Pay attention to the balance of the practitioner.</p>	<p>Air cushion + espalier</p>	<p>If too easy: do not stand on the bar or go lower while squatting.</p> <p>For low intensity (i.e., experimental condition): without the squat, only balance on the cushion.</p>
<p>5. Elastic arm curl</p>	<p>One elastic band under each foot and the other end in each hand, knees slightly bent, pelvis in retroversion,</p>	<p>Elastic band</p>	<p>If too easy: shorten the elastic (take the elastic higher) or take a stronger elastic.</p> <p>For low intensity (i.e., experimental condition): take an</p>

	<p>perform an arm flexion.</p> <p>Caution: do not completely stretch the arms at the bottom of the movement, do not roll the shoulders forward.</p>		<p>elastic band with less resistance or take a 0.5 kg dumbbell.</p>
<p>6.Moving the box</p>	<p>Take the box on the ground while keeping your back straight, knees bent, abs tight.</p> <p>Stand up then go towards the block in front of you, rest and take back the box, and return towards the block in front of you, and so on.</p>	<p>Box + dumbbells + round blocks</p>	<p>If too easy: put more weight (dumbbells) in the box.</p> <p>For low intensity (i.e., experimental condition): Remove the weights (dumbbells) out the box and/or do not bend the knees (only walking with the box).</p>

642 *Notes.* Each exercise consisted of 1-min period of exercise and 30-s rest period.

643 **Supplemental Table S2**644 *Descriptive statistics across weeks*

	Mean	SD	Range
Evaluation of each exercise session			
Perceived effort			
Week 1	4	1.0	3-5
Week 2	4	0.9	3-5
Week 3	3.8	1.2	3/6
Week 4	3.3	0.5	3-4
Week 5	3.7	0.8	3-5
Week 6	3.4	0.5	3-4
Week 7	3.6	0.5	3-4
Week 8	3.6	0.8	3-5
Affective evaluation			
Week 1	6.1	2.9	3-10
Week 2	7.8	1.6	5-10
Week 3	6	3.1	0-8
Week 4	6.7	1.6	4-9
Week 5	5.4	3.1	0-8
Week 6	7.4	1.4	6-9
Week 7	7	3.6	0-10
Week 8	7.3	2.1	4-10
Self-efficacy			
Week 1	5.9	1.3	4-7
Week 2	5.8	1.2	4-7
Week 3	5.8	1.0	5-7
Week 4	6	1.3	4-7
Week 5	5.6	1.4	4-7
Week 6	5.9	0.9	5-7
Week 7	5.7	0.9	5-7
Week 8	5.7	1.1	4-7
Future intention			
Week 1	5.9	1.6	3-7
Week 2	5.7	1.2	4-7
Week 3	5.8	1.3	4-7
Week 4	5.4	1.4	3-7
Week 5	5.6	1.5	3-7
Week 6	6.1	1.2	4-7
Week 7	6	1.4	4-7
Week 8	5.9	1.7	3-7
PA behaviors			
Self-reported measure (in min per day)			
Week 1	136.2	68.2	55.7-246.4
Week 2	147.7	74.6	62.1-263.6
Week 3	172.9	111.9	53.6-323.6
Week 4	183.5	99.6	55.7-337.1
Week 5	210.3	113.1	85.1-398.6
Week 6	201.3	112.9	68.6-352.9
Week 7	199.7	112.2	47.1-333.6
Week 8	185.7	114.3	45.6-305.1
Accelerometer-based measure (in min/day)			
Week 1	126.3	120.5	35.5-361.5

<i>Week 2</i>	84.7	104.5	18-269
<i>Week 3</i>	66.5	81.9	15.5-210.5
<i>Week 4</i>	87.2	102.1	14.5-237.5
<i>Week 5</i>	137.3	126.2	6.5-356.5
<i>Week 6</i>	158.8	203.9	12-553.5
<i>Week 7</i>	57.7	55.9	8.5-118.5
<i>Week 8</i>	146.5	158.8	25-413.5

645 *Notes.* PA = physical activity; SD = standard deviation

646 **Supplemental Figure S1.**647 *Self-reported physical activity by week*

648

649 *Notes.* Dots represent the observations for each participant. Grey lines represent each
650 participants evolution of the self-reported physical activity across weeks. The black line
651 represents the averaged evolution of the self-reported physical activity across weeks.

Supplemental Material 1. Detailed description of the implicit association test

Implicit attitudes toward PA were assessed using an implicit association test (Greenwald et al., 1998). In this computerized task, participants were asked to quickly sort four types of words [physical activity, sedentary behaviors, positive attributes (i.e., good), negative attributes (i.e., bad)], by pressing a key on a keyboard. Following previous recommendations (Greenwald et al., 2003), this test consisted of seven blocks. In the first block, categories related to *PA* and *sedentary behaviors* were presented in green in the upper-left and upper-right corners of the black screen and the stimuli (i.e., words related to either *PA* or sedentary behaviors) appeared in random order on the center of the screen in white. Participants categorized the stimuli by pressing the letter “E” or “I” for the left and right side, respectively. Following an incorrect answer, a red cross appeared on the screen and participants were asked to correct their response. The intertrial interval was 400 ms for words correctly categorized. The response latency from onset of the word to pressing a response key was recorded. In the second block, participants were asked to sort stimuli related to the *good* and *bad* categories, following the same procedure than in the first block. Then, in the third (i.e., practice trials) and fourth (i.e., test trials) blocks, participants were asked to sort the words into one of the two categories: *physical activity/good* (e.g., on the left side) and *sedentary behaviors/bad* (e.g., on the right side). The fifth block was identical to block 1, but the position of the categories was inverted (e.g., whether *PA* was presented on the left side, it was now moved on the right side). Finally, the sixth (i.e., practice trials) and seventh (i.e., test trials) blocks were similar to the third and fourth blocks, but the categories were inverted (e.g., whether participants were asked to sort *PA/good* [e.g., on the left side] and *sedentary behaviors/bad* [e.g., on the right side], they were now asked to sort *sedentary behaviors/good* [e.g., on the left side] and *PA/bad* [e.g., on the right side]). The practice trials (i.e., third and sixth blocks) consisted of 20 trials and the test trials (i.e., fourth and seventh blocks) of 40 trials, as recommended (Greenwald et al., 2003). The side on which

the categories appeared was counterbalanced across participants. The eight physical activity- (i.e., *active, move, run, effort, walk, sport, stairs, bike*) and sedentary- (i.e., *sofa, sitting, armchair, rest, television, lying down, chair, reading*) related words, and the eight positive (i.e., *vigor, euphoria, vitality, exhilarating, pleasant, joyful, satisfying, fun*) and negative (i.e., *distress, exhaustion, fatigue, suffering, sad, painful, boring, disappointing*) attributes were selected based on previous studies (Cheval et al., 2017b; Chevance et al., 2017; Conroy et al., 2010; Hyde et al., 2012; Rebar et al., 2015).

For each participant, the D-score was calculated by subtracting the mean response time in the so-called *compatible test block* (i.e., *physical activity/good* and *sedentary/bad*) from the mean response time in the *incompatible test block* (i.e., *physical activity/bad* and *sedentary/good*) and then by dividing this mean difference by the pooled standard deviation across both blocks (Greenwald et al., 2003). The D-score range from -2 to +2, indicating negative and positive implicit attitudes toward PA (vs. sedentary behaviors), respectively. Values of .15, .35, and .64 were considered as a slight, moderate, and strong, respectively (Blanton et al., 2015).

Supplemental Material 2. Additional measures***Evaluation of each exercise session***

These variables were assessed 5-min after the end of each exercise session.

Affective evaluation of the exercise session. The affective evaluation of the exercise session was assessed using the following item (Hargreaves and Stych, 2013): “How pleasant or unpleasant did you find the exercise session?” Participants answered on a 21-point scale from -10 (*Very unpleasant*) through 0 (*Neutral*) to +10 (*Very pleasant*).

Self-efficacy toward the exercise session. The self-efficacy toward the exercise session was measured using the following item adapted from the Needs Satisfaction-Thwarting Scale (Cheval et al., 2017a): The stem prior the item was “To what extent do you feel capable to carry out the exercises requested by the exercise session. Participants answered on a 7-point bipolar scale with 1 (*Not capable at all*) to 7 (*Very capable*).

Perceived effort toward the exercise session. The Rate of perceived exertion toward the exercise session was assessed using the Borg CR-10 scale (Borg, 1998). This one-item scale started with the stem “How did you perceive the level of effort (intensity) of the exercise session?” Participants answered on a 12-point scale ranging from 0 (*Nothing*) through 0 (*Somewhat hard*) to 10 (*Very, very hard*). In line with the recommendations (Borg, 1998), the research assistant gave standard instruction on how to use the scale. This scale was also used by the participant to monitor the effort intensity during the exercise session (see procedure).

Intentions to be physically during the next week. Intentions to be physically active during the next week were measured using the following item (Cheval et al., 2015): “Over the next seven days, I intend to carry out at least 30 minutes moderate-to-vigorous physical activity per day on five or more days of the week during my free time or my transportation”. Respondents answered on a scale ranging from 1 (*Not at all agree*) to 7 (*Strongly agree*).

Global evaluation of physical activity

These variables were assessed at baseline, at the end of the control condition (i.e., four weeks), and at the end of the experimental condition (i.e., eight weeks).

Instrumental attitudes toward physical activity. Instrumental attitudes toward physical activity were assessed using two items (Rhodes and Courneya, 2003). The stem prior to each item was “Would you say that being physically activity is something...”. Participants answered on a seven-point bipolar scale with 1 (*useless*) to 7 (*useful*) and from 1 (*harmful*) to 7 (*beneficial*). Items were averaged to create an overall measure of instrumental attitudes toward to be physically active.

Intentions to be physically active. Intentions to be physically active were measured using the following two items (Cheval et al., 2015): “Usually, I intend to carry out at least 30 minutes moderate-to-vigorous physical activity per day on five or more days of the week during my free time or my transportation”; “I am determined to carry out at least 30 minutes moderate-to-vigorous physical activity per day on five or more days of the week during my free time or my transportation”. Respondents answered each item on a scale ranging from 1 (*Not at all agree*) to 7 (*Strongly agree*). The items were averaged to create an overall measure of intention to be physically active.

Self-efficacy toward physical activity. Self-efficacy toward physical activity was assessed using one item of the Needs Satisfaction-Thwarting Scale (Cheval et al., 2017a). The stem prior the item was “To what extent do you feel capable to carry out at least 30 minutes moderate-to-vigorous physical activity per day on five or more days of the week during your free time or your transportation”. Participants answered on a 7-point bipolar scale with 1 (*Not capable at all*) to 7 (*Very capable*).

Supplemental material 3. Additional analyses testing the impact of the intervention on the evaluation of the exercise sessions.

Statistical analysis

For the outcomes related to the evaluation of the exercise sessions, we used a linear MEM that included the two conditions (control condition vs. experimental condition) as fixed factor. These models specified participants as a random factor and included random effects for the conditions. The models were adjusted for usual physical activity.

Affective evaluation of the exercise session

No significant differences in the affective evaluation of the exercise sessions were observed between the control condition and the experimental condition ($b = .04$, 95%CI = -1.44 to 1.51, $p = .963$).

Perceived effort

No significant differences in the perceived effort associated to the exercise sessions were observed between the control condition and the experimental condition ($b = -.25$, 95%CI = -.61 to .11, $p = .235$).

Self-efficacy

No significant differences in the self-efficacy toward the exercise sessions were observed between the control condition and the experimental condition ($b = -.14$, 95%CI = -.74 to .46, $p = .657$).