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Evolution of physical activity habits after a context change: The case of COVID-19 lockdown

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Objective. Habits, defined as well-learned associations between cues and behaviours, are essential for health-related behaviours, including physical activity (PA). Despite the sensitivity of habits to context changes, little remains known about the influence of a context change on the interplay between PA habits and behaviours. We investigated the evolution of PA habits amidst the spring COVID-19 lockdown, a major context change. Moreover, we examined the association of PA behaviours and autonomous motivation with this evolution.

Design. Three-wave observational longitudinal design.

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Methods. PA habits, behaviours, and autonomous motivation were collected through online surveys in 283 French and Swiss participants. Variables were self-reported with reference to three time-points: before-, mid-, and end-lockdown.

Results. Mixed effect modelling revealed a decrease in PA habits from before- to mid-lockdown, especially among individuals with strong before-lockdown habits. Path analysis showed that before-lockdown PA habits were not associated with mid-lockdown PA behaviours ($\beta = -.02$, $p = .837$), while mid-lockdown PA habits were positively related to end-lockdown PA behaviours ($\beta = .23$, $p = .021$). Autonomous motivation was directly associated with PA habits ($ps < .001$) and withto before- and mid-lockdown PA behaviours ($ps < .001$) (but not with end-lockdown PA behaviours) and did not moderate the relations between PA behaviours and habits ($ps > .072$).

Conclusion. PA habits were altered, and their influence on PA behaviours was impeded during the COVID-19 lockdown. Engagement in PA behaviours and autonomous motivation helped in counteracting PA habits disruption.

Statement of contribution

What is already known on this subject?

- Habits can play a key role in the regulation of physical activity (PA) during the COVID-19 lockdown.
- Because of their cue-dependent nature, habits are sensitive to a context change, such as the COVID-19 lockdown.
- How PA habits evolved following such a context change and the association of PA behaviours and autonomous motivation with this evolution remains largely unknown.

What does this study add?

- COVID-19 lockdown was associated with a decline in PA habits, especially among individuals with strong before-lockdown habits.
- Before-lockdown PA habits were not significantly associated with PA behaviours once the context changed, while habits developed during lockdown fostered the engagement in PA behaviours in this new context.
- Engaging in renewed PA behaviours during lockdown and exhibiting autonomous motivation was positively related to PA habits.

Background

Physical activity (PA) is associated with many beneficial outcomes relating to physical and mental health (Rebar et al., 2015; Warburton, 2006). In particular, during the COVID-19 pandemic, engaging in active behaviours has been shown to be of special relevance to counteract the detrimental mental health effects of lockdown, which was imposed in most parts of the world during spring 2020 (World Health Organization, 2020). Such detrimental effects include, for instance, anxiety and depression (Xiong et al., 2020). Yet, a fast-growing literature reveals that individuals' PA behaviours were altered during this period: while most individuals decreased their engagement in PA, a portion of the population increased it (Cheval et al., 2020; Constandt et al., 2020; Deschasaux-Tanguy et al., 2021; Gallè et al., 2020; Sañudo, Fennell, & Sánchez-Oliver, 2020). Among other motivational determinants (e.g., intention, self-efficacy), PA habits offer a potential explanation for changes in PA (Kaushal, Keith, Aguiñaga, & Hagger, 2020; Rhodes, Liu, Lithopoulos, Zhang, & Garcia-Barrera, 2020).

Habits, defined as well-learned associations between cues and the enactment of a certain behaviour (Gardner, 2015), are considered a key factor for the regulation of physical activity: people with stronger habits for instigating bouts of PA are more likely to

engage in PA (Gardner, de Bruijn, & Lally, 2011; Phillips & Gardner, 2016; Rebar et al., 2016).[1] Indeed, a meta-analysis showed a medium-sized correlation between habits and PA behaviours (r = .43; Gardner et al., 2011). In particular, habits can 'lock in' intentional behaviours such as PA, making engagement in these behaviours less cognitively effortful. Studies have shown that when individuals have strong habits, they are likely to act in line with these habits even when their intention is momentarily weakened – thereby favouring the maintenance of behaviours over time (Gardner, Lally, Lally, & Rebar, 2020). When contextual cues are encountered, a mental representation of the cue–behaviour association is activated, triggering an impulse to act with minimal conscious awareness (Neal, Wood, Labrecque, & Lally, 2012). Contextual cues that prompt PA can stem from multiple sources, including environmental (e.g., a location in which individuals are used to exercising), temporal (e.g., jogging every Wednesday after work), or social ones (e.g., going to the gym with colleagues; Kaushal & Rhodes, 2015; Maher, Rebar, & Dunton, 2021; Pimm et al., 2016). For instance, one study found that 90% of regular exercisers reported that their PA behaviours were automatically prompted by a particular location or a specific time (Tappe, Tarves, Oltarzewski, & Frum, 2013).

Major context changes and PA habits: the case of COVID-19 lockdown

Because of this cue-dependent nature (Orbell & Verplanken, 2010), the potential of habits to trigger behaviours is sensitive to a context change (i.e., discontinued exposure to regular environments; Verplanken & Wood, 2006). According to the discontinuity hypothesis (Verplanken, Walker, Davis, & Jurasek, 2008), when contextual cues are no longer available in one's environment, habits are, at least temporarily, disrupted and do not translate in behaviours anymore – an effect especially pronounced among individuals with strong initial habits. Yet, for PA habits, this hypothesis has received little empirical support (Gardner, 2015). Only two studies have provided indirect support to the discontinuity hypothesis by showing a decrease in PA behaviours after holidays (Fredslund & Leppin, 2019) or after a move to university (Wood, Tam, & Witt, 2005). However, PA habits were not directly assessed, thereby preventing the assessment of how habits evolved following a context change. To fill this knowledge gap, the present study aimed to examine how PA habits evolved from before to during the spring 2020 lockdown imposed in France and Switzerland, the countries in which this study was conducted.

Indeed, this period raised an ecological contextual change which may have impacted PA habits. In France and Switzerland, restrictive measures were applied within a few days from each other and only slightly differed between these two countries (Figure 1). In France, restrictive measures included the limitation of individual outdoor activities to one hour, in a one-kilometer perimeter, with a proof of displacement and the closure of gym and sports clubs. In Switzerland, restrictive measures included the limitation of outdoor activities to a maximum of five persons (but no formal restriction related to outdoor movement) and the closure of gym and sports clubs. There are at least two reasons to expect that, across this period, the influence of PA habits on behaviours has changed. First, associations underpinning PA habits might have been weakened due to

[1] *Habit can manifest in behaviour in two ways: people may be habitually triggered to 'decide' to engage in PA (i.e., 'habitually instigated' PA), or habit may aid fluid performance of the sequence of acts included in a bout of PA (i.e., 'habitually executed' PA; (Phillips & Gardner, 2016). Social cognition research demonstrating the contribution of habit to PA has tended to focus on habitual instigation only (Gardner, Rebar, et al., 2020; Verplanken & Melkevik, 2008). In this paper, we use the terms 'habit' as synonymous with habitual instigation and habitually instigated behaviour, respectively.*

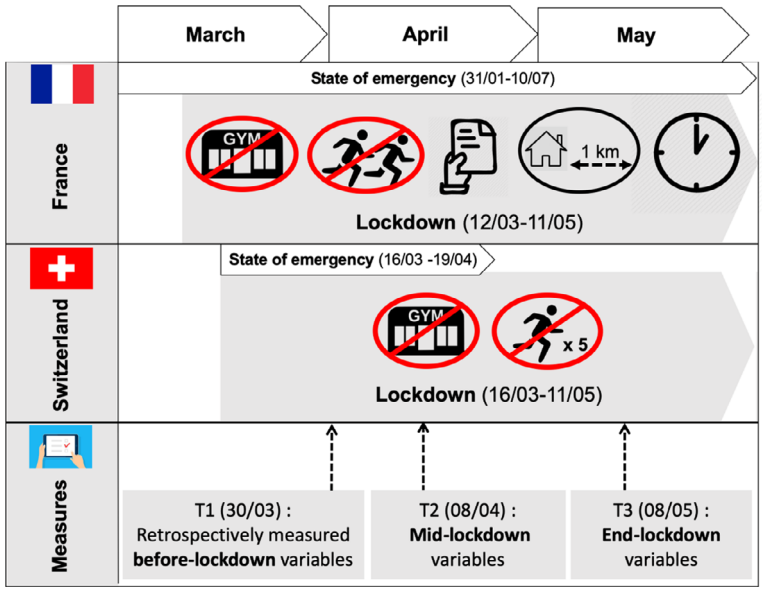

Figure 1. Illustration of restrictive measures during the lockdown in France and Switzerland and of the three-wave longitudinal design of the study.

discontinued cue exposure (e.g., not packing one's sport bag before going to work), thus having less impact on PA behaviours. Alternatively, PA habits might have remained intact but, because cues were no longer encountered, did not translate in PA behaviours, instead remaining dormant (Gardner, 2012). Regardless the mechanism at work, it is predicted that the association of previous habits with consecutive PA behaviours will decrease following a context change.

Association of PA behaviours with the evolution of PA habits after a context change

Crucially, as proposed by the discontinuity hypothesis (Verplanken et al., 2008), a context change, such as the one catalysed by the lockdown, can also foster a mindset of being in 'the mood for change' (Verplanken & Roy, 2016). During this 'window of opportunity', individuals are prone to engage in deliberative processes, leading to the renegotiation of previous behaviours (Verplanken & Roy, 2016). This discontinuity hypothesis may thus explain why some studies observed an increase of PA behaviours during lockdown (Cheval et al., 2020; Constandt et al., 2020; but see Deschasaux-Tanguy et al., 2021; Gallè et al., 2020; Sañudo et al., 2020 for contradictory findings).

In turn, engaging in PA behaviours after a context change may influence the evolution of PA habits. Indeed, one mechanism through which habits can evolve is the habit formation process, which emphasizes the crucial role of behaviours in the development of habits (Gardner & Lally, 2018; Lally & Gardner, 2013). In the first stages of this process, behavioural repetition in a stable context is the most proximal driver of the evolution of habits (Gardner & Lally, 2018; Lally & Gardner, 2013). The context-behaviour repetition fosters the establishment of strong mental cue–behaviour associations, making other alternatives less accessible (Danner, Aarts, & de Vries, 2007). For example, two studies revealed that the daily practice of the same exercise in the same context leads to a quick

increase in habits (Fournier et al., 2017; Lally, Van Jaarsveld, Potts, & Wardle, 2010). Hence, during lockdown, the replacement of previous PA behaviours (e.g., exercising after a teleworking session rather than after a day spent in office) or the instigation of new behaviours (e.g., cycling around home after lunch with one's children), as a response to take advantage of this window of opportunity, may have sustained – or even strengthened – PA habits.

Furthermore, as habits develop, they acquire the capacity to prompt the engagement in behaviours in stable contexts (Gardner et al., 2011; Rebar et al., 2016). Hence, while before-lockdown habits may not translate into PA behaviours during lockdown, any replacing or newly formed PA habits during the early stages of lockdown may drive consecutive PA behaviours. The same reasoning can be applied to the link between previous PA behaviours and consecutive PA behaviours. Indeed, previous research emphasizes that past behaviours are an important predictor of consecutive behaviours (Hagger, Chatzisarantis, & Biddle, 2002; McEachan, Conner, Taylor, & Lawton, 2011), especially when the context remains stable (Ouellette & Wood, 1998). Hence, before-lockdown PA behaviours seem less likely to be associated with PA behaviours in the early stages of lockdown, than PA behaviours in the early stages of lockdown with PA behaviours at the later stages of lockdown. In sum, the association of previous PA habits and previous behaviours with consecutive habits and behaviours should be less pronounced when a context change occurred between two time-points.

Association of autonomous motivation with the evolution of PA habits after a context change

Autonomous motivation, defined as the extent to which a behaviour is consistent with self-endorsed reasons for action (e.g., for pleasure or personal interest; Ryan & Deci, 2017), likely plays an important role in the evolution of habits. Indeed, the evolution of habits is conceptualized as being a reinforcement process of reward responses from engaging in behaviour in consistent contexts (Wood, 2017). Empirical evidence supports the notion that autonomous motivation impacts the evolution of habits (Gardner & Lally, 2018; Lally & Gardner, 2013). Theoretically, autonomous motivation may foster the development of habits through several, but not mutually exclusive, pathways: (1) directly, (2) indirectly via increased behavioural repetition, and (3) interactively by strengthening the effect of behaviours on habits development. For the first pathway, there is evidence that autonomous motivation is positively and directly associated with PA habits (Gardner & Lally, 2013; Radel, Pelletier, Pjevac, & Cheval, 2017), with one study reporting this direct effect within the COVID-19 lockdown context (Kaushal et al., 2020). Regarding the indirect effect, literature showed that autonomous motivation increases engagement in PA (see Ntoumanis et al., 2020 for a review), with two studies observing this association during the COVID-19 lockdown (Kaushal et al., 2020; Lesser & Nienhuis, 2020). In turn, a greater engagement in PA may promote the development of PA habits (Judah, Gardner, & Aunger, 2013). Regarding the interactive effect, previous work revealed that habits develop more quickly when PA behaviours are performed for autonomous reasons (Gardner & Lally, 2013; Radel et al., 2017).

Further, according to the self-activation hypothesis (Verplanken et al., 2008), the impact of autonomous motivation on the evolution of PA habits could be particularly high following a context change. Indeed, this hypothesis states that values influence behaviours when they are self-endorsed and cognitively activated (Verplanken et al., 2008). Based on the habit discontinuity and self-activation hypotheses, well-integrated

values are especially salient in individuals' thought system following a context change and, in turn, become particularly likely to guide behaviours. For instance, employees who recently moved house and held pro-environmental values were more likely to engage in sustainable commuting (Verplanken et al., 2008). Hence, because autonomous motivation reflects self-endorsed values (Ryan & Deci, 2017), it should play a key role in predicting PA behaviours and PA habits during lockdown.

The present study

The purpose of the present study was to investigate the association between the COVID-19 lockdown, a major context change, and the evolution of PA habits. Moreover, it aimed to examine the associations of PA behaviours and autonomous motivation with this evolution. Individuals living in France and Switzerland completed three online questionnaires in reference of three time-points (i.e., before, mid-, and end-lockdown) and reported their PA habits, PA behaviours, and motivation towards PA. Our specific hypotheses regarding how habits evolved and the associations of PA habits with behaviours and autonomous motivation are summarized in Table 1 and Figure 2.

Methods

Participants and procedure

Participants living in France or Switzerland were recruited through social media and word-of-mouth. They were asked to complete short online questionnaires, written in French, at three time-points, spanning different phases of lockdown (Figure 1). To be included in the study, participants had to live either in France or in Switzerland and be older than 18 years. No other exclusion criteria were specified to recruit a convenience sample as diverse as possible. Questionnaires were completed on a secured web survey hosted by the university supporting this study. The first questionnaire was launched on 30 March, during the early lockdown (i.e., two weeks after the start of restrictive measures). However, in this first questionnaire, participants were asked to retrospectively report their before-lockdown PA habits, behaviours, and motivation (e.g., 'This part of the questionnaire focuses on your physical activity behaviours before the lockdown period'). After completing the first questionnaire, participants were asked whether they would agree to answer to a second questionnaire and, if so, they were invited to give their e-mail address. The second questionnaire was launched on 13 April, corresponding to the early middle of the lockdown. The third questionnaire was launched on 8 May, corresponding to the end of lockdown. In the second and third questionnaires, they were invited to indicate their current mid- and end-lockdown PA habits, PA behaviours, and motivation. As an incentive, for each completed questionnaire, a 0.50 Euro donation was made to a foundation studying COVID-19 biomarkers. For sample size estimation, we relied on a RMSEA test and a likelihood ratio test, two approaches which have been widely used to estimate sample size in paths models (MacCallum, Browne, & Cai, 2006; Satorra & Saris, 1985). For the RMSEA test, the number of participants needed for a model including up to 33 degrees of freedom, with RMSEA [0.00; 0.08], power = 90%, and α-rate = .05 was N = 150 (MacCallum et al., 2006). For the likelihood ratio test, the number of participants for a model including up to 33 degrees of freedom, with a small effect size (d = .20), power = 90%, and an α-rate = .05 was N = 159 (Satorra & Saris, 1985). Given that we anticipated a loss of at least 40% from the first to the second wave (Gustavson, von Soest,

Table 1. Hypotheses, underlying theoretical mechanisms, and statistical analyses

Hypotheses		Theoretical mechanisms	Statistical analyses
H1a	PA habits would decline from before- to mid-lockdown	Habits are sensitive to context change (such as the COVID-19 lockdown), because of their cue-dependent nature	Mixed effect models
H1b	The evolution of PA habits would be moderated by before-lockdown habits: individuals with weak (vs. strong) before-lockdown habits would report an increase (vs. a decrease) in habits	The discontinuity hypothesis states that a context change (e.g., COVID-19 lockdown) can foster the development of habits among individuals with weak pre-existing habits	Mixed effect models
H2	The association between before- and mid-lockdown PA habits would be weaker than the association between mid- and end-lockdown PA habits	Habits are sensitive to context change (e.g., COVID-19 lockdown), because of their cue-dependent nature	Path analysis
H3	PA behaviours would be positively associated with PA habits at all three time-points (H3)	Behavioural repetition in a stable context (e.g., before or across the COVID-19 lockdown) is the most proximal driver of the evolution of habits	Path analysis
H4	Before-lockdown PA habits would not be significantly related to mid-lockdown PA behaviours, while mid-lockdown PA habits would be positively associated with end-lockdown PA behaviours	The discontinuity hypothesis states that, after a context change (e.g., COVID-19 lockdown), previous habits do not translate in behaviours, because of their cue-dependent nature	Path analysis
H5	The association between before- and mid-lockdown PA behaviours would be weaker than the association between mid- and end-lockdown PA behaviours	Past behaviours drive subsequent behaviours, especially when the context remains stable (e.g., from mid- to end-COVID-19 lockdown)	Path analysis
H6a	Autonomous motivation would be positively associated with PA habits at the three time-points	The self-activation hypothesis states that autonomous motivation directly favours the development of habits, especially after a context change (e.g., COVID-19 lockdown)	Path analysis
H6b	Autonomous motivation would be positively associated with PA behaviours at the three time-points	The self-activation hypothesis states that autonomous motivation favours the engagement in behaviours, especially after a context change (e.g., COVID-19 lockdown)	Path analysis
H7b	Autonomous motivation would moderate the relationships between PA behaviours and habits: the association between PA behaviours and habits would be stronger when people report strong (vs. weak) autonomous motivation	Habits develop more quickly when PA behaviours are performed for autonomous reasons	Path analysis

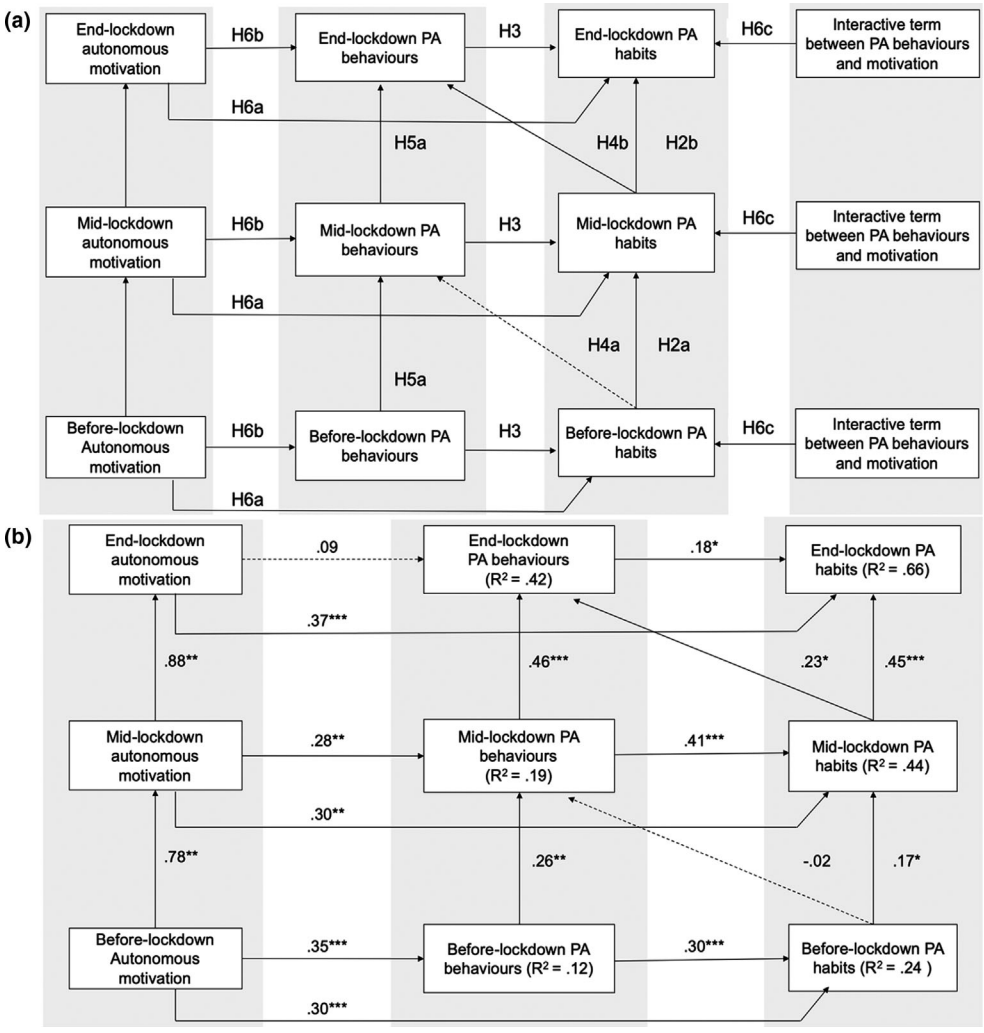

Figure 2. Path diagrams illustrating the hypothetical (a) and evidenced associations (b) of physical activity (PA) behaviours and autonomous motivation for PA with PA habits. *Note*. Significant and non-significant associations are represented with solid and dashed lines, respectively. Standardized beta coefficients (β) and *R*-squared (R^2) are reported. ***$p < .001$; **$p < .01$; *$p < .05$; ^$p < .10$. PA = physical activity. The interactive terms between PA behaviours and autonomous motivation are not represented in Figure 3B as these variables were not included in the final model.

Karevold, & Røysamb, 2012), we planned to recruit around 250 participants in the first wave. It should be noted, however, that the questionnaires remained open for 8 days, regardless of the amount of collected data.

A total of 283 participants living in France or Switzerland completed the first questionnaire (age = 40 ± 18 years; body mass index [BMI] = 22.8 ± 3.7 kg/m^2; 60% women; 73% French; see Table S1 for demographical and health-related information). A total of 123 participants completed the second questionnaire (age = 41 ± 19 years; BMI = 22.8 ± 3.9 kg/m^2; 70% women; 76% French). A total of 113 participants

completed the third questionnaire (age = 43 ± 18 years; BMI = 22.7 ± 3.5 kg/m^2; 68% women; 76% French).

Measures

PA habits

Physical activity habits were assessed using the 4-item automaticity subscale of the Self-Reported Habit Index (Gardner, Abraham, Lally, & de Bruijn, 2012; Verplanken & Orbell, 2003) in reference of before, the middle, and the end of lockdown. Items began with the proposition: 'In general, the decision to engage in PA is something that...' and was completed by four statements (e.g., 'I do automatically'). Participants answered on a Likert scale ranging from 1 (*Strongly disagree*) to 7 (*Strongly agree*). Items were averaged to create a global score (Cronbach' αs > .87; Table 2).

Total PA

Total PA was assessed in reference of before, the middle, and the end of lockdown using an adapted version of the International PA Questionnaire (Craig et al., 2003), a well-validated tool among healthy adults (Hagströmer, Oja, & Sjöström, 2006). Participants were asked to estimate the weekly average time (in min) spent in vigorous and moderate PA during leisure time. Times reported in each intensity were summed to obtain weekly time spent in moderate-to-vigorous PA.

Autonomous motivation for PA

Autonomous motivation towards PA was assessed using a 4-item scale (Brunet, Gunnell, Gaudreau, & Sabiston, 2015; Sheldon & Elliot, 1998) in reference of before, the middle, and the end of lockdown. Participants were invited to rate the degree to which the statements reflected their motivation to adopt a physically active lifestyle during leisure time. Answers were given on a Likert scale ranging from 1 (*Not at all for this reason*) to 7

Table 2. Descriptive statistics

Variables	Mean ± *SD*	Range	α	ICC
PA habits				
Before-lockdown	4.60 ± 1.79	1–7	.88	.71
Mid-lockdown	4.06 ± 1.75	1–7	.89	
End-lockdown	4.07 ± 1.79	1–7	.91	
Moderate-to-vigorous PA (min/week)				
Before-lockdown	232 ± 195	0–960	–	.56
Mid-lockdown	224 ± 187	0–945	–	
End-lockdown	224 ± 199	0–1260	–	
Autonomous motivation				
Before-lockdown	6.01 ± 1.18	1–7	.86	.89
Mid-lockdown	6.07 ± 1.22	1–7	.87	
End-lockdown	5.97 ± 1.19	1–7	.89	

ICC = intra-class correlations coefficient; PA = physical activity; SD = standard-deviation. ICC reflects stability in the construct at the participant-level across time.

(*Totally for this reason*). Autonomous motivation was calculated as the average response to the 2-item intrinsic (e.g., 'Because of the pleasure I feel during PA') and 2-item identified (e.g., 'Because I believe it is really important to be physically active') sub-scales (Cronbach' αs > .86; Table 2).

Statistical analyses

To examine the evolution of PA habits across time (H1), linear mixed effect models were computed. This approach handles missing data and takes into account the nested structure of the data (i.e., multiple measurement from the same individuals; Boisgontier & Cheval, 2016; Judd, Westfall, & Kenny, 2017). In the first step, the linear and quadratic effects of time on habits were entered as fixed effects to assess the evolution of PA habits over time. Then, to examine the moderating influence of before-lockdown PA habits, a 2-way interaction between time (both linear and quadratic) and before-lockdown PA habits was added. Based upon the stems of the 7-point Likert scale, participants were categorized as having weak (i.e., a score <3), moderate (a score ≥3 and <6), or strong (i.e., a score ≥6) PA habits before the lockdown. Models included a random intercept for participants and a random slope for linear time. Standardized beta coefficients (β) with 95% confidence interval (95% CI) are reported. Models were built using the lmerTest and lme4 packages (Bates, Mächler, Bolker, & Walker, 2015; Kuznetsova, Brockhoff, & Christensen, 2015), in R software ® (R Core Team, 2016).

Second, the associations between PA habits, PA behaviours, and autonomous motivation across time were examined using path analysis (Brown, 2006). Based on previous work (Judah, Gardner, Kenward, DeStavola, & Aunger, 2018), a longitudinal model was computed and included all hypothetical pathways (see Figure 2A). Regarding missing data, after conducting a Hawkins' test, there was no sufficient evidence to reject that values were missing at complete random (p =.452; Jamshidian, Jalal, & Jansen, 2014). Hence, a full information maximum likelihood (FIML) approach was used in subsequent analysis. In comparison with case deletion or multiple imputation, this approach has been shown to produce unbiased estimates (Enders & Bandalos, 2001) and valid model fit information (Enders, 2001). Given the high rate of missing values in our sample, auxiliary variables were also added to the fitted model to reduce bias in estimation (Collins, Schafer, & Kam, 2001; Graham, 2003). The following auxiliary variables were included: participants' gender, age, body mass index, zone of residence, number of children, and number of individuals at home during the COVID-19 lockdown (see Table S1 for descriptive statistics). Although some auxiliary variables displayed missing values, previous research suggests that it may not be a problematic issue (Enders, 2008). Multiple indices were computed to examine the goodness of the fitted model: the root mean square error of approximation (RMSEA), the standardized root mean squared residual (SRMR), the comparative fit index (CFI), and the Tucker–Lewis index (TLI; Brown, 2006; MacCallum & Austin, 2000). An acceptable model fit is indicated by RMSEA, SRMR <.08, and TLI, CFI >.90. Given the complexity of the hypothesized model, we planned to adopt a backward strategy (Kline, 2015), whereby variables that do not improve the fit of the model are removed, based on inspection of the z Wald test statistic. β and 95% CI were computed to examine the strength of the associations between variables. All analyses were conducted using the lavaan package (Rosseel, 2012). To compare the strength of the associations, the overlapping of β and 95% CI was examined. When coefficient intervals overlapped by less than 50%, β coefficients could be considered significantly different from each other, with p <.05 (Cumming, 2009; Figure S1).

Results

Before lockdown, participants engaged in moderate-to-vigorous PA for 232 ± 195 min a week (with 53 % above the recommended 150-min threshold), reported moderate PA habits (M = 4.60 ± 1.79) and a high autonomous motivation (M = 6.01 ± 1.18; Table 2).

Mixed effect modelling revealed a significant effect of quadratic time on PA habits (p <.001), with PA habits decreasing from before to mid-lockdown (β = −.16, 95% CI [−.25; −.07], p <.001), but not significantly evolving from mid- to end-lockdown (β =.13, 95% CI [−.00;.27], p =.058). A significant interaction between time and before-lockdown PA habits was observed (Figure 3). Simple effects revealed that participants with strong before-lockdown PA habits exhibited a decline in PA habits from before- to mid-lockdown (β = −.30, 95% CI [−.46; −.13], p <.001), but PA habits did not significantly evolve from mid- to end-lockdown (β =.26; 95% CI [−.05;.56], p =.100). On the contrary, participants with weak before-lockdown PA habits exhibited an increase in PA habits from before- to mid-lockdown (β =.58, 95% CI [.40;.75], p <.001), but this increase was significantly decelerated from mid- to end-lockdown (β = −.51, 95% CI [−.84; −.20], p =.002). Evolution of PA behaviours and autonomous motivation across time is presented in Supporting Information (Figures S2 and S3).

In the path analysis, when all the hypothetical pathways were included, the model demonstrated inadequate fit to the data (CFI = .886; TLI = .829, RMSEA = .083 90% CI [0.066; 0.100], SRMR = .070). Interactive terms between PA behaviours and autonomous motivation at the three time-points did not improve model fit and were non-significant (zs < 1.80, ps > .072). When these associations were removed, the adjusted model showed acceptable fit to the data (CFI = .994; TLI = .988, RMSEA = .026, 90% CI [0.000; 0.061], SRMR = .027) and was thus retained (Figure 2B). The model explained 24%, 44%, and 66% of variance in PA habits before, in the middle, and at the end of lockdown, respectively, and 12%, 19%, and 42% of PA behaviours before, in the middle, and at the end of lockdown.

Associations between PA habits across time (H1a and H1b)

Before-lockdown PA habits were significantly associated with mid-lockdown PA habits (β = .17, CI = [0.02; 0.32], p = .035). Mid-lockdown PA habits were also significantly

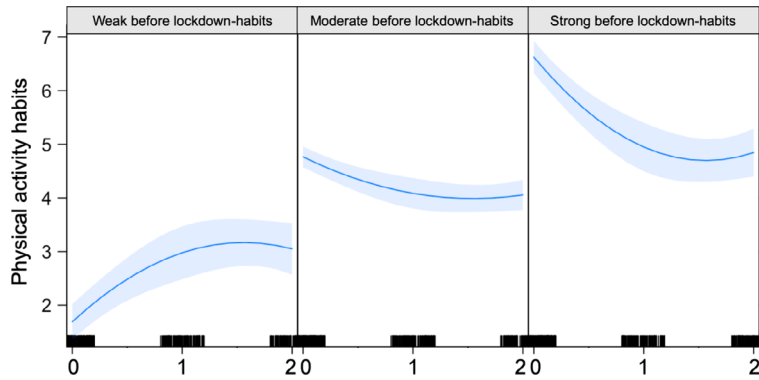

Figure 3. Evolution of PA habits across time, as a function of before-lockdown PA habits. *Note.* Evolution of PA habits was plotted as a function of the quadratic effect of time. PA: Physical activity; Time 0: before-lockdown; Time 1: mid-lockdown; Time 2: end-lockdown.

associated with end-lockdown PA habits (β = .45, CI = [0.30; 0.59], $p < .001$). The association of PA habits from before-lockdown to mid-lockdown was significantly lower than that from mid-lockdown to end-lockdown (percentage of CIs' overlapping < 50%).

Associations between PA behaviours and PA habits across time (H2)

Physical activity behaviours were positively associated with PA habits at the three time-points (β = .30, 95% CI [0.19; 0.41], $p < .001$ for before-lockdown, β = .41, 95% CI [0.27; 0.56], $p < .001$ for mid-lockdown, β = .18, 95% CI [0.05; 0.31], $p = .012$ for end-lockdown). No significant difference in the magnitude of these associations was found (percentage of CIs' overlapping > 50%).

Associations between previous PA habits and behaviours with consecutive PA behaviours across time (H3a, H3b, H3c, H3d)

Before-lockdown PA habits were not significantly associated with mid-lockdown PA behaviours (β = −.02, 95% CI [−0.20; 0.16], $p = .837$). Mid-lockdown PA habits were positively associated with end-lockdown PA behaviours (β = .23, 95% CI [0.03; 0.42], $p = .021$). The association between before-lockdown PA habits and mid-lockdown PA behaviours was significantly lower than that of mid-lockdown PA habits and end-lockdown PA behaviours (percentage of CIs' overlapping < 50%).

Before-lockdown PA behaviours were positively associated with mid-lockdown PA behaviours (β = .26, 95% CI [0.10; 0.43], $p = .002$). Mid-lockdown PA behaviours were positively associated with end-lockdown PA behaviours (β = .46, 95% CI [0.29; 0.64] $p < .001$). The association between before-lockdown PA behaviours and mid-lockdown PA behaviours was significantly lower than that of mid-lockdown PA behaviours and end-lockdown PA behaviours (percentage of CIs' overlapping < 50%).

Associations of autonomous motivation with PA habits across time (H4a, H4b, H4c)

Autonomous motivation was directly and positively related to PA habits at the three time-points (β = .30, 95% CI [0.19; 0.41], $p < .001$ for before-lockdown; β = .30, 95% CI [0.15; 0.45], $p = .001$ for mid-lockdown; β = .37, 95% CI [0.25; 0.50], $p < .001$ for end-lockdown). No significant differences in the magnitude of these three associations were found (percentage of CIs' overlapping > 50%).

Autonomous motivation was significantly related to before-lockdown PA behaviours (β = .35, 95% CI [0.23; 0.46], $p < .001$) and to mid-lockdown behaviours (β = .28, 95% CI [0.11; 0.45, $p = .001$). No significant difference in the magnitude of these associations was found (percentage of CIs' overlapping > 50%). However, but autonomous motivation was not significantly associated with end-lockdown PA behaviours (β = .09, 95% CI [−0.07; 0.26], $p = .270$).

Discussion

Main findings

The present study investigated the association between the COVID-19 lockdown, a major context change, and the evolution of PA habits. Moreover, it aimed to examine the association of PA behaviours and autonomous motivation with this evolution. Findings

revealed a global decrease in PA habits across the COVID-19 lockdown, but this evolution depended on before-lockdown PA habits. Individuals with strong before-lockdown PA habits exhibited a sharp decrease, while individuals with weak before-lockdown PA habits demonstrated the reverse pattern (i.e., a short increase in habit strength, then followed by a quick deceleration). These findings, in addition to the weak association between before-lockdown and mid-lockdown habits, support the assumption that habits are sensitive to a context change. In addition, results showed that before-lockdown PA habits were not significantly associated with PA behaviours once the context changed. However, engaging in renewed PA behaviours during lockdown and exhibiting autonomous motivation counteracted such disruption of PA habits.

Comparisons with other studies

Findings showed that PA habit strength decreased following a context change – especially among individuals with strong before-lockdown habits. These results are in line with the discontinuity hypothesis (Verplanken et al., 2008), proposing that a context change can disrupt existing habits (Verplanken & Wood, 2006). Nevertheless, while previous studies only indirectly inferred PA habits' disruption through changes in behaviours (Fredslund & Leppin, 2019; Wood et al., 2005), our study is the first to provide a formal test of this assumption by assessing habits both before and after a context change. By contrast, an increase in PA habits was observed among individuals with weak before-lockdown habits. As proposed by the discontinuity hypothesis (Verplanken et al., 2008), this finding may result from the fact that a context change can also foster the development of habits. One possible adjuvant of this development may rely on the disruption of other habits, such as the ones related to sedentary behaviours. Indeed, while sedentary opportunities act as temptations, distracting individuals from their intention to be physically active (Cheval et al., 2018; Cheval, Sarrazin, Boisgontier, & Radel, 2017; Cheval, Sarrazin, Isoard-Gautheur, Radel, & Friese, 2015), lockdown settings may have reduced individuals' exposure to some of these cues. For example, someone who was used to have a drink in a bar or to go to the cinema after work was deprived of such opportunities during lockdown, thereby opening new perspectives on the adoption of more physically active behaviours. Nevertheless, this reasoning only applies for outside-home sedentary behaviours as, on the opposite, individuals were particularly exposed to sedentary opportunities at home during lockdown (e.g., watching TV).

Further, results revealed that before-lockdown PA habits were not significantly related with mid-lockdown PA behaviours. These results also align with the discontinuity hypothesis (Verplanken et al., 2008), which proposes that pre-existing habits do not drive behaviours after a context change. Although two previous studies observed significant associations between previous habits and PA behaviours during lockdown (Kaushal et al., 2020; Rhodes et al., 2020), the strength of the association (r = .24 for Rhodes et al., 2020; r = .34 for Kaushal et al., 2020) was weaker than the commonly reported relationship between habits and behaviours (r = .43; Gardner et al., 2011). These results can be explained by the fact that, during lockdown, some contextual cues were no longer encountered during lockdown (e.g., going to the gym club on Wednesdays after work with colleagues), which, in turn, made habits dormant and impeded their influence on behaviours (Gardner, 2012). Likewise, the discontinuity to cue exposure is also likely to decrease PA habits, which in turn became too weak to instigate behaviours.

By contrast, mid-lockdown PA habits were positively associated with end-lockdown PA behaviours. This result suggests that people may have quickly adjusted existing habits

(e.g., exercising after a teleworking session rather than after a day spent in office) or developed new habits (e.g., cycling around home with one's children) that could effectively guide PA behaviours in the new context. Nevertheless, other mechanisms such as the re-activation of old habits (e.g., coming back to one's parents' home and walking around the neighbourhood as one used to do before leaving parental home) might also explain this pattern. Moreover, the association between previous and consecutive PA behaviours was more salient from mid- to end-lockdown, than from the before- to end-lockdown. In other words, similarly to the influence of habits on behaviours, past behaviours seem especially likely to drive consecutive behaviours when the context remains stable (Ouellette & Wood, 1998). Of note, this study focused on the associations between PA habits and PA behaviours, following the COVID-19 lockdown. However, a growing number of studies highlight the numerous and complex pathways through which habits may explain, in conjunction with other socio-cognitive variable (e.g., intention, self-regulatory skills) PA behaviours (Fleig et al., 2013; Gardner, Lally, et al., 2020). In this perspective, a more comprehensive account of changes in PA behaviours could be provided by including additional variables alongside with habits.

Autonomous motivation was directly and positively associated with PA habits before and during lockdown. These results align with the idea that autonomous motivation can foster the development of PA habits (Gardner & Lally, 2018; Lally & Gardner, 2013). Moreover, as found in previous studies conducted within COVID-19 lockdowns in the United Stated and Australia (Kaushal et al., 2020; Lesser & Nienhuis, 2020), autonomous motivation was positively associated with before and mid-PA behaviours. In turn, these higher levels of PA behaviours were positively related to PA habits. These results support the mediated association of autonomous motivation with PA habits (Gardner & Lally, 2013; Judah et al., 2013; Radel et al., 2017). They also align with the self-activation hypothesis which states that, after a context change, autonomous motivation is especially likely to guide behaviours, thereby potentially energizing the development of habits (Verplanken et al., 2008).

However, autonomous motivation was not associated with end-lockdown PA behaviours at the end of the lockdown, nor moderated the association between PA behaviours and habits. This non-expected finding may result from the fact that autonomous motivation can only foster PA behaviours when individuals have control over the considered behaviour (Hagger & Chatzisarantis, 2014). Yet, during lockdown, behaviours for which individuals were autonomously motivated might have been disallowed by restrictive measures (e.g., swimming, playing football in a club). Hence, it seems plausible that, at the end of lockdown, some individuals were no longer engaging in PA for autonomous reasons (e.g., the intrinsic pleasure of the performed activity). A second explanation lies in the fact that the COVID-19 lockdown represents a unique period, which cannot be compared with other context changes, such as moving house (Verplanken et al., 2008). In particular, the COVID-19 lockdown was imposed on individuals and transitory (at the time of the study, it was expected to last for about 3 months in France and Switzerland). Hence, at odds with the self-activation hypothesis (Verplanken et al., 2008), this context change might not have triggered a long-term activation of any particular self-endorsed values for action.

Strengths and limitations

The present study has several strengths. At the theoretical level, the present study advances existing literature on PA habits by providing direct evidence about the

association between a context change and the evolution of PA habits. Further, it sheds light on the role of behaviours and autonomous motivation in this evolution, in particular by testing the self-activation hypothesis on PA habits. Moreover, the use of a longitudinal design with repeated measurements of PA habits, behaviours, and autonomous motivation was also a strength.

However, this study includes at least four limitations. First, the Self-Report Habit Index was used to capture a global habit strength – that is, an overall perception of the automaticity of a category of actions, such as physical activity, across multiple contexts – (Gardner et al., 2012) but the scale did not specify any cue–behaviour links (see Sniehotta & Presseau, 2012 for a discussion). Consequently, the way we used the scale prevents the disentanglement of whether the evolution of habits and of their associations with behaviours results from dormant habits, a degradation of before-lockdown habits, or to the development of new PA habits. Future studies assessing specific PA habits and the cues on which they are based upon should seek to unravel these different mechanisms. Similarly, we did not assess the extent to which participants experienced a change in their before-lockdown PA behaviours due to the COVID-19 lockdown (e.g., walking around home was not as strongly affected by the context as practicing in a sport or in fitness club). Accordingly, as the context would have differentially impacted PA behaviours depending on the type of PA participants usually engaged in, measuring the extent to which individuals experienced a change in their PA behaviours is recommended for future research. Second, the reliance on self-reported measures has been criticized for the assessment of PA habits (Hagger, Rebar, Mullan, Lipp, & Chatzisarantis, 2015; Rebar, Gardner, Rhodes, & Verplanken, 2018) and behaviours (Dyrstad, Hansen, Holme, & Anderssen, 2014). Furthermore, before-lockdown variables were retrospectively assessed during the early period of the COVID-19 lockdown, which might have resulted in recall bias. Third, our sample size was relatively small, with a somewhat large attrition rate, thereby limiting the generalization of the present findings. Fourth, this longitudinal design did not enable to infer causality in the associations between the variables.

Conclusion

This study drew on the COVID-19 lockdown to examine how PA habits evolved following a major context change. Our findings suggest that, although such disruptive settings can weaken existing habits, individuals can quickly renegotiate or develop new PA habits. Encouraging the engagement in PA behaviours and manifesting an autonomous motivation towards PA may be important in interventions aiming at sustaining PA habits after a context change.

Conflicts of interest

All authors declare no conflict of interest.

Author contributions

Silvio Maltagliati (Conceptualization; Data curation; Formal analysis; Methodology; Software; Visualization; Writing – original draft) Amanda Rebar (Conceptualization; Methodology; Writing – review & editing) Layan Fessler (Investigation; Writing – review & editing) Cyril Forestier (Writing – review & editing) Philippe Sarrazin (Writing – review &

editing) Aïna Chalabaev (Writing – review & editing) David Sander (Writing – review & editing) Hamsini Sivaramakrishnan (Writing – review & editing) Dan Orsholits (Writing – review & editing) Matthieu P. Boisgontier (Writing – review & editing) Nikos Ntoumanis (Writing – review & editing) Benjamin Gardner (Conceptualization; Methodology; Writing – review & editing) Boris Cheval (Conceptualization; Data curation; Funding acquisition; Investigation; Methodology; Project administration; Resources; Supervision; Validation; Writing – original draft)

Data availability statement

The data sets generated and/or analysed during the current study are available in the Zenodo repository [https://doi.org/10.5281/zenodo.4264162].

References

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Boisgontier, M. P., & Cheval, B. (2016). The anova to mixed model transition. *Neuroscience & Biobehavioral Reviews*, *68*, 1004–1005. https://doi.org/10.1016/j.neubiorev.2016.05.034

Brown, T. A. (2006). Confirmatory factor analysis for applied research. *Choice Reviews Online*, *44* (05), 44-2769. https://doi.org/10.5860/CHOICE.44-2769

Brunet, J., Gunnell, K. E., Gaudreau, P., & Sabiston, C. M. (2015). An integrative analytical framework for understanding the effects of autonomous and controlled motivation. *Personality and Individual Differences*, *84*, 2–15. https://doi.org/10.1016/j.paid.2015.02.034

Cheval, B., Radel, R., Neva, J. L., Boyd, L. A., Swinnen, S. P., Sander, D., & Boisgontier, M. P. (2018). Behavioral and neural evidence of the rewarding value of exercise behaviors: A systematic review. *Sports Medicine*, *48*, 1389–1404. https://doi.org/10.1007/s40279-018-0898-0

Cheval, B., Sarrazin, P., Boisgontier, M. P., & Radel, R. (2017). Temptations toward behaviors minimizing energetic costs (BMEC) automatically activate physical activity goals in successful exercisers. *Psychology of Sport and Exercise*, *30*, 110–117. https://doi.org/10.1016/j.psychsport.2017.02.006

Cheval, B., Sarrazin, P., Isoard-Gautheur, S., Radel, R., & Friese, M. (2015). Reflective and impulsive processes explain (in)effectiveness of messages promoting physical activity: A randomized controlled trial. *Health Psychology*, *34*(1), 10–19. https://doi.org/10.1037/hea0000102

Cheval, B., Sivaramakrishnan, H., Maltagliati, S., Fessler, L., Forestier, C., Sarrazin, P., . . . Boisgontier, M. P. (2020). Relationships between changes in self-reported physical activity, sedentary behaviour and health during the coronavirus (COVID-19) pandemic in France and Switzerland. *Journal of Sports Sciences*, *39*, 699–704. https://doi.org/10.1080/02640414.2020.1841396

Collins, L. M., Schafer, J. L., & Kam, C. M. (2001). A comparison of inclusive and restrictive strategies in modern missing data procedures. *Psychological Methods*, *6*, 330–351. https://doi.org/10.1037/1082-989X.6.4.330

Constandt, B., Thibaut, E., De Bosscher, V., Scheerder, J., Ricour, M., & Willem, A. (2020). Exercising in times of lockdown: An analysis of the impact of COVID-19 on levels and patterns of exercise among adults in Belgium. *International Journal of Environmental Research and Public Health*, *17*, 4144. https://doi.org/10.3390/ijerph17114144

Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., . . . Oja, P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & Science in Sports & Exercise*, *35*, 1381–1395. https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Cumming, G. (2009). Inference by eye: Reading the overlap of independent confidence intervals. *Statistics in Medicine*, *28*(2), 205–220. https://doi.org/10.1002/sim.3471

Danner, U. N., Aarts, H., & de Vries, N. K. (2007). Habit formation and multiple means to goal attainment: Repeated retrieval of target means causes inhibited access to competitors. *Personality and Social Psychology Bulletin*, *33*, 1367–1379. https://doi.org/10.1177/0146167207303948

Deschasaux-Tanguy, M., Druesne-Pecollo, N., Esseddik, Y., Szabo de Edelenyi, F., Alles, B., Andreeva, V. A., … Touvier, M. (2021). Diet and physical activity during the coronavirus disease 2019 (COVID-19) lockdown (March-May 2021): results from the French NutriNet-Santé cohort study. *American Journal of Clinical Nutrition*. https://doi.org/10.1093/ajcn/nqaa336

Dyrstad, S. M., Hansen, B. H., Holme, I. M., & Anderssen, S. A. (2014). Comparison of self-reported versus accelerometer-measured physical activity. *Medicine & Science in Sports & Exercise*, *46* (1), 99–106. https://doi.org/10.1249/MSS.0b013e3182a0595f

Enders, C. K. (2001). The impact of nonnormality on full information maximum-likelihood estimation for structural equation models with missing data. *Psychological Methods*, *6*, 352–370. https://doi.org/10.1037/1082-989X.6.4.352

Enders, C. K. (2008). A note on the use of missing auxiliary variables in full information maximum likelihood-based structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal*, *15*, 434–448. https://doi.org/10.1080/10705510802154307

Enders, C., & Bandalos, D. (2001). The relative performance of full information maximum likelihood estimation for missing data in structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal*, *8*, 430–457. https://doi.org/10.1207/S15328007SEM0803_5

Fleig, L., Pomp, S., Parschau, L., Barz, M., Lange, D., Schwarzer, R., & Lippke, S. (2013). From intentions via planning and behavior to physical exercise habits. *Psychology of Sport and Exercise*, *14*, 632–639. https://doi.org/10.1016/j.psychsport.2013.03.006

Fournier, M., d'Arripe-Longueville, F., Rovere, C., Easthope, C. S., Schwabe, L., El Methni, J., & Radel, R. (2017). Effects of circadian cortisol on the development of a health habit. *Health Psychology*, *36*, 1059–1064. https://doi.org/10.1037/hea0000510

Fredslund, E. K., & Leppin, A. (2019). Can the Easter break induce a long-term break of exercise routines? An analysis of Danish gym data using a regression discontinuity design. *BMJ Open*, *9* (2), e024043. https://doi.org/10.1136/bmjopen-2018-024043

Gallè, F., Sabella, E. A., Ferracuti, S., De Giglio, O., Caggiano, G., Protano, C., … Napoli, C. (2020). Sedentary behaviors and physical activity of Italian undergraduate students during lockdown at the time of CoViD−19 pandemic. *International Journal of Environmental Research and Public Health*, *17*, 6171. https://doi.org/10.3390/ijerph17176171

Gardner, B. (2012). Habit as automaticity, not frequency. *European Health Psychologist*, *14*(2), 32–36.

Gardner, B. (2015). A review and analysis of the use of 'habit' in understanding, predicting and influencing health-related behaviour. *Health Psychology Review*, *9*(3), 277–295. https://doi.org/10.1080/17437199.2013.876238

Gardner, B., Abraham, C., Lally, P., & de Bruijn, G.-J. (2012). Towards parsimony in habit measurement: Testing the convergent and predictive validity of an automaticity subscale of the Self-Report Habit Index. *International Journal of Behavioral Nutrition and Physical Activity*, *9*(1), 102. https://doi.org/10.1186/1479-5868-9-102

Gardner, B., de Bruijn, G.-J., & Lally, P. (2011). A systematic review and meta-analysis of applications of the self-report habit index to nutrition and physical activity behaviours. *Annals of Behavioral Medicine*, *42*(2), 174–187. https://doi.org/10.1007/s12160-011-9282-0

Gardner, B., & Lally, P. (2013). Does intrinsic motivation strengthen physical activity habit? Modeling relationships between self-determination, past behaviour, and habit strength. *Journal of Behavioral Medicine*, *36*, 488–497. https://doi.org/10.1007/s10865-012-9442-0

Gardner, B., & Lally, P. (2018). Modelling habit formation and its determinants. In B. Verplanken (Eds.), *The psychology of habit: Theory, mechanisms, change, and contexts* (pp. 207–229). Switzerland: Springer. https://doi.org/10.1007/978-3-319-97529-0_12

Gardner, B., Lally, P., & Rebar, A. L. (2020). Does habit weaken the relationship between intention and behaviour? Revisiting the habit-intention interaction hypothesis. *Social and Personality Psychology Compass*, *14*(8), e12553. https://doi.org/10.1111/spc3.12553

Gardner, B., Rebar, A. L., & Lally, P. (2020). 'Habitually deciding' or 'habitually doing'? A response to Hagger (2019). *Psychology of Sport and Exercise*, *47*, 101539. https://doi.org/10.1016/j.psychsport.2019.05.008

Graham, J. W. (2003). Adding missing-data-relevant variables to FIML-based structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal*, *10*(1), 80–100. https://doi.org/10.1207/S15328007SEM1001_4

Gustavson, K., von Soest, T., Karevold, E., & Røysamb, E. (2012). Attrition and generalizability in longitudinal studies: Findings from a 15-year population-based study and a Monte Carlo simulation study. *BMC Public Health*, *12*, 918. https://doi.org/10.1186/1471-2458-12-918

Hagger, M. S., & Chatzisarantis, N. L. D. (2014). An integrated behavior change model for physical activity. *Exercise and Sport Sciences Reviews*, *42*(2), 62–69. https://doi.org/10.1249/JES.0000000000000008

Hagger, M. S., Chatzisarantis, N. L. D., & Biddle, S. J. H. (2002). A meta-analytic review of the theories of reasoned action and planned behavior in physical activity: Predictive validity and the contribution of additional variables. *Journal of Sport and Exercise Psychology*, *24*(1), 3–32. https://doi.org/10.1123/jsep.24.1.3

Hagger, M. S., Rebar, A. L., Mullan, B., Lipp, O. V., & Chatzisarantis, N. L. D. (2015). The subjective experience of habit captured by self-report indexes may lead to inaccuracies in the measurement of habitual action. *Health Psychology Review*, *9*(3), 296–302. https://doi.org/10.1080/17437199.2014.959728

Hagströmer, M., Oja, P., & Sjöström, M. (2006). The International Physical Activity Questionnaire (IPAQ): A study of concurrent and construct validity. *Public Health Nutrition*, *9*, 755–762. https://doi.org/10.1079/PHN2005898

Jamshidian, M., Jalal, S., & Jansen, C. (2014). MissMech: An R package for testing homoscedasticity, multivariate normality, and missing completely at random (MCAR). *Journal of Statistical Software*, *56*(6), 1–31. https://doi.org/10.18637/jss.v056.i06

Judah, G., Gardner, B., & Aunger, R. (2013). Forming a flossing habit: An exploratory study of the psychological determinants of habit formation. *British Journal of Health Psychology*, *18*, 338–353. https://doi.org/10.1111/j.2044-8287.2012.02086.x

Judah, G., Gardner, B., Kenward, M. G., DeStavola, B., & Aunger, R. (2018). Exploratory study of the impact of perceived reward on habit formation. *BMC Psychology*, *6*(1), 62. https://doi.org/10.1186/s40359-018-0270-z

Judd, C. M., Westfall, J., & Kenny, D. A. (2017). Experiments with more than one random factor: Designs, analytic models, and statistical power. *Annual Review of Psychology*, *68*, 601–625. https://doi.org/10.1146/annurev-psych-122414-033702

Kaushal, N., Keith, N., Aguiñaga, S., & Hagger, M. S. (2020). Social cognition and socioecological predictors of home-based physical activity intentions, planning, and habits during the COVID-19 pandemic. *Behavioral Sciences*, *10*(9), 133. https://doi.org/10.3390/bs10090133

Kaushal, N., & Rhodes, R. E. (2015). Exercise habit formation in new gym members: A longitudinal study. *Journal of Behavioral Medicine*, *38*, 652–663. https://doi.org/10.1007/s10865-015-9640-7

Kline, R. B. (2015). *Principles and practice of structural equation modeling* (4th ed.). New York: Guilford Publications.

Kuznetsova, A., Brockhoff, P. B., & Christensen, R. H. B. (2015). Package 'lmertest.' *R Package Version*, *2*(0).

Lally, P., & Gardner, B. (2013). Promoting habit formation. *Health Psychology Review*, *7*(sup1), S137–S158. https://doi.org/10.1080/17437199.2011.603640

Lally, P., Van Jaarsveld, C. H. M., Potts, H. W. W., & Wardle, J. (2010). How are habits formed: Modelling habit formation in the real world. *European Journal of Social Psychology*, *40*, 998–1009. https://doi.org/10.1002/ejsp.674

Lesser, I. A., & Nienhuis, C. P. (2020). The impact of COVID-19 on physical activity behavior and well-being of Canadians. *International Journal of Environmental Research and Public Health*, *17*, 3899. https://doi.org/10.3390/ijerph17113899

MacCallum, R. C., & Austin, J. T. (2000). Applications of structural equation modeling in psychological research. *Annual Review of Psychology*, *51*(1), 201–226. https://doi.org/10.1146/annurev.psych.51.1.201

MacCallum, R. C., Browne, M. W., & Cai, L. (2006). Testing differences between nested covariance structure models: Power analysis and null hypotheses. *Psychological Methods*, *11*(1), 19–35. https://doi.org/10.1037/1082-989X.11.1.19

Maher, J. P., Rebar, A. L., & Dunton, G. F. (2021). The influence of context stability on physical activity and sedentary behaviour habit and behaviour: An ecological momentary assessment study. *British Journal of Health Psychology*. https://doi.org/10.1111/bjhp.12509

McEachan, R. R. C., Conner, M., Taylor, N. J., & Lawton, R. J. (2011). Prospective prediction of health-related behaviours with the theory of planned behaviour: A meta-analysis. *Health Psychology Review*, *5*(2), 97–144. https://doi.org/10.1080/17437199.2010.521684

Neal, D. T., Wood, W., Labrecque, J. S., & Lally, P. (2012). How do habits guide behavior? Perceived and actual triggers of habits in daily life. *Journal of Experimental Social Psychology*, *48*, 492–498. https://doi.org/10.1016/j.jesp.2011.10.011

Ntoumanis, N., Ng, J. Y. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., … Williams, G. C. (2020). A meta-analysis of self-determination theory-informed intervention studies in the health domain: Effects on motivation, health behavior, physical, and psychological health. *Health Psychology Review*, *3*, 1–31. https://doi.org/10.1080/17437199.2020.1718529

Orbell, S., & Verplanken, B. (2010). The automatic component of habit in health behavior: Habit as cue-contingent automaticity. *Health Psychology*, *29*, 374–383. https://doi.org/10.1037/a0019596

Ouellette, J. A., & Wood, W. (1998). Habit and intention in everyday life: The multiple processes by which past behavior predicts future behavior. *Psychological Bulletin*, *124*(1), 54–74. https://doi.org/10.1037/0033-2909.124.1.54

Phillips, L. A., & Gardner, B. (2016). Habitual exercise instigation (vs. execution) predicts healthy adults' exercise frequency. *Health Psychology*, *35*(1), 69–77. https://doi.org/10.1037/hea0000249

Pimm, R., Vandelanotte, C., Rhodes, R. E., Short, C., Duncan, M. J., & Rebar, A. L. (2016). Cue consistency associated with physical activity automaticity and behavior. *Behavioral Medicine*, *42*(4), 248–253. https://doi.org/10.1080/08964289.2015.1017549

R Core Team (2016). *R A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing.

Radel, R., Pelletier, L., Pjevac, D., & Cheval, B. (2017). The links between self-determined motivations and behavioral automaticity in a variety of real-life behaviors. *Motivation and Emotion*, *41*, 443–454. https://doi.org/10.1007/s11031-017-9618-6

Rebar, A. L., Dimmock, J. A., Jackson, B., Rhodes, R. E., Kates, A., Starling, J., & Vandelanotte, C. (2016). A systematic review of the effects of non-conscious regulatory processes in physical activity. *Health Psychology Review*, *10*, 395–407. https://doi.org/10.1080/17437199.2016.1183505

Rebar, A. L., Gardner, B., Rhodes, R. E., & Verplanken, B. (2018). The measurement of habit. In B. Verplanken (Eds.), *The psychology of habit. Theory, mechanims, change, and contexts* (pp. 31–49). Switzerland: Springer.

Rebar, A. L., Stanton, R., Geard, D., Short, C., Duncan, M. J., & Vandelanotte, C. (2015). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychology Review*, *9*, 366–378. https://doi.org/10.1080/17437199.2015.1022901

Rhodes, R. E., Liu, S., Lithopoulos, A., Zhang, C., & Garcia-Barrera, M. A. (2020). Correlates of perceived physical activity transitions during the COVID-19 pandemic among Canadian adults. *Applied Psychology: Health and Well-Being*, *12*, 1157–1182. https://doi.org/10.1111/aphw.12236

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling. *Journal of Statistical Software*, *48*(1), 1–36. https://doi.org/10.18637/jss.v048.i02

Ryan, R., & Deci, E. (2017). *Self-determination theory. Basic psychological needs in motivation, development and wellness*. New York: Guilford Press.

Sañudo, B., Fennell, C., & Sánchez-Oliver, A. J. (2020). Objectively-assessed physical activity, sedentary behavior, smartphone use, and sleep patterns pre- and during-COVID-19 quarantine in young adults from Spain. *Sustainability*, *12*, 5890. https://doi.org/10.3390/su12155890

Satorra, A., & Saris, W. E. (1985). Power of the likelihood ratio test in covariance structure analysis. *Psychometrika*, *50*(1), 83–90. https://doi.org/10.1007/BF02294150

Sheldon, K. M., & Elliot, A. J. (1998). Not all personal goals are personal: Comparing autonomous and controlled reasons for goals as predictors of effort and attainment. *Personality and Social Psychology Bulletin*, *24*, 546–557. https://doi.org/10.1177/0146167298245010

Sniehotta, F. F., & Presseau, J. (2012). The habitual use of the self-report habit index. *Annals of Behavioral Medicine*, *43*(1), 139–140. https://doi.org/10.1007/s12160-011-9305-x

Tappe, K., Tarves, E., Oltarzewski, J., & Frum, D. (2013). Habit formation among regular exercisers at fitness centers: An exploratory study. *Journal of Physical Activity and Health*, *10*, 607–613. https://doi.org/10.1123/jpah.10.4.607

Verplanken, B., & Melkevik, O. (2008). Predicting habit: The case of physical exercise. *Psychology of Sport and Exercise*, *9*(1), 15–26. https://doi.org/10.1016/j.psychsport.2007.01.002

Verplanken, B., & Orbell, S. (2003). Reflections on past behavior: A self-report index of habit strength. *Journal of Applied Social Psychology*, *33*, 1313–1330. https://doi.org/10.1111/j.1559-1816.2003.tb01951.x

Verplanken, B., & Roy, D. (2016). Empowering interventions to promote sustainable lifestyles: Testing the habit discontinuity hypothesis in a field experiment. *Journal of Environmental Psychology*, *45*, 127–134. https://doi.org/10.1016/j.jenvp.2015.11.008

Verplanken, B., Walker, I., Davis, A., & Jurasek, M. (2008). Context change and travel mode choice: Combining the habit discontinuity and self-activation hypotheses. *Journal of Environmental Psychology*, *28*(2), 121–127. https://doi.org/10.1016/j.jenvp.2007.10.005

Verplanken, B., & Wood, W. (2006). Interventions to break and create consumer habits. *Journal of Public Policy & Marketing*, *25*(1), 90–103. https://doi.org/10.1509/jppm.25.1.90

Warburton, D. E. R. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal*, *174*, 801–809. https://doi.org/10.1503/cmaj.051351

Wood, W. (2017). Habit in personality and social psychology. *Personality and Social Psychology Review*, *21*, 389–403. https://doi.org/10.1177/1088868317720362

Wood, W., Tam, L., & Witt, M. G. (2005). Changing circumstances, disrupting habits. *Journal of Personality and Social Psychology*, *88*, 918–933. https://doi.org/10.1037/0022-3514.88.6.918

World Health Organization (2020). Overview of Public Health and Social Measures in the context of COVID-19. Available at: https://www.who.int/publications/i/item/overview-of-public-health-and-social-measures-in-the-context-of-covid-19. Accessed April 01, 2020.

Xiong, J., Lipsitz, O., Nasri, F., Lui, L. M. W., Gill, H., Phan, L., . . . McIntyre, R. S. (2020). Impact of COVID-19 pandemic on mental health in the general population: A systematic review. *Journal of Affective Disorders*, *277*, 55–64. https://doi.org/10.1016/j.jad.2020.08.001

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Supporting Information

The following supporting information may be found in the online edition of the article:

Figure S1. Comparison of the associations of PA behaviours, autonomous motivation, and PA habits before, in the middle and at the end of lockdown.
Figure S2. Evolution of PA behaviours across time.
Figure S3. Evolution of autonomous motivation toward PA across time.

Table S1. Demographical and health-related information.