Does Intrinsic Motivation Strengthen Physical Activity Habit? Modelling Relationships Between Self-Determination, Past Behaviour, and Habit Strength

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Abstract

Habit formation is thought to aid maintenance of physical activity, but little research is available into determinants of habit strength aside from repeated performance. Previous work has shown that intrinsically motivated physical activity, underpinned by inherent satisfactions derived from activity, is more likely to be sustained. We explored whether this might reflect a tendency for self-determined activity to become more strongly habitual. A sample of 192 adults aged 18-30 completed measures of motivational regulation, intention, behaviour, and habit strength. Results showed that self-determined regulation interacted with past behaviour in predicting habit strength: prior action was more predictive of habit strength among more autonomously motivated participants. There was an unexpected direct effect of self-determined regulation on habit strength, independently of past behaviour. Findings offer possible directions for future habit formation work.

Keywords

Physical activity; Habit; Self-determination; Intrinsic motivation; Extrinsic motivation

Physical activity (PA) helps to prevent cardiovascular disease, diabetes and some cancers, can aid management of ill-health, and can reduce stress, anxiety and depression (Warburton, Nicol, & Bredin, 2006). The UK government recommends that adults engage in PA of at least moderate intensity for at least 150 minutes per week, the equivalent of 30 minutes on 5 days per week (Department of Health, UK, 2011). Similar guidance is offered in the US (Haskell et al., 2007). Yet, around 95% of the UK and US populations fail to meet these recommendations (Chaudhury & Esliger, 2009; Troiano et al., 2008).

Psychological theories and concepts offer a basis for PA promotion interventions (Rhodes & Pfaeffli, 2010). Health behaviour models have tended to emphasise reasoned concepts, as summarised by intention, as key to behaviour change (Ajzen, 1991), but while favourable baseline intentions are important in initiating PA, they may have less impact on maintenance (Armitage, 2005). Post-initiation, dissatisfaction with PA may erode positive intentions and prompt disengagement (Rothman, 2000). Perhaps consequently, many interventions fail to promote sustained change, with short-term gains eroding and activity levels returning to baseline (Marcus et al., 2006).

Habit offers a mechanism for PA maintenance (Rothman, Sheeran, & Wood, 2009). Habits are behavioural patterns enacted automatically upon encountering contextual cues, acquired through repetition in the presence of those cues (Lally, van Jaarsveld, Potts, & Wardle, 2010; Verplanken & Aarts, 1999). Repeated performance in unvarying settings reinforces mental context-behaviour associations, such that subsequently encountering the context activates behaviour directly, with minimal forethought (Orbell & Verplanken, 2010). Automaticity distinguishes habitual from reasoned action: acting on intention requires volition and may be effortful, but habitual action may proceed with minimal cognitive demand, without awareness or a conscious intention (Bargh, 1994). Hence, while intention is typically depicted as a 'reflective' determinant of behaviour, characterised by deliberative forethought, habit is seen as an 'impulsive' determinant, characterised by immediate stimulus-responses mediated by rapid activation of low-level associative knowledge (e.g. Strack & Deutsch, 2004). Subsequently, PA habits are not only frequently performed, but also tend to moderate the intention-behaviour relationship, with the impact of intentions on behaviour diminishing as habit strength increases (de Bruijn & Rhodes, 2011; Gardner, de Bruijn, & Lally, 2011). The dominance of habit over intention in action regulation has prompted interest in habit development as an intervention goal, because forming a habit should shield PA from possible losses in motivation (Lally & Gardner, in press; Rothman et al., 2009).

Promoting habits requires an understanding of the formation process, but limited health-related human habit formation research is available. One study focused on participants performing a self-chosen dietary or PA behaviour in response to a salient once-daily cue for 12 weeks (Lally et al., 2010). Habit strength, as indexed by daily self-reports of the automaticity with which behaviour was enacted, typically increased asymptotically: initial repetitions caused greatest increments, which gradually reduced in size with further repetition, until automaticity reached a plateau, though some participants did not reach the plateau during the study period. For PA behaviours, the median time for automaticity to plateau was modelled as 91 days, and the median value at which automaticity peaked was 35, on a scale of 0 (no habit) to 42 (strongest habit). Interquartile ranges in timing (74 days) and peak automaticity (17 points) indicated considerable variation across participants and activities (Lally et al., 2010). Variables additional to repetition may determine the speed of formation, or the level at which automaticity plateaus (Judah, Gardner, & Aunger, 2012; Lally & Gardner, in press).

A study of dental flossing habit formation found that positive attitudes towards the health benefits of flossing predicted stronger habits four weeks later, controlling for repetition frequency (Judah et al., 2012). The authors suggested that experiencing valued consequences of flossing (e.g. teeth looking better, feeling cleaner) may have reinforced habit. Habit theory supports this explanation. Repeated sequential presentation of context, behaviour and rewarding outcomes can imbue the context with the motivational properties of the rewards, so that the context comes to signal both the opportunity and an incentive for action, increasing its cached value as a cue to action (Daw, Niv, & Dayan, 2005; de Wit & Dickinson, 2009; Wood & Neal, 2007). This should however be expressed via an interaction between perceived consequences and behavioural repetition in determining habit strength, whereby repetition becomes a stronger determinant of habit strength where performance leads to positive consequences. The absence of an interaction between attitudes and behavioural frequency in the flossing study may have been due to lack of variation in frequency: 70% of the sample flossed on at least 25 of the 28 days study period (Judah et al., 2012). Interestingly, both flossing intention and attitude were measured, yet only attitude impacted on habit strength (Judah et al., 2012). While motivation may be important in reinforcing habit, its effect could not therefore be attributed to motivation strength (i.e. intention), but rather the beliefs, expectations and arguments underpinning motivation (i.e. attitudes).

Self-Determination Theory proposes that motivation can be categorised according to whether it is driven by reasons emanating from the self (e.g. pleasure or satisfaction), or in response to external demands (e.g. expectation of rewards or punishments) (Ryan & Deci, 2000). The theory proposes a series of motivational regulation types graded on a continuum of autonomy (i.e. self-determination)[1]. Applied to PA, these include: *amotivation*, where a person lacks any motivation to be physically active (this is not however synonymous with habitual behaviour because, although activated automatically, habitual behaviour proceeds in line with motivation where habit and motivation concur; Gardner, 2009a); *external regulation*, where PA motivation is regulated by tangible rewards or avoidance of punishments; *introjected regulation*, driven by self-administered and intrapersonal contingencies of activity (e.g. pride, guilt, anxiety); *identified regulation*, underpinned by expected personally valued outcomes of activity; *integrated regulation*, arising from the congruence of activity with self-identity; and *intrinsic regulation*, characterised by inherent interest in activity itself. While the focus on consequences renders external, introjected, and identified regulation as forms of extrinsic motivation, identified regulation resides on the autonomous pole of the continuum, together with integrated and intrinsic regulation (Ryan & Connell, 1989).

Self-determined regulation is associated with greater PA frequency, duration and intensity (Duncan, Hall, Wilson, & Jenny, 2010; Edmunds, Ntoumanis, & Duda, 2006; Standage, Sebire, & Loney, 2008; Wilson, Rodgers, Loitz, & Scime, 2006). Internally driven regulation prompts stronger PA intentions (Biddle, Soos, & Chatzisarantis, 1999) and, when controlling for intention strength, intentions based on autonomous motivation are more likely to translate into PA (Chatzisarantis, Biddle, & Meek, 1997). Regulatory style also determines maintenance, with autonomously regulated activity more likely to be sustained over time (Daley & Duda, 2006; Ryan, Frederick, Lepes, Rubio, & Sheldon, 1997; Silva et al., 2011;

[1] Within Self-Determination Theory, the term ‘regulation’ refers to regulation of behaviour (Ryan & Deci, 2000). This assumes that motivation directs behaviour, and so conflicts with the habit perspective which posits that behaviours may proceed impulsively, in the absence of motivation (Wood & Neal, 2007). Hence, we use the term ‘regulation’ to pertain to the regulation of *motivation to engage in* behaviour, rather than of behaviour itself.

Thøgersen-Ntoumani & Ntoumanis, 2006). This may perhaps reflect a tendency for self-determined PA to become habitual.

We conducted an exploratory study to investigate whether motivational regulation contributes directly to PA habit strength. Determinants of habit strength can be categorised into one or more of four sequential stages: those that influence the formation of an intention to initiate a new behaviour; those that aid the translation of intention into action; those that promote repeated performance of behaviour (in a consistent context); and those that moderate the impact of (context-dependent) behavioural repetition on automaticity development (Lally & Gardner, in press). Previous research supports the role of self-determination at the former three stages (e.g. Hagger & Chatzisarantis, 2008), but to our knowledge no theoretical or empirical insights are available into the role of self-determination at the latter stage. Our study focuses on the role of self-determination in reinforcing the link between repetition and habit strength. Habit may be strengthened by rewarding experiences or consequences (de Wit & Dickinson, 2009; Wood & Neal, 2007). Assuming that self-determined regulation maps on to actual outcomes – such that autonomously motivated actors derive internal benefits such as satisfaction, and externally motivated actors derive external benefits such as avoidance of social sanctions – we predicted that autonomous regulation would enhance the relationship between behaviour frequency and habit strength more strongly than would non-self-determined motivation. Self-Determination Theory predicts that autonomously motivated activity fulfils fundamental human needs for competence and autonomy (Ryan & Deci, 2000), thus promoting self-esteem, self-worth and well-being (Georgiadis, Biddle, & Chatzisarantis, 2001). We reasoned that these consequences may have greater reward value than external incentives (such as compliance with physician recommendations), or that autonomous activity may better retain its reward value over time, continuing to reinforce habit strength where external incentives may be more susceptible to devaluation.

To our knowledge, no studies have adequately investigated motivation regulation and habit strength. Previous studies have been limited by an operationalization of habit as frequent, rather than automatic, behaviour (Beck, Gillison, & Standage, 2010; Chatzisarantis, Hagger, Biddle, & Karageorghis, 2002). Yet, automaticity is the ‘active ingredient’ that underpins the effect of habit on action (Gardner, 2012; Sniehotta & Presseau, 2012), and automaticity-based habit measures are available (Gardner & Abraham, 2009; Verplanken & Orbell, 2003). As a preliminary step in our analysis, we first predicted that habit would have an effect on behaviour maintenance that cannot be attributed to past performance alone:

Hypothesis 1: Habit will predict PA behaviour when controlling for past PA behaviour.

Support for Hypothesis 1 would indicate that habit is a unique predictor of future behaviour, thereby justifying treatment of habit as an outcome variable of interest in the main analysis.

For the main analysis, we used a motivation regulation measure that scores each participant on an autonomy continuum, with lower scores indicating non-self-determined motivation and higher scores self-determined motivation (Markland & Ingledew, 2007; Markland & Tobin, 2004). Hence:

Hypothesis 2: Controlling for intention, self-determined regulation will interact with past behaviour in predicting habit strength, such that more autonomous regulation will strengthen the relationship between past behaviour and habit strength.

Support for Hypothesis 2 would suggest that self-determination bolsters the impact of past physical activity on habit strength, and that this effect cannot be attributed to stronger intentions.

Method

Design and Procedure

A prospective survey design was used, though Hypothesis 1 was tested using prospective data and Hypothesis 2 using cross-sectional data. At baseline (Time 1; T1), participants completed a web-based questionnaire measuring past behaviour, habit, intention, motivation regulation type, and demographics, and provided their email address. Seven days later (T2), participants were emailed a link to a questionnaire measuring behaviour over the preceding week. Non-responders were sent a maximum of two daily reminder emails. Data collection commenced at the beginning of November 2011. The baseline questionnaire was preplanned to shut in mid-December to permit termination of follow-up data (allowing for reminders) prior to the Christmas vacation. Approval was obtained from the University College London Psychology and Language Sciences Ethics Committee.

Participants

Participants were adults aged 18-30. The age criterion was imposed to achieve a less heterogeneous sample. Recruitment was via two channels: an advertisement placed on the University College London Psychology Subject Pool website, and an email advertisement distributed to the university's Psychology students. Email recipients were encouraged to forward the email to eligible others, with a £25 cash prize offered to the person(s) who thereby recruited most participants (Gardner, 2009b). Eligible participants that completed both questionnaires received either an entry into a £25 cash prize draw, or course credit.

A total of 222 participants were recorded at T1. Three participants younger than 18 years and three older than 30 years were excluded (and not contacted further), leaving 216 eligible T1 participants. At T2, 199 (92.1%) participants responded, but 7 could not be matched to a T1 email address and so were removed. Our final sample comprised 192 participants (46 male, 146 female; 143 full- or part-time students, 45 full- or part-time employed, 4 unemployed; mean age = 22.05 years, SD = 3.59). Study completers did not differ on any study variable from those who did not respond at T2 (minimum two-tailed *p* = .28).

A priori power analysis, assuming medium effects for a maximum of seven predictors of habit within a multiple regression design, indicated that *N* = 97 was sufficient to achieve power at .80, where $p<.05$.

Measures

We anticipated that the (predominantly student-based) sample would be inactive during study hours, and so items focused on leisure-time PA (Chatzisarantis & Hagger, 2007; Rhodes, de Bruijn, & Matheson, 2010).

Behaviour was measured at both timepoints using two items. The first item was worded to maximise compatibility with intention and habit measures (‘[*Over the last seven days, on how many days...]* ‘...did you engage in active sports and/or vigorous physical activities for at least 30 minutes during your leisure time?’). A second item, included to boost reliability, was derived from Godin and Shephard’s (1985) Leisure Time Exercise Questionnaire and related to strenuous activity (‘...did you do strenuous activity for more than 30 minutes during your leisure time?’), which was defined as that which ‘makes you breathe much harder than normal, e.g. running, soccer, basketball, vigorous swimming’. Responses ranged from 0-7 days. Similar self-report activity items have shown convergent validity with objective physical activity indicators (Gionet & Godin, 1989), and computed mean scores at both timepoints were reliable (T1: α = .94, r = .88, p<.001; T2: α = .94; r = .89, p<.001). T1 scores were used as indices of *past behaviour*, and T2 scores as indices of *behaviour*.

Leisure-time PA *habit* was measured only at baseline, using a four-item automaticity subscale of the Self-Report Habit Index previously shown to have satisfactory content validity, reliability and predictive validity (Gardner & Abraham, 2009; Verplanken & Orbell, 2003). Following previous PA habit research (Chatzisarantis & Hagger, 2007; Rhodes et al., 2010), items related to '*engaging in active sports and/or vigorous physical activities during my leisure time…'* ('... is something I do automatically', '...is something I do without thinking', '...is something I do without having to consciously remember', '...is something I start doing before I realise I'm doing it'; 1 [*'Strongly disagree'*] – 7 [*'Strongly agree'*]; α = .95).

Intention was assessed only at baseline, via two items ('[I intend to] / [I will try to] engage in active sports and/or vigorous physical activities for at least 30 minutes during my leisure time on most days next week'; 1 [*Strongly disagree*] – 7 [*Strongly agree*]; α = .91; r = .83, p<.001).

Self-determination was measured only at baseline using a *relative autonomy* index, which was computed using scores from the 19-item revised Behavioural Regulation in Exercise Questionnaire (BREQ-2; Markland & Tobin, 2004). The BREQ-2 encompasses subscales of statements pertaining to five regulation types, with responses ranging from 1 (*'Not very true of me'*) to 5 (*'Very true of me'*): *amotivation* (4 items; e.g. 'I don't see why I should have to exercise'; α = .85), *external* (4 items; e.g. 'I exercise because other people say I should'; α = .84), *introjected* (3 items; e.g. 'I feel guilty when I don't exercise'; α = .85), *identified* (4 items; e.g. 'I value the benefits of exercise'; α = .87), and *intrinsic* regulation (4 items; e.g. 'I exercise because it's fun'; α = .95). The BREQ-2 excludes a measure of integrated regulation, due to pilot work showing difficulty in reliably discerning integrated from identified or intrinsic regulation (but see Wilson et al., 2006). Following Markland and

Ingledew (2007), relative autonomy was computed by assigning negative weights to non-self-determined regulation types (amotivation –3; external regulation –2; introjected regulation –1) and positive weights to self-determined types (identified regulation +2; intrinsic regulation +3). The resultant relative autonomy scale had a possible range of -25 to +19, with lower scores denoting non-self-determined regulation, and higher scores self-determined regulation.

Analyses

Data were analysed using correlation and regression. Bivariate correlations of $r \geq .10$, .30 and .50 were respectively interpreted as small, medium, and large effects (Cohen, 1992). Assumptions of normality, homoscedasticity, non-multicollinearity, and independence and distribution of errors were checked. Age and gender were entered as covariates in regression analyses but are not reported.

The impact of habit on behaviour was assessed using a model in which behaviour was regressed on habit at the first step, and past behaviour was added at the second step. We also intended to control for intention, and investigate a potential habit x intention interaction term, but multicollinearity between habit and intention scores rendered the model unreliable, as indicated by large variance proportion loadings for both variables (habit: .58; intention: .73) on a single eigenvalue (condition index = 10.74; Field, 2009).

The contribution of self-determination to habit strength was tested using a three-step regression model, in which past behaviour and intention were entered as covariates at the first step, relative autonomy at the second step, and a relative autonomy x past behaviour interaction term at the third step.

The interaction term was computed as the multiplicative product of the standardised and means-centred moderator (i.e. relative autonomy) and independent (past behaviour) variables. The significant interaction term was investigated using simple slopes analysis, to model the association between independent (past behaviour) and dependent variables (habit strength) at 1 SD below the mean, at the mean, or 1 SD above the mean value of the moderator variable (relative autonomy) (Aiken & West, 1991). To assess the ecological validity of predicted slopes, the sample was also profiled according to values on the moderator and independent variables. Scores ≥1 SD below the mean, within ±1 SD of the mean, and ≥1 SD above the mean of each variable were treated as 'low', 'moderate', and 'high' respectively, creating three values for each variable and so nine (3 x 3) profile cells.

Results

Unless otherwise reported, all effects were significant at $p \leq .001$.

Descriptives and correlations

At both timepoints, participants engaged in 30 minutes of vigorous leisure-time PA on average on ~1.6 days (Table 1). At each timepoint, 11 participants (5.7%) reported engaging in 30 minutes of vigorous leisure-time PA on five or more days, 9 of whom did so at both timepoints. Behaviour and past behaviour were strongly correlated (r = .80), indicating behavioural stability over the two timepoints. Participants generally had moderate PA habits (M = 3.70) and intentions (M = 4.31). Habit and intention were strongly intercorrelated (r = .75), and correlated with behaviour at both timepoints (rs ≈ .63).

Mean relative autonomy (M = 7.14), and scores on each behavioural regulation index, indicated that physical activity motivation was typically internally regulated. Mean scores were below the scale midpoint for amotivation and external regulation, at the midpoint for introjected regulation, and above the midpoint for identified and intrinsic regulation. Relative autonomy correlated negatively with amotivation (r = -.72) and external regulation (r = -.53), and positively with introjected (r = .20, p = .005), identified (r = .81), and intrinsic regulation (r = .87). Positive correlations were observed between amotivation and external regulation (r

= .29), and between introjected, identified, and intrinsic regulation (*r* range: .37 to .81), with typically negative associations between the former two and the latter three types (*r* range: -.16 [*p*=.03] to -.54).

Relative autonomy was strongly positively correlated with habit (*r* = .64). Amotivation (*r* = -.35) and external regulation (*r* = -.22, *p*=.002) correlated negatively with habit, and introjected (*r* = .25), identified (*r* = .64) and intrinsic regulation (*r* = .66) correlated positively and progressively more strongly with habit.

Does habit predict behaviour?

Together, demographics and habit predicted 40% of variance in behaviour (Model F[3,188] = 41.27). Adding past behaviour at the second step enhanced the model (R^2 = .66; ΔR^2 = .27, ΔF = 148.42), and within this model, habit remained significantly predictive (β = .21) over and above past behaviour (β = .67). Hypothesis 1 was supported.

Does regulatory type predict habit strength?

At step 1, covariates accounted for 62% of variance in habit strength (Model F[4,187] = 74.65), and within this model, past behaviour (β = .26) and intention (β = .20) were significant predictors, but age (β = .06, *p*=.18) and gender (β = .06, *p*=.24) were not (Table 2). Adding relative autonomy at the second step enhanced the model (ΔR^2 = .05, ΔF = 27.19), and the relative autonomy x past behaviour interaction improved the model further (ΔR^2 = .014, ΔF = 8.20, *p*=.005). Within the latter model, relative autonomy unexpectedly retained a positive effect on habit strength (β = .34), and the intrinsic regulation x past behaviour interaction term was also predictive (β = .14, *p*=.005). Simple slopes analysis showed that the past behaviour-habit relationship strengthened as relative autonomy increased. Differences were most pronounced among participants who frequently engaged in PA, of whom those reporting greater relative autonomy typically reported stronger habits (β = .28) than did those with mean relative autonomy scores (β = .12, *p*=.04). There was no past behaviour-habit association among participants with less relative autonomy (β = -.04, *p*=.71).

Profiling showed that most participants reported moderate engagement in PA and moderate relative autonomy (102 participants; 53.1%). Past behaviour scores (*M* = 1.50, *SD* = 1.68) were distributed such that it was impossible for participants to score ≥1 SD below the mean (i.e. ≤ -0.18 days), and so infrequent past behaviour cells were empty. Of 27 participants reporting frequent prior PA, one (0.5% of total sample) scored low, 16 (8.3%) scored moderately, and 10 (5.2%) scored high on relative autonomy. This suggests that, while the datapoint for frequent past behaviour and weak relative autonomy may lack validity, values at mean and high relative autonomy were valid and the observed interaction was genuine.

In summary, self-determination predicted PA habit strength independently, and also moderated the relationship between prior PA and habit strength: frequent PA was more predictive of habit among participants with more autonomous motivation. Hypothesis 2 was supported.

Discussion

This study explored the role of self-determined motivational regulation in determining habit. Autonomous (i.e. self-determined) regulation interacted with past behaviour in predicting habit, such that past behaviour was more predictive of habit strength among participants whose motivation was determined by intrinsic interest in engaging in PA. We also unexpectedly found a direct effect of relative autonomy on habit strength, over and above the influence of past behavioural frequency. While design limitations preclude conclusion about the causal direction of observed effects, these findings point to possible research directions for future habit formation work.

Previous work has shown that PA underpinned by self-authored motivation is likely to persist over time (Daley & Duda, 2006; Ryan et al., 1997; Thøgersen-Ntoumani & Ntoumanis, 2006). We explored whether this reflected a tendency for PA to become habitual where based on autonomous motivation, as underpinned by either the personal importance assigned to the consequences of PA or inherent interest in PA itself (intrinsic regulation). Habits form through repeated performance in consistent settings (Lally et al., 2010), and past behaviour was significantly more predictive of habit strength among the more intrinsically motivated. There was variation in autonomous motivation among participants engaging in PA most frequently, and in PA frequency among the most autonomously motivated, suggesting that the observed relative autonomy x past behaviour interaction was empirically valid. We speculate that the enjoyment of intrinsically motivated PA may more strongly reinforce the relationship between past performance and habit strength, or better retains its reinforcement value, than do external contingencies, but longitudinal habit formation tracking work is needed to test this explanation. From a practical perspective, PA habit promotion interventions should adopt an autonomy-supportive approach so as to promote the internalisation of PA motivation, and so facilitate autonomous regulation. Autonomy-supportive interventions might, for example, provide multiple activity options, promote self-authored goal-setting, and minimise dependence on external contingencies such as tangible rewards or incentives (Silva et al., 2011).

Habit theory predicts that variables other than behavioural repetition should impact on habit strength only indirectly, either by prompting greater repetition, or by moderating the influence of repetition on habit development (de Wit & Dickinson, 2009; Lally & Gardner, in press; Wood & Neal, 2007). Yet, we found self-determined motivation to strengthen habit, independently of the effects of past behaviour. While unanticipated by habit theory, our findings do however echo a recent study that tracked flossing habit formation and observed stronger habits among participants with positive attitudes towards the health consequences of flossing, independently of repetition history (Judah et al., 2012). The observed direct effect of relative autonomy may perhaps reflect a tendency for extrinsic motivation (i.e. the expectation of tangible rewards or punishments) to restrict automaticity development. Automatic action is characterised by minimal awareness or forethought (Bargh, 1994), and habit theory predicts that behaviours reinforced by tangible rewards or punishments can become automatic, if such external contingencies remain present, salient, and valued (Moors & de Houwer, 2006; Wood & Neal, 2007). Yet, our findings suggest that PA underpinned by monitoring of the likely administration of rewards or punishments may be less likely to become automatic and impulsive, instead remaining consciously determined via reflective processes. It is however unclear whether any such effect would arise from inconsistent administration or decreased salience of expected rewards for PA, or external rewards having lesser reinforcement value. Alternatively, these findings may represent methodological artifice. Some participants may have inferred motivational regulation from their habitual actions through a post-hoc self-perception process, such that habitual actors were more inclined to report self-determination and non-habitual actors reported external motivation. Indeed, cross-sectional designs are of limited utility for inferring causality for habitual actions, given the dynamic and multidirectional relationships between motivation, behavioural frequency and habit (Weinstein, 2007). Antecedents of habit are better revealed by modelling determinants of habit strength among those forming habits for unfamiliar behaviours (Judah et al., 2012), but such studies are expensive and time-consuming. These limitations make our work best suited to the generation of hypotheses for more rigorous and reliable habit formation research.

Our methodology limits the robustness of findings. Firstly, the cross-sectional design precluded examination of whether participants were forming habits, or whether they had established stable levels of PA habit strength. Multiple timepoint habit measures are needed to assess whether predictors of habit strength determine variation in the level at which PA automaticity peaks, or the speed with which habits develop. Secondly, while we sought to predict habit, it is possible that, given the strong observed habit-intention correlation, self-reported habits may have simply reflected conscious intentions, with strong intenders reporting accordingly strong PA habits, and vice versa. This problem is common in studies which focus on intention-concordant habits: habits typically develop from frequent performance of intentional action (Lally & Gardner, in press; Lally et al., 2010), and so, in the absence of intervention, habit and intention are likely to concur (Gardner, 2009a). We echo calls for tests of the role of counter-intentional habits in studies of habitual action (e.g. intentions to be physically active versus sedentary habits; Gardner et al., 2011). Thirdly, we used PA over the preceding week as a proxy for prior repetition, but this may fail to capture past performance history. Motivation regulation measures may therefore have captured residual variance attributable to repetition history. Lastly, neither our behaviour nor habit measure acknowledged the context-dependency with which behaviour must be repeated for habit to form (Lally et al., 2010; Ouellette & Wood, 1998). These measures may therefore have conflated incidences of PA which proceeded habitually in some contexts, and volitionally in others (Sniehotta & Presseau, 2012). Conversely however, idiosyncratic cue-specific habit measures will likely fail to capture habits prompted by contexts other than those specified in the measure. Context-free habit measures administered at population level may be preferable for estimating the automatic component of PA across participants and contexts.

Notwithstanding these limitations, our study is the first to document a relationship between motivational regulation and habit strength. PA driven by the personal value assigned to PA, rather than the instrumental value of the consequences of PA, may strengthen the impact of repeated performance on PA, either by truncating the number of repetitions required for habit to form, or by prompting the formation of stronger habits with equal repetition. Given design limitations, these findings primarily offer potential directions for exploration using more rigorous methods, rather than intervention recommendations. Habit formation research may benefit from assessment of the extent to which PA is based on internal motivation, rather than expected contingencies.

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Table 1. Correlations and descriptive statistics

	2.	*3.*	*4.*	*5.*	*6.*	*7.*	*8.*	*9.*	*10.*	*11.*	*12.*	*Range†*	*Mean*	*SD*
Time 2 measure														
1. Behaviour	.80***	.63***	.64***	.50***	-.33***	-.10	.33***	.55***	.52***	-.05	-.16*	0–7	1.62	1.63
Time 1 measures														
2. Past behaviour		.63***	.63***	.49***	-.35***	-.16*	.31***	.52***	.48***	-.04	-.18*	0–7	1.50	1.68
3. Habit strength			.75***	.64***	-.35***	-.22*	.25***	.64***	.66***	-.01	-.20**	1–7	3.70	1.83
4. Intention				.57***	-.35***	-.12	.38***	.66***	.60***	-.11	-.18*	1–7	4.31	1.92
Regulatory type††														
5. Relative autonomy					-.72***	-.53***	.20**	.81***	.87***	.04	-.09	-25–+19	7.14	6.82
6. Amotivation						.29***	-.26***	-.54***	-.46***	-.05	-.07	1–5	1.46	0.67
7. External regulation							.22**	-.16*	-.20**	-.12	.07	1–5	1.78	0.87
8. Introjected regulation								.56***	.37***	-.03	.09	1–5	2.95	1.19
9. Identified regulation									.81***	.01	-.01	1–5	3.65	1.03
10. Intrinsic regulation										-.03	-.14*	1–5	3.58	1.14
Demographics														
11. Age											.07	18–30	22.05	3.59

12. Gender†††												46 male, 146 female

N = 192. ***p<.001, **p<.01, *p<.05. † Range refers to possible, not actual, range. †† Scores on regulatory type variables represent scale means, except relative autonomy, for which scores are summed. ††† Gender coded as 0 = male, 1 = female.

Table 2. Regression of habit strength on past behaviour, intention, and relative autonomy

Step	*Variable entered*	*Beta*	*Beta*	*Beta*
1.	Past behaviour	.26***	.20***	.12*
	Intention	.59***	.47***	.47***
2.	Relative autonomy		.28***	.34***
3.	Relative autonomy x past behaviour			.14**
	Model F	74.65***	73.52***	65.01***
	Unadjusted R^2	.62	.66	.68
	R^2 change		.05***	.01**

N = 192. *p≤.05, **p≤.01, ***p≤.001. Age and gender are controlled for but are not reported.

Table 3. Past behaviour-relative autonomy profiles.

		Past behaviour			
		Below mean n *(%)*	*Mean* n *(%)*	*Above mean* n *(%)*	*Row total* n *(%)*
Relative autonomy	*Low*	0 (0%)	35 (18.2%)	1 (0.5%)	*36 (18.7%)*
	Medium	0 (0%)	102 (53.1%)	16 (8.3%)	*118 (61.4%)*
	High	0 (0%)	28 (14.6%)	10 (5.2%)	*38 (19.8%)*
	Column total	*0 (0%)*	*165 (85.9%)*	*27 (14.0%)*	

N = 192.

Figure 1. Relative autonomy as moderator of past behaviour-habit relationship.