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Active without thinking? Distinguishing between automatic responses as predictors of physical activity

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Abstract

Background. Regular physical activity (PA) improves both physical and mental health, yet most people are insufficiently active. Identifying modifiable determinants of PA can aid development of effective PA promotion interventions. It is well recognised that PA is at least partly regulated by automatic processes, which capture simple associations that trigger behaviour without conscious thought. Yet, few attempts have been made to differentiate the roles of specific automatic processes on different forms of PA. This study aimed to model the unique effects of three automaticity variables – i.e., automatic valuations, approach-avoidance tendencies, and habit strength – on engagement in sport, leisure-based and total PA. **Methods**. A cross-sectional survey design was used. A sample of 226 individuals (mean age 23.70 years, *SD* = 5.43, range = 17-61) self-reported engagement in sport-based PA, leisure-time PA, and active travel. They also reported habit strength for sport and for leisure-time activity, and completed response-time tasks capturing automatic valuations and approach tendencies towards PA. Correlation analyses were used to assess the magnitude of relationships between all variables, and regression analyses to model associations between automaticity variables and sport and leisure-time PA, respectively. **Results**. Automatic valuations, approach tendencies, and sport habit strength all independently and positively predicted sport-based PA and total PA engagement. However, leisure-time PA was predicted only by leisure activity habit strength, not automatic valuations or approach-avoidance. Leisure-time habit strength was the only predictor of a composite PA engagement measure combining total time in sport, leisure-time activity and active travel. **Discussion**. Study limitations, including over-representation of females, and people who were highly active, demand that caution is exercised when extrapolating from our findings, and our study warrants replication using more rigorous methods. Nonetheless, our results preliminarily suggest that promoting positive automatic valuations, approach tendencies, and habit strength could encourage engagement in sport-based PA, whereas interventions to increase PA more generally might more fruitfully emphasis PA habit formation.

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Introduction

Physical activity (PA), defined as any musculoskeletal movement that expends energy beyond its basal rate (Caspersen et al., 1985), is beneficial to both physical and mental health (Penedo & Dahn, 2005). Regular PA reduces the risk of several chronic illnesses such as cardiovascular disease, type 2 diabetes, and some cancers, and also alleviates symptoms of depression and anxiety (Anderson & Durstine, 2019; Stanton et al., 2014). The World Health Organization recommends that, each week, adults aged 18-64 years should engage in at least 150 minutes of moderate intensity PA, or at least 75 minutes of vigorous intensity PA, or an equivalent combination of the two (World Health Organization, 2020). However, global estimates show that 31.3% of adults worldwide fail to meet these guidelines (Strain et al., 2024). Therefore, physical inactivity is a major public health issue that urgently needs to be addressed through behaviour change interventions. Such interventions are likely to be most effective if they target known determinants of PA (Salvo et al., 2021; Sheeran et al., 2017).

Individual-level influences on PA can be most comprehensively categorised using a crude and pragmatic distinction between reflective and automatic processes (Evans & Stanovich, 2013; Melnikoff & Bargh, 2018; Rhodes et al., 2019; Strack & Deutsch, 2004). Reflective processes capture inputs on behaviour based on conscious, relatively slow, effortful, and rule-based analyses of information related to the pros and cons of action (Sheeran et al., 2013). Reflective regulatory constructs relevant to PA include cognitive appraisals such as self-efficacy, intentions, and beliefs regarding the perceived consequences of PA or inactivity (e.g., Hagger, 2016; Rhodes et al., 2019). In contrast, automatic processes are characterised by fast processing that may occur outside of conscious awareness (Sheeran et al., 2013). Automatic processes operate via networks of associations between various objects and concepts stored in memory, as acquired over various past experiences (Rebar, 2017). When these associations are activated by cues, behavioural responses are rapidly prompted (Rebar & Rhodes, 2020). Some researchers argue that behaviour is primarily influenced by automatic responses, unless reflective processes intervene and override, or augment, initial automatic reactions (Evans & Stanovich, 2013). Both reflective and automatic processes influence PA behaviour (Brand & Cheval, 2019; Brand & Ekkekakis, 2018; Cheval & Boisgontier, 2021; Phipps et al., 2021; Strobach et al., 2020). Reviews suggest that reflective variables only account for a small proportion of variation in PA (Feil et al., 2023; Rhodes & Dickau, 2012; Sheeran & Webb, 2016), and that augmenting deliberative models with accounts of automaticity-based variables increases their utility for predicting PA (Gardner et al., 2011; Rebar et al., 2016). PA promotion interventions should therefore target both reflective and automatic processes.

Adopting a dual-process perspective to PA depends on understanding the specific automatic processes that influence PA. Yet, while deliberative influences on PA have been extensively studied (e.g., Rhodes et al., 2019), automatic responses relevant to PA remain a relatively under-researched area. The term 'automatic response' refers to several different variables that operate via the automatic system, each of which may be independently associated with PA; for example, automatic valuations, approach-avoidance tendencies, and habits (see Rebar, 2017). One such variable is automatic valuation, which refers to associations held between a concept (e.g., PA) and affective feelings (e.g., good or bad; pleasantness or unpleasantness; Conroy & Berry, 2017). Automatic valuations, sometimes termed 'implicit attitudes', are thought to be formed outside of conscious awareness (Rebar et al., 2016). Automatic valuations are affect-driven responses that are independent of conscious cognitive appraisals, hence use of the term 'valuation' rather than 'evaluation', which has connotations of reflective thought (Brand & Ekkekakis, 2018). Automatic valuations of PA are typically measured with implicit association tests (Greenwald et al., 2022). These tests require participants to quickly and accurately categorize stimuli (e.g., words related to PA, and in some cases, sedentary behaviour, as the contrasting behaviour, into categories defined by paired attribute labels (e.g., "good" vs. "bad"; see e.g., Bluemke & Friese, 2008; Hofmann et al., 2010). This creates a variable representative of relative positive or negative automatic valuations of PA. A meta-analysis of 26 studies showed a small, positive relationship between automatic PA valuations and greater PA (r = 0.11; Chevance et al., 2019). One study found that positive automatic valuations of PA, as measured using a single-category implicit association task, predicted a device-based measure of mean daily step counts over one week, even when controlling for deliberative influences such as intentions, beliefs, and expectations (Conroy et al., 2010; see too Chevance et al., 2018).

Approach-avoidance tendencies are also thought to be involved in the automatic regulation of PA. Approach-avoidance tendencies capture automatic motivational orientations expressed as sensorimotor impulses (i.e., non-conscious 'pushes' or 'pulls') that direct an actor towards (or away from) action, capturing an action orientation to (or repulsion from) certain environmental stimuli (Hofmann et al., 2008). Approach and avoidance tendencies are typically measured with reaction timed tasks. For example, PA approach and avoidance tendencies have been assessed with a timed task in which respondents press keys to move a manikin either toward or away from PA stimuli (Cheval et al., 2015, 2016, 2018; Hannan et al., 2019). Studies using such tasks have shown that a tendency to approach PA-related stimuli predicts greater PA engagement with small-to-medium effect sizes (Cheval et al., 2018). For example, one study showed that a tendency to automatically approach images of PA positively and prospectively predicted an accelerometer-based measure of PA duration, accounting for approximately 10% of the variability in activity levels (Cheval et al., 2015). Approach tendencies have also been shown to predict PA duration after controlling for deliberative influences related to exercise-related intentions and explicit motivation (Hannan et al., 2019).

Perhaps the most extensively studied automaticity-based predictor of PA is habit (Gardner et al., 2020a; Gardner et al., 2024; Hagger, 2019). As studied in the PA context (Gardner et al., 2020b; Hagger, 2019), habit can be defined as a process through which an impulse to initiate an action (e.g., PA) is automatically elicited upon exposure to a cue, due to activation of a cue-action association learned through repeated performance (Gardner, 2015). Habit, the strength of which is typically measured in the PA domain using a self-report scale that requires participants to reflect on the extent to which they experience common 'symptoms' of habitual responding (Gardner et al., 2012; Verplanken & Orbell, 2003), is thought to be a key determinant of PA maintenance (Kwasnicka et al., 2016). A meta-analysis of five studies found a medium-to-large relation between self-reported habit strength and PA engagement ($r = 0.43$), comparable to the typical magnitude of intention-behaviour relationships (Gardner et al., 2011). Multiple studies indicate that PA habit strength positively predicts PA over and above the influence of deliberative variables such as intentions and control perceptions (e.g., Verplanken & Melkevik, 2008). Furthermore, habit can moderate the intention-behaviour relationship, such that people with a stronger PA habit can maintain PA engagement even in instances in which they momentarily lack conscious motivation (Gardner et al., 2011; Gardner et al., 2020a).

Importantly, all these forms of automatic response appear to be modifiable. One study showed that automatic valuations towards PA could be made more favourable with evaluative conditioning training, at least over the short term (Qiu & Zhang, 2020). Similarly, approach-avoidance tendencies towards PA can be trained, at least acutely. In one study, participants who completed a computerised task in which they learned to automatically approach images of PA and avoid images of SB spent more time performing a subsequent PA task (i.e., performing squats; Cheval et al., 2016). Lastly, several studies show that habits can be purposively formed through repeated performance in consistent settings (Gardner et al., 2022). One study showed that people who enacted their plans regarding which form of PA to perform, and at which point in their daily routine to perform it, showed asymptotic gains in daily self-reported habit strength (Lally et al., 2010; see too Keller et al., 2021).

In sum, there is considerable evidence that stronger automatic valuations, approach tendencies, and habits are each associated with engagement in PA, and that each of these automatic responses may be modified. While one study sought to document bivariate correlations between various automatic response measures and exercise behaviour (Zenko & Ekkekakis, 2019), to our knowledge, no study has yet sought to model the unique contribution of each of these automaticity variables to PA engagement. This gives rise to two research gaps. First, it is unclear whether these variables can be empirically distinguished. It is possible, for example, that computerised tasks assessing tendencies to approach or avoid PA may tap the same underlying construct as self-report measures of habit associations. Assuming different automatic responses can be captured however, a second problem is that it remains unclear which automatic responses should be prioritised when developing automaticity-based PA interventions. If engagement in PA – whether total PA, or specific forms of PA such as sport-based and leisure-time PA – is most strongly predicted by one form of automatic response for example, it would be most cost-effective to develop intervention strategies that focus on that process, rather than expending resources on predictors that have less influence on behaviour change.

The aim of this exploratory study was to identify the unique contribution of three forms of automatic response—i.e., automatic valuation, approach-avoidance tendencies, and habit strength—in predicting PA engagement over a one-week period. Using a survey design, we sought to address two research questions. First, do established measures of automatic valuations, approach-avoidance tendencies, and habit strength capture distinct constructs? Second, assuming that these three forms of automatic response can be empirically distinguished, what is the unique contribution of each of these variables to PA duration? We measured the duration of PA undertaken in a typical week rather than the frequency of PA, because PA guidelines focus on the total amount of time people should be physically active, rather than the number of PA bouts they should engage in (World Health Organization, 2020). In measuring PA, we differentiated between three domains—sport-based PA, leisure-time PA, and PA accrued through active travel—as determinants have been shown to differ systematically between these types of PA (Ball et al., 2014; Eime et al., 2023; Evans et al., 2022). We also constructed a measure of total PA engagement across the week, which combined all three domain-specific PA measures. Our predominant areas of interest were sport-based PA and leisure-time PA because, unlike incidental PA, which is incurred by engagement in other activities (ten Broeke et al., 2023), these represent structured, voluntary forms of PA that might feasibly be encouraged through purposive intervention. Nonetheless, we also included PA from active travel to enhance the comprehensiveness of our composite total-PA measure. Whereas automatic valuations and approach-avoidance tendencies have to date been assessed as responses to PA in general (Cheval et al., 2016; Chevance et al., 2018), habit strength should ideally be measured in relation to specific forms of PA (Diefenbacher et al., 2023; Rebar et al., 2018). Thus, we used one measure of sport-based PA habit strength and one measure of leisure-time PA habit. Given that our study was the first to explore the unique contribution of different automatic responses, no hypotheses were set regarding which automatic responses would be most predictive of PA engagement.

Material and methods

Study Procedure

The study was conducted by a multi-national team across four countries over a period spanning 2020-21. A cross-sectional online survey design was used. For logistical reasons, participants were recruited from Australia, Switzerland, the UK, and USA (i.e., each of the countries in which at least one project team member was based at the time of recruitment). In all four countries, email advertisements were distributed through faculty, course, and lab mailing lists to staff and students. In Australia and the UK, recruitment was also undertaken through advertisements posted on social media. In Switzerland, participants were also recruited from the host institution's research participation pool. To be eligible, participants had to be aged 18 years or older and have access to a laptop or PC desktop computer. Participants in Australia, the UK, and the USA who completed the study were offered a gift voucher worth AUS$10 (~US$6.50), £7 (~US$8.50) and US$10 respectively. Participants in Switzerland were offered course credits for their participation.

The study was conducted online using Inquisit Millisecond 6.2® software, in English (Australia, UK, USA) and French (Switzerland). Individuals who met the eligibility criteria were invited to click on a URL within the study advertisement, which directed them to the study page. After providing informed consent, participants were asked to download the Inquisit software onto their device by following the URL link provided. Once launched, participants completed a questionnaire measuring PA behaviour, habit strength toward PA and demographics (sex, age, height, weight). Participants then completed measures of automatic valuations of PA (versus SB) and approach-avoidance tendencies towards PA. The order of these two measures was randomised between participants in a 1:1 ratio using built in randomization functions of the Inquisit software. Upon completion of the study, participants had the option of providing their email address to receive compensation. At the end of the study, participants were debriefed and instructed on how to uninstall Inquisit from their device. Ethical approval was obtained from the host institution's Ethics Committee in each country: Australia (22643), Switzerland (CCER-2019-00065), UK (MRSU-20/21-21217), USA (CSUB IRB Protocol 21-178).

Participants

Consistent with existing evidence showing small-to-moderate associations between each automatic variable and PA engagement (e.g., Chevance et al., 2019; Gardner et al., 2011; Hannan et al., 2019; Phillips & Gardner, 2016), a power analysis conducted in the R package_*pwr* indicated that a minimum sample size of N = 293 was required to achieve power at 0.80 (where $p < .05$) for small correlations ($r = 0.20$; Champely, 2020).

Of 308 participants who completed the study, data from 82 were excluded as they did not complete all relevant study measures. Our final sample consisted of 226 participants (140 females, 78 males, 2 use another term, 6 did not disclose). Mean age was 23.70 years ($SD = 5.43$, range = 17-61). For participants who reported both their height and weight ($n = 207$), mean body mass index (BMI) was 24.29 kg/m^2 ($SD = 3.30$, range = 18.00-37.33). Most (52.6%) participants were within the 'normal/healthy' range, one individual was 'underweight' (≤18.5 kg/m^2), 36.8% were overweight, and 10.5% had obesity (≥30 kg/m^2).

Measures

PA was measured using a modified version of the International PA Questionnaire (IPAQ; Craig et al., 2003). The IPAQ has previously demonstrated acceptable validity and reliability (Craig et al., 2003; Dinger et al., 2006). Each item asked participants to self-report the average length of time they spent in a typical week doing competitive or club sports-related PA (i.e., 'time spent in training sessions and during competitions only'), using active travel modes (i.e., 'physical activities you usually do to travel from place to place'), and engaging in moderate and vigorous leisure-time PA. We instructed participants to consider 'moderate' activities as those 'that take moderate physical effort and make you breathe somewhat harder than normal', and 'vigorous' activities as those 'that require greater physical effort, dramatically increasing your breathing and heart rate compared to normal'. To avoid double-counting, we requested that they 'do NOT include time spent being active when moving from one place to another', and 'do NOT include time spent being active in sports, club competitions or training' when reporting moderate and vigorous activities. Domain-specific PA was calculated as the reported sum of minutes spent in each type of activity, and total PA was calculated as the sum of minutes spent in each of the three domains.

Automatic valuations of PA (relative to SB) were measured using a version of the Implicit Association Test (IAT; Greenwald et al., 1998), as adapted for PA by Chevance et al. (2017) – see Supplementary Table 1. This response-timed categorisation task, which assesses the relative strength of automatic affective associations between two opposing behaviours (PA versus SB), has shown acceptable reliability and validity as a predictor of PA (Chevance et al., 2017; De Oliveira Calado et al., 2022). On each trial, a word appeared in the centre of the screen belonging to one of two pairs of categories: behaviours ("Physical activity" and "Sedentary behavior/behaviour") and attributes ("Good" and "Bad"; see Appendix Table for words used). Participants were required to sort the word into its corresponding category as quickly and accurately as possible by pressing one of two response keys ("E" or "I"). Depending on the block, one category from each category pair was assigned to the "E" key and its counterpart to the "I" key. Each word remained on the screen until a response key was pressed. If a word was incorrectly categorised (e.g., categorising the word "rest" as "Physical activity"), a red cross appeared in the middle of the screen and participants had to press the correct response key before proceeding onto the next trial. The intertrial interval was 400 ms. The response latency from onset of the word to pressing a response key was recorded, with no response deadline imposed. During each block, the labels of the categories assigned to the "E" key appeared in the top left corner of the screen whilst the labels of the categories assigned to the "I" key appeared on the right. For clarity, words belonging to the two behaviour categories appeared in white font whilst words belonging to the two attribute categories appeared in green font. The IAT was divided into seven blocks which were delivered in numerical order for all participants (see Table 1 for the assignment of categories to response keys in each block).

For the IAT, the DW-score was computed using the scoring algorithm by Richetin et al. (2015), as follows. First, for each participant, the 10% fastest and slowest latencies for both correct and incorrect responses were truncated. Next, the average response latencies from blocks 3 and 4 were subtracted from that of blocks 6 and 7, and finally this difference was divided by the pooled standard deviation of latencies across all trials. Scores ranged from -2 to +2 with a positive score reflecting more favourable attitudes towards PA relative to SB. Internal consistency of trials was high (Spearman Brown Split Half *r* = 0.90).

Table 1 - Measuring automatic valuations: structure of the Implicit Association Test detailing the assignment of categories to response keys in each block

Block	Number of trials	Response category	
		Left (“E” key)	Right (“I” key)
1	20	Physical Activity	Sedentary Behaviour
2	20	Good	Bad
3	20	Physical Activity + Good	Sedentary Behaviour + Bad
4	40	Physical Activity + Good	Sedentary Behaviour + Bad
5	20	Sedentary Behaviour	Physical Activity
6	20	Sedentary Behaviour + Good	Physical Activity + Bad
7	40	Sedentary Behaviour + Good	Physical Activity + Bad

Note: In each block, words belonging to each category appeared in the same number of trials.

Approach-avoidance tendencies towards physical activity were measured using the manikin task adapted from Cheval et al. (2014). The manikin task has been suggested to more reliably capture approach-avoidance tendencies than does a measure involving physically pushing a joystick away, or pulling it closer (Krieglmeyer & Deutsch, 2010). Participants were instructed to move a human stick-figure (a manikin) upwards or downwards by pressing the keys “U” and “N” respectively, using only their index fingers. Each trial began with a fixation cross presented in the centre of the screen followed by the manikin appearing either above or below it with equal probability. An image of a human stick-figure engaging in either PA or SB was then presented in the centre of the screen (see Appendix Figure for images used). Depending on the block, participants were asked to move the manikin either towards or away from the image as quickly as possible. For incorrect responses, error feedback was presented as a red cross in the middle of the screen. The intertrial interval was 1000 ms. For each trial, the response latency from the onset of the image to the key press was recorded. Participants completed two blocks of trials, each consisting of eight practice trials and 48 test trials. In one block, participants were instructed to approach (move the manikin towards) images of PA and avoid (move the manikin away from) images of SB. These instructions were reversed for the other block. In each block, all 12 images appeared twice above and twice below the manikin. The order of blocks was counterbalanced across participants.

Data from the manikin task were processed following recommendations by Krieglmeyer and Deutsch (2010). Incorrect responses, and response latencies below 150 ms or above 1500 ms, which occurred in 0.01% of trials, were excluded. Approach tendencies towards PA were calculated by subtracting the median response latency for avoiding images of PA from the median response latency for approaching images of PA. A positive value reflects tendencies to automatically approach PA-related stimuli rather than to avoid it (i.e. approach bias).

Habit strength was assessed using the valid and reliable four-item Self-Report Behavioural Automaticity Index (SRBAI; Gardner et al., 2012; Verplanken & Orbell, 2003), for sport-based and leisure-time PA respectively. The SRBAI has shown good reliability and validity for capturing a range of habitual behaviours, including PA habits (Gardner et al., 2012; see too Verplanken & Orbell, 2003). Item wording was selected to refer to the automatic initiation (or ‘instigation’) of PA, rather than its performance (or ‘execution’; Gardner et al., 2016). Sport-based PA habit strength was measured using the stem ‘deciding to play sport is something…’, and leisure-time PA habit strength using the stem ‘deciding to do moderate or vigorous physical activities in my free time is something…’ (‘…I do automatically’, ‘…I do without having to consciously remember’, ‘…I do without thinking’, ‘…I start doing before I realize I’m doing it’). Reliability for both measures was good (sport-based PA α = .84, leisure-time PA α = .91).

Data Management and Analyses

Data were analysed using R version 4.2.3 (R Core Team, 2023). First, descriptive and bivariate correlations were calculated. This allowed us to explore the magnitude of relationships between each automatic response variable, and between automatic responses and PA measures.

Correlation coefficients were interpreted using Cohen's (1992) effect sizes, with r coefficients of .10, .30 and .50 indicating small, medium, and large effects, respectively.

Regression models were run to identify the unique contribution of each automatic response variable to PA, controlling for survey language, sex, and age. Four sets of regression models were run, one for each PA outcome variable (i.e., sport-based PA, leisure time PA, active travel, and total PA). Box-Cox corrections (Box & Cox, 1964; Venables & Ripley, 2002) were applied to all regression models because PA variables were positively skewed. While our main outcomes of interest were sport-based and leisure time PA, we also ran models predicting total PA across the three domains and, for completeness, PA from active travel. In accordance with the compatibility principle (Ajzen & Fishbein, 2005), only sport-based PA habit strength was used to operationalise habit when predicting sport-based PA, and only leisure time habit strength was used when predicting leisure time PA. However, sport-based habit and leisure time habit strength were entered as independent predictors in additional, exploratory models predicting active travel PA and total PA.

Sample descriptives

Participants reported a mean total of nearly 500mins of PA, across the three domains, in a typical week. Most PA time was accrued from active travel (mean 181min) and sport (mean 180min). On average, participants also had slightly positive automatic valuations towards PA and exhibited a tendency to approach (rather than avoid) PA-related stimuli (a mean approach bias toward PA of 100.36 ms). Sport-based habit strength (mean 4.69 on a 1-7 scale) was slightly stronger than leisure-time PA habit strength (mean 3.37).

Associations between automatic response variables

Automatic PA valuations showed a small-to-medium positive association with PA approach tendencies, and sport-based and leisure-time PA habit strength were positively correlated, with a small-to-medium effect size. Automatic PA valuations were not associated with either sport-based or leisure-time PA habit strength, nor were approach tendencies. The three automatic response variables were therefore considered as empirically distinct, justifying inclusion of these as independent predictors in subsequent analyses.

Results

Descriptive Statistics and Bivariate Associations

Descriptive statistics and bivariate correlations between study variables are displayed in Table 2.

Associations with PA behaviour

Automatic valuations were not associated with total PA, leisure time PA, or active travel, but showed a small positive correlation with sport-based PA. Approach tendencies had a small positive correlation with sport-based PA, but no association with total PA, leisure time PA or active travel. Sport-based PA habit strength showed a small-to-medium positive correlation with sport-based PA, but was not associated with total PA, leisure time PA or active travel. Leisure-time PA habit strength showed a medium-to-strong positive correlation with leisure time PA engagement, and a medium positive correlation with total PA, but no association with sport-based PA or active travel.

Automatic Responses as Predictors of Physical Activity Behaviour

Table 3 shows the results of regression models predicting different forms of PA, assessing the unique contribution of automatic valuations, PA approach tendencies, and sport-based and leisure time PA habit after adjusting for other automatic responses, age, sex and survey language.

Predicting sport-based PA

All three automatic response variables independently and positively predicted sport-based PA, though the model explained only 7% of variance (model $R^2 = .07$, $p < .001$).

Predicting leisure time PA

Leisure-time habit strength was the only significant predictor of leisure-time PA, with automatic valuations and approach-avoidance tendencies having no influence. The overall model explained 28% of variance (R^2 = .28, p <.001).

Additional analyses

Leisure PA habit strength was also the only significant predictor of total PA (p < .001) in a model combining all automatic response variables (including both sport-based and leisure time PA habit strength). This model explained 13% of variance in total PA (R^2 = .13, p < .001). None of the automatic response variables predicted active travel (R^2 = .01, p = .35).

Discussion

This study aimed to isolate the unique contribution of each of three forms of automatic response—i.e., automatic valuations of PA, tendencies to approach (versus avoid) PA, and habit strength—as predictors of PA behaviour. Small correlations observed between the measures used to capture these variables suggested that we were able to successfully discriminate between the three variables. All three variables positively and uniquely predicted time spent in sport-based PA, but leisure-time PA habit strength was the only predictor of leisure-time PA. When considering total PA engagement, which combines measures of time spent in sport-based and leisure PA, and active travel, leisure-time PA habit strength was the only significant predictor. We urge caution in interpreting our findings, because the amount of variability in PA predicted by automatic processes was generally low. Nonetheless, our findings suggest that interventions targeting automatic processes may have the potential to increase engagement in sport-based activity, rather than in other forms of PA. To increase engagement in PA across multiple domains however, interventions may need to focus more on promoting habit formation.

While it is well documented that PA behaviours are regulated by automatic processes (e.g., Hagger, 2019; Rebar et al., 2016), our study is the first, to our knowledge, to model the unique contribution of different automatic processes to the prediction of PA engagement. Echoing previous research, each of the three automatic responses we explored was found to predict engagement in at least one form of PA (Rebar et al., 2016). In addition, all automaticity variables uniquely contributed to engagement in sport-based PA. Specifically, participants tended to report more time in sport-based PA where they also self-reported stronger habits (i.e., learned cue-response associations that automatically initiate PA) (Gardner, 2015; Gardner et al., 2016), and where their reactions to computer-based tasks indicated more positive automatic valuations of PA, and stronger approach tendencies (i.e., automatic attraction to PA stimuli). However, when modelling total PA, based on total time spent in sport, leisure-time PA, and engaged in active travel, leisure-time PA habit was the only significant predictor; automatic valuations and approach tendencies had no impact. Taken together, these findings suggest that engagement in competitive or club-related sport is driven by a range of automatic processes, but that the only automatic process involved in leisure-time PA is habit. This might perhaps reflect the purposeful nature of sport-related PA, such that those with stronger automatic biases towards activity, whether arising from automatic valuations, approach tendencies, or habits, are more likely to engage in sport. By contrast, leisure-time PA, however, may incorporate activities that incur activity incidentally, such as cycling or gardening, for which automatic biases favouring PA may be less influential (see ten Broeke et al., 2023).

Our results qualify findings from previous research in two ways. First, while automatic valuations and approach tendencies have been shown to predict PA in previous studies (Cheval et al., 2018; Chevance et al., 2018, 2019), these findings have been based on modelling the impact of each of these processes in isolation (e.g., Zenko & Ekkekakis, 2019). Our study suggests that, after adjusting for other automatic responses, automatic valuations and approach tendencies have negligible association with total PA. This cannot be attributed to conceptual overlap between these processes. While all three variables in the present study represent a subtype of automaticity (Rebar, 2017), the small correlations observed when using recognised measures of these variables may indicate that these constructs are empirically distinct (Cheval et al., 2014; Chevance et al., 2019; Gardner et al., 2012). Future research is needed to tease out measurement variability

Table 2 - Descriptive statistics and bivariate associations of physical activity and automatic regulatory constructs (N = 226)

	Measurement unit	Possible range	Mean (SD)	2.	3.	4.	5.	6.	7.	8.
1. Sport PA	Minutes	-	180.35 (83.01)	.21*	.14*	.53*	.13*	.14*	.17*	.10
2. Leisure time PA	Minutes	-	133.58 (127.23)		.22*	.72*	.10	.12	-.06	.44*
3. Active travel PA	Minutes	-	181.21 (146.76)			.76*	-.01	.07	-.07	.09
4. Total PA	Minutes	-	495.14 (245.94)				.09	.15	.00	.32*
5. Automatic valuations of PA (vs sedentary behaviour)	DW score	-2 – +2	0.70 (0.51)					.16*	.06	.05
6. Approach (vs avoidance) tendencies towards PA	Milliseconds	-	100.36 (108.26)						.05	.05
7. Sport PA habit strength		1 – 7	4.69 (0.75)							.22*
8. Leisure PA habit strength		1 – 7	3.37 (1.62)							

Note: *p < .05. SD: standard deviation. Total PA is the sum of sport PA, leisure-time PA and active travel.

Table 3 - Results of Stepwise Regression Models with Box-Cox Corrections of the Unique Contribution of Automatic Processes with Physical Activity Behaviour (N = 226)

	Sport PA		Leisure time PA		Active Travel		Total PA	
	b (SE)	β	*b* (SE)	β	*b* (SE)	β	*b* (SE)	β
Intercept	17.20 (3.14)*	-	0.83 (2.07)	-	11.92 (3.54)*	-	4.74 (0.17)*	-
Automatic valuations of PA (vs sedentary behaviour)	1.67 (0.76)*	0.15	1.00 (0.80)	0.07	-0.20 (0.86)	-0.01	0.08 (0.04)	0.12
Approach tendencies towards PA	0.01 (0.00)*	0.19	0.00	0.05	0.00 (0.00)	0.05	0.00 (0.00)	0.12
Sport PA habit strength	1.29 (0.51)*	0.17	-	-	-0.35 (0.59)	-0.04	-0.00 (0.03)	-0.01
Leisure PA habit strength	-	-	2.15 (0.25)*	0.50	0.34 (0.28)	0.09	0.07 (0.01)*	0.33
Adj. R^2	0.07*	-	0.28*	-	0.01	-	0.13*	-

Note: **p < .05. SE: standard error, b = unstandardised Beta coefficients, β = standardised Beta coefficient. All models include covariates of age, sex, and survey language.

from true construct variability before the conceptual distinctions can be verified. Second, assuming the robustness of our observations that multiple automatic processes predict sport-based PA but only habit predicts total PA, previous studies purportedly showing the impact of automatic valuations and approach tendencies on PA may have actually captured the influence of these processes on sport-based PA in particular. For example, one meta-analysis found positive associations between PA automatic valuations and self-reported moderate and vigorous PA, but no association in studies that included light-intensity PA as an outcome measure (Chevance et al., 2019).

The relative lack of empirical overlap between automatic processes warrants discussion. Automatic valuations of PA showed a small but significant positive correlation with a greater tendency to approach PA-related stimuli, but habit was not related to automatic valuations or approach-avoidance tendencies. This may be due to differences in how the three automatic response variables were measured. First, automatic valuations and approach-avoidance tendencies were captured using response-timed categorisation tasks, which aim to indirectly tap the associations underlying automatic responses to PA stimuli (Rebar, 2017), whereas habit was self-reported. Both measurement types are prone to error; while often assumed to offer objective and unbiased assessments of automatic processes, implicit measures can produce unreliable, context-sensitive responses (Corneille & Gawronski, 2024), and the validity of self-reporting habit has been questioned (Hagger et al., 2015; but see Orbell & Verplanken, 2015). Additionally, concerns have been raised that push-pull measures such as the Manikin Task, which we used to assess approach-avoidance tendencies, may at least partly capture the extent to which a stimulus is perceptually compatible with push or pull movements, rather than a true tendency to approach or avoid that stimulus in real-world settings (e.g., Gawronski & de Houwer, 2014). Similarly, the response-time tasks we used assume equal response precision across participants, but it is possible that some participants completed the tasks in quiet conditions whereas others may have been in more distracting environments, which may have slowed responses, or that different computer processing speeds affected the presentation of tasks or the precision of observed response times. The nature and magnitude of such methodological noise may have systematically differed between our measures, problematising observed associations between the three automatic responses. Second, we used a habit measure that requires participants to reflect on experiences indicative of automatic responding, such as whether PA is undertaken without thinking, or is initiated without having to remember to do so (Gardner et al., 2012; Orbell & Verplanken, 2015). This measure presupposes engagement in behaviour; participants must perform PA in order to consider the extent to which their PA is undertaken in a habitual manner. Unlike our automatic valuation and approach tendency measures, our habit measure thus conflated automatic responding with behavioural engagement (Gardner & Tang, 2014). Third, habit was measured in relation to specific forms of PA, whereas automatic valuations and approach-avoidance tendencies were assessed in relation to PA as a more generic concept. It is perhaps unsurprising, for example, that a measure of leisure-time PA habit strength predicted leisure-time PA but a measure of automatic responses to generic PA stimuli did not, given superior compatibility between the behaviour and habit measures (Ajzen & Fishbein, 2005). A lack of compatibility may have suppressed true relationships between the three automatic response variables, potentially compounding problems arising from a relative lack of correspondence between response-time measures of some automatic processes, and self-reported habit and behaviour. Fourth, and relatedly, we captured habit using a context-free measure, which may have further weakened compatibility between the three automatic response measures. Habitual responses are by definition context-specific, yet our habit measure tapped only the automaticity with which PA is undertaken in general, rather than the automaticity of PA *in specific settings*. Context-free measures are likely to summarise the automaticity of PA across multiple settings, so may both underestimate the strength of some PA habits (e.g., doing a morning workout) and overestimate the automaticity of non-habitual responses in other settings (e.g., cycling for pleasure;) (Diefenbacher et al., 2023; Rebar et al., 2018). The apparent lack of correspondence between habit and other automatic processes in this study may thus arise from problems inherent in capturing habit via a context-free self-report measure versus inferring automaticity via response-time tasks. Additionally, it is also theoretically possible that the context-free measure we used to assess habit also captured non-habit forms of automaticity, which is problematic when seeking to differentiate habit from other automatic processes, though negligible correlations between habit and other processes in this study suggests that this did not occur. Nonetheless, future research should seek to replicate our findings using alternative, non-self-report habit measures more sensitive to performance context (Rebar et al., 2018).

Potential study limitations must be acknowledged. Given our sample size was slightly less than was required to find small effects, it may be that some small but meaningful associations were not detected due to a lack of statistical power. Additionally, our PA measure focused on duration, not frequency. Yet, the automatic responses we assessed would be expected to influence the decision to initiate engagement in PA, rather than the subsequent duration of engagement. For example, habit measures that focus on the automatic selection of action predict PA frequency more strongly than do measures of automatic execution of PA (Phillips & Gardner, 2016). Additionally, data were collected during the Covid pandemic (2020-21), which disrupted typical PA engagement for many people (e.g., Maltagliati et al., 2021). The disruption of opportunities for PA during this period, due to pandemic-related restrictions, may have caused greater disconnect between automatic responses to PA and PA engagement, though we did not collect data regarding whether or how participants' PA may have been disrupted. The complex and ever-changing magnitude of Covid-related restrictions within and between countries during the data collection period precludes a meaningful assessment to what extent, or how, reported automatic processes and behaviours may have differed from their usual non-pandemic baseline. Future research should seek to establish whether our findings hold in stable, post-pandemic contexts. Our sample was predominantly recruited via university-based channels and overrepresented females, which limits its generalisability. University students tend to engage in more PA than the general public (e.g., Stanford et al., 2013), and female students tend to be less active than males (e.g., Clemente et al., 2016). Moreover, the sample was highly active, reporting an average of over 6 hours of total weekly PA (484mins), and so may not represent the many people who fail to achieve the 150mins of moderate-to-vigorous PA recommended in international guidance (Strain et al., 2024). It is possible that the highly active profile of participants led to restriction of range effects, such that a lack of variability in automatic valuation, approach-avoidance tendencies, and habit strength may have suppressed true relationships between automatic responses and PA engagement. Future research should seek to engage with less active populations, to ensure that findings generalise to populations most in need of support to increase their PA. Alternatively, we may have generated inaccurate measures of PA. Self-reported PA is known to overestimate true PA engagement (Hyde et al., 2012; Prince et al., 2008). Furthermore, we calculated total PA as the sum total of time spent in sport, leisure-time PA, and active travel. While we instructed participants to exclude sports-related and active travel PA from estimates of moderate and vigorous PA, it is possible that some boundary examples – such as weight training in a gym, which may benefit competitive sports performance – may have been double-counted, thereby introducing error into our total PA measure. Lastly, we used a cross-sectional design, from which causality cannot be established. For these reasons, our findings are preliminary and warrant replication using more robust methods less reliant on self-report.

Conclusion

This study sought to identify the unique contribution of three automatic responses to PA—automatic valuations, approach-avoidance tendencies, and habit—to PA engagement. All three processes predicted engagement in sport-based PA, but only leisure time habit strength predicted a measure of total PA engagement. Given methodological limitations, including studying a highly active sample, operationalising PA according to duration rather than frequency, and use of a cross-sectional design, we urge caution in interpreting our findings, and call for further, more methodologically robust research to replicate our results among a more representative sample of the general public. Additionally, effect sizes were small, indicating that automatic processes play only a modest role in sustaining PA. Nonetheless, if our findings were replicated using more rigorous methods, they would suggest that, to promote greater uptake of sport-based PA, interventions should be designed to help people form stronger habits (see Gardner et al., 2020c), develop positive affective associations with PA (see Conroy & Kim, 2021; Rasera et al., 2022), and to learn to actively approach PA opportunities (see Maltagliati et al., 2024; Qiu & Zhang, 2020). Future work is needed to develop understanding of how – for example, through which mechanistic mediators – automatic responses influence PA behaviour. To encourage PA across multiple domains however, interventions might fruitfully focus more on promoting the formation of leisure-time PA habits.

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Conflict of interest disclosure

The authors declare that they have no conflict of interest relating to the content of this article.

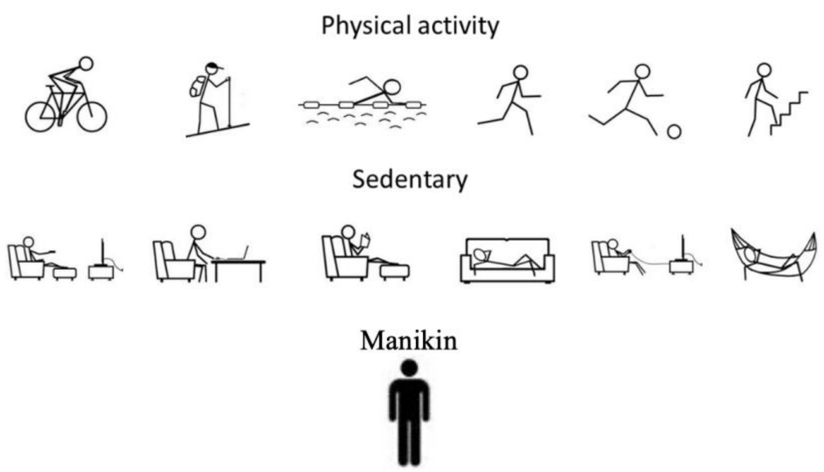
Data, script, and code availability

Data, scripts and code (Rebar et al., 2025) can be freely accessed online via the Open Science Framework: https://doi.org/10.17605/OSF.IO/HMA38

Appendices

Appendix Table - Words used in Automatic Valuation measure (adapted from Greenwald et al., 1998, by Chevance et al., 2017)

Positive valence words	Negative valence words	Physical Activity words	Sedentary Behaviour words
Vigor	Dreadful	Active	Sofa
Euphoria	Exhausting	Move	Sit
Vitality	Fatigue	Run	Armchair
Uplifting	Tiring	Effort	Rest
Pleasant	Sadness	Walk	Television
Joyous	Annoying	Sport	Lay down
Satisfying	Boring	Stairs	Couch
Amusing	Disappointing	Bike	Read



Appendix Figure - Images used in Approach-Avoidance measure (Manikin Task)

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