Predictors of School Students' Leisure-Time Physical Activity: An Extended Trans-Contextual Model Using Bayesian Path Analysis

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Research

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Abstract

Background:

The trans-contextual model (TCM) has been applied to identify the determinants of leisure-time physical activity participation in secondary school students. In the current study, the TCM was extended to include additional constructs that represent non-conscious, implicit processes that lead to leisure-time physical activity participation alongside the motivational and social cognition constructs from the TCM. The current study used baseline and follow-up data from an intervention study to test the extended TCM.

Methods:

The current study adopted a two-wave prospective design. Secondary-school students (*N* = 502) completed measures of perceived autonomy support from physical education (PE) teachers, autonomous motivation in PE and leisure-time contexts, social cognition constructs (attitudes, subjective norms, perceived behavioral control), intentions, trait self-control, habits, and past behavior all in a leisure-time physical activity context. Five weeks later, students (*N* = 298) completed a follow-up self-report measure of their leisure-time physical activity.

Results:

Bayesian path analyses supported two key premises of the model: perceived autonomous support predicted autonomous motivation in PE, and autonomous motivation in PE predicted autonomous motivation in leisure time. However, while both forms of autonomous motivation predicted social cognition constructs and intentions, they did not predict leisure-time physical activity participation. Trait self-control, attitudes, and past behavior were direct predictors of intentions and leisure-time physical activity participation. Specifying informative priors for key model relations using Bayesian analysis yielded greater precision for some of the estimates.

Conclusions:

Findings raise some questions on the efficacy of the original TCM, but highlight the value of extending the TCM to incorporate additional constructs representing non-conscious processes.

Introduction

Research indicates that low levels of physical activity are associated with deleterious effects on the physical and mental health in young people. For example, inadequate physical activity is linked with increased risk of developing chronic conditions such as juvenile obesity, and increased levels of cardiovascular disease risk factors, in school-aged children and adolescents [1, 2]. In addition, physical inactivity is associated with compromised mental health outcomes including increased depressive symptoms and psychological distress, and reduced psychological well-being and quality of life [3]. In contrast, regular physical activity participation is related to reduced chronic disease risk and adaptive mental health outcomes in young people [4, 5]. However, children and adolescents in many nations are not sufficiently active to confer health benefits and reduce disease risk [6]. As a consequence, national and international health organizations have developed guidelines for the required amount of physical activity to promote health in young people, and developed national strategies and campaigns aimed at promoting physical activity in this population [7].

Given the imperative for promoting physical activity among young people, researchers have sought to identify optimally effective strategies to enhance physical activity in this population, and contexts in which these strategies will have maximal reach. Physical education (PE) has been suggested as a potentially useful existing network that can be utilized to deliver interventions promoting physical activity both inside school, and, importantly, outside school, in children and adolescents [8, 9]. Researchers have, therefore, aimed to explore the potentially efficacious strategies to promote increased physical activity in this context. Such an endeavor necessitates an understanding of the determinants of children and adolescents' physical activity participation in a PE context and, importantly, also whether those determinants relate to physical activity participation outside of school in students' leisure time [10]. This is because students only receive a discrete number of hours of PE in any given week, which, in itself, is not sufficient to meet physical activity guidelines. Therefore, understanding how factors linked to engagement in physical activity in school relate to physical activity performed in another context, leisure time, is critical to informing potential strategies delivered in PE that promote physical activity participation in children and adolescents in their leisure time. Such an approach is also consistent with one of the key pedagogical aims of PE to provide young people with the necessary skills to lead an active lifestyle [11].

The Trans-Contextual Model

The trans-contextual model [TCM; 10] was developed to provide a theoretical explanation of the constructs and processes that link engagement in physical activity in school PE with physical activity participation in leisure time. The model draws on multiple theories to outline the processes by which school students' motivation toward physical activity in PE relates to their motives and beliefs toward, and actual participation in, physical activity in their leisure time. The model integrates core constructs and processes from self-determination theory [12], the hierarchical model of intrinsic and extrinsic motivation [13], and the theory of planned behavior [TPB; 14]. Next, we outline the key premises of the model relating to the determinants of children and adolescents' leisure-time physical activity and the processes involved.

Based on self-determination theory, the first premise of the TCM focuses on the origins of school students' motivation toward activities in PE, and how their motivation relates to their behavior in PE. The model predicts that the social environment in educational settings fostered by social agents and leaders (e.g., PE teachers) will determine the type or *form* of motivation students experience when performing tasks (e.g., physical activities in PE) and, importantly, their persistence on tasks. Central to the theory is the distinction between autonomous and controlled forms of motivation. Autonomous motivation is a form of

motivation reflecting self-endorsed reasons for acting such that behaviors are experienced as originating from the self and chosen. Autonomously motivated individuals tend to persist on tasks and experience adaptive concomitant outcomes including increased interest, engagement, and well-being. Multiple studies in educational contexts, including those in PE, have supported links between students' autonomous motivation and their persistence on activities [15, 16]. Fostering autonomous motivation toward physical activity in PE contexts is, therefore, considered adaptive and desirable. In addition, theory suggests that display of autonomy-supportive behaviors by social agents such as PE teachers when instructing students will promote autonomous motivation toward physical activities performed in PE. Research has indicated that students who perceive their PE teacher as displaying behaviors that support their autonomy are more likely to report autonomous motivation toward physical activities during their PE lessons [17, 18]. Taken together, these predictions form the basis of the first premise of the TCM: students perceived autonomy support from their teachers in PE will relate to their autonomous motivation toward physical activity in a PE context.

A central prediction of the TCM, consistent with its moniker, is that there will be a trans-contextual relationship between students' autonomous motivation toward physical activities across PE and leisure-time contexts. This prediction is based on Vallerand's [19] hierarchical model, which describes the process by which motivation is transferred across contexts. Vallerand proposed that forms of motivation from self-determination theory operate at general, contextual, and specific levels. Within the contextual level, some cross-contextual interplay between forms of motivation is proposed, such that individuals experiencing autonomous motivation toward activities in one context will also cite autonomous motives toward similar behaviors in other related contexts. This forms the second premise of the TCM: school students' level of autonomous motivation toward physical activities in a PE context will be related to their autonomous motivation toward physical activities performed outside of school in their leisure time.

A final prediction of the TCM is that autonomous motivation toward physical activities in a leisure-time context will be related to students' beliefs and intentions toward, and future participation in, leisure-time physical activity. Deci and Ryan's [12] original conceptualization of self-determination theory proposed that individuals with autonomous motives toward a particular behavior are likely to perform the autonomously-motivated behavior again in future. The mechanism underpinning this motivation is the satisfaction of basic psychological needs of autonomy, competence and relatedness, particularly the need for autonomy. If an individual has experienced a behavior as autonomously motivated, it is likely to be internalized and integrated into the individuals repertoire of behaviors that satisfy their need for autonomy, and they are therefore more likely to actively seek out opportunities to engage in the behavior in future. To do so, they need to align their system of beliefs and intentions involved in the decision to perform that behavior in future. In the TCM, this process is modeled by the sets of beliefs from the TPB, a leading social cognition theory [14]. Consistent with Deci and Ryan's predictions, autonomously-motivated individuals are likely to form positive intentions to perform the behavior in future, and report favorable attitudes, subjective norms, and perceived behavioral control, the immediate belief-based determinants of intentions [20]. This forms the third premise of the TCM: students' autonomous motivation toward physical activity in leisure time will be related to their future participation in leisure-time physical activity mediated by the belief-based social cognition determinants (attitudes, subjective norms, and perceived behavioral control) and their intentions toward participating in leisure-time physical activity in future.

The key premises of the TCM have received substantial empirical support, including relations between perceived autonomy support and autonomous motivation in a PE context, the trans-contextual relationship of autonomous motivation in PE and leisure-time physical activity contexts, and the effect of leisure-time autonomous motivation on subsequent leisure-time physical activity participation mediated by beliefs and intentions from the TPB [10, 21-23]. Furthermore, research has replicated model predictions across national groups with notable cultural differences [24] and supported its generalizability in other educational contexts [25, 26]. Finally, a meta-analysis of studies applying the model in PE and leisure-time physical activity contexts provides converging evidence supporting model predictions across multiple studies [27].

Extending the Model

While the TCM has displayed utility in identifying the determinants of leisure-time physical activity participation from motivational and social cognition determinants across contexts, it has been criticized on several grounds [for a review see 27]. One important critique is that it neglects consideration of additional constructs known to account for unique variance in motivation, intentions, and leisure-time physical activity participation. For example, researchers have extended the TCM to include effects of students' perceived autonomy support from multiple salient social agents, including parents and peers [24], and the role of satisfaction of basic psychological needs [23]. Both additions have increased the variance explained in autonomous motivations and intentions, and broadened the scope of the model to include additional salient processes. Such modifications, while theoretically consistent, empirically supported, and valuable from the perspective on understanding processes, have not been shown to increase explained variance in leisure-time physical activity participation, which still remains relatively modest. For example, a meta-analysis of the TCM suggested that the model accounts for 36.64% of the variance in leisure-time physical activity participation, suggesting that substantive variance remains unexplained [27]. Researchers have subsequently been encouraged to recognize the TCM, consistent with many integrated models, as a flexible, modifiable model that should be subject to modification with additional constructs that account for additional variance in behavior, provided those modifications are theoretically plausible and, subsequently, can be supported empirically [28].

In keeping with its constituent theories, the TCM focuses exclusively on motivational and social cognition determinants of leisure-time physical activity participation. However, such an approach does not account for the potential influence of factors that affect individuals' behavior beyond their awareness and reflect non-conscious, automatic processes that determine behavior [29, 30]. There has been a proliferation of research on behavioral determinants reflecting these processes in physical activity contexts [31-34], and reflect a general rise in interest in dual-process theories of motivation and social cognition [35]. Such theories propose that individuals' behavior is determined by constructs that reflect conscious, reasoned decision making such as autonomous motivation and the social cognition constructs from the TPB. These determinants reflect a deliberative, effortful decision-making process that involves consideration of the reasons, merits, and detriments of a course of action, and action is a function of this reasoning. The determinants, and the network of relations among them, specified in the TCM reflect such a process. However, dual-process theories suggest that action is also guided by constructs that reflect implicit decision-making that impact behavior with little effortful deliberation. Such constructs include implicit attitudes, habits, and individual difference constructs [31, 36, 37]. Non-conscious processes are adaptive because they eschew the necessity for engaging in costly, effortful decision making when such decisions have

been made previously, when a coherent of beliefs and related behavioral responses stored in memory are available and, once activated, will lead to effective, efficient decision-making [29, 38]. Importantly, constructs reflecting these non-conscious processes are proposed to impact behavior directly without mediation by intentions and are, therefore, independent of the reasoned processes. These constructs may, therefore, account for the additional variance in leisure-time physical activity participation in the TCM unaccounted for by its social cognition and motivational constructs.

Two prominent behavioral determinants that reflect non-conscious processes are habit and trait self-control. Although research on habits has historically considered effects of past behavior as a viable proxy for habitual effects [39], recent research has focused on habit as a construct [36, 40]. This approach reflects advances in theory characterizing habit as integral to the psychological process by which behaviors become automated and controlled non-consciously. Theories of habit suggest that habitual behaviors are a function of behavioral experiences in the presence of consistent environmental, situational, or internal cues, and often experienced as automatic, effortless, and highly accessible [40, 41]. These components, particularly the automaticity component of behavior, have been captured in self-reported measures of habit, which are meta-cognitive measures of individuals' experience of behaviors as habitual [36, 42]. Such measures have been shown to predict behavior independent of intention-mediated measures, and are also associated with action accessibility and behavioral performance in stable contexts.

Another behavioral determinant that has been proposed to reflect non-conscious processes is trait self-control. Trait self-control reflects individual differences in capacities and self-regulatory skills that enable individuals to resist impulses and temptations, and engage in sustained, effortful behavior to attain long-term goal-directed outcomes [43]. Trait self-control has been consistently related to adaptive behaviors, including physical activity, across multiple contexts and populations [44]. Research has also demonstrated that behavioral effects of trait self-control may be direct, independent of intentions [45]. Such effects reflect generalized tendencies to engage in adaptive behaviors without the need for deliberation or consideration. This may be the case when the individual has a past history of engaging in the adaptive behavior and their adaptive skill sets to engage in the behavior is reflected in their trait self-control [46]. However, a case has also been made for effects of trait self-control on behavior mediated by intentions [47, 48]. Such effects reflect situations where individuals have to actively engage in effortful deliberation to overcome a maladaptive behavior, or engage in a new behavior, that requires deliberation. Effects of trait self-control in motivational and social cognition theories may, therefore, relate to behavior via two pathways, directly, and indirectly through intentions. Research incorporating trait self-control in the model has supported these dual effects, with direct and intention-mediated effects on physical activity participation [47].

There is also research demonstrating that attitudes may predict behavior directly, and such direct effects may also reflect non-conscious decision making [49-52]. Although the original conceptualization of the TPB specifies that attitudes represent individuals' cognitive reflections on their future participation in a target behavior and, as such, should relate to behavior mediated by intentions, empirical research has identified direct effects for some behaviors and in some contexts [51]. Researchers have suggested that this is due to the attitude construct capturing both affective and cognitive components. The cognitive component reflects utilitarian beliefs about performing the behavior in future (e.g., performing the behavior will be useful or beneficial), while the affect component reflects judgements about whether performing the behavior will be emotionally appealing (e.g., performing the behavior will be enjoyable, or evoke happiness or sadness). The affective component encompasses visceral approach or avoidance responses that are well-learned through behavioral experience [53]. As a consequence, a direct effect of attitude on behavior may reflect a further spontaneous, automatic process which affects behavior independent of intentions.

In the present study, we aimed to extend the TCM by including these constructs as additional determinants alongside the constructs of the model in a test of the model. This extension is expected to provide additional information on the determinants of leisure-time physical activity behavior, particularly effects of constructs representing non-conscious processes not accounted for in the original TCM. These constructs are proposed, therefore, to relate to leisure-time physical activity participation directly, independent of effects of the other motivational and social cognition constructs in the model. In addition, effects of trait self-control were expected to be mediated by intention, consistent with the dual effects for this construct and previous research [47].

A Bayesian Approach

The accumulation of research evidence applying the TCM presents opportunities to capitalize on this data in studies conducting new tests of the model. The widespread use of Bayesian analytic procedures facilitates such an approach by allowing researchers to incorporate existing knowledge into their analyses and, in doing so, provide more precise estimates of the parameters in model tests [54, 55]. Traditional frequentist multivariate approaches to data analysis adopt a strict inflexible approach to estimating model parameters, which has disadvantages in that data that diverges from the strictly-specified model tends not to fit well. Bayesian analytic procedures assume that model parameters have inherent uncertainty that can be represented by a distribution. Bayesian analysis compares prior distributions of the expected model parameters (known as 'priors') and the observed or sampling distribution of the same model parameters in a given dataset [56]. The analysis combines the prior and observed distributions using Bayes theorem to produce a posterior distribution for each model parameter [54, 55, 57]. In the absence of prior data on the point estimates and distributions of a particular parameter, a researcher has to specify relatively broad and imprecise priors. These *non-informative* priors will yield posterior point estimates and distributions of model parameters that are not greatly influenced by the priors. Where previous data exists, the researcher can specify highly informative priors. If the observed data represents the priors well, the model specifying informative priors should yield more precise point estimates and distributions of model parameters, as indicated by a narrowing of the 95% credibility intervals about the posterior parameter estimates. This allows researchers to use prior knowledge of previous tests of parameters in a model, perhaps generated in multiple previous studies, to inform and update current observations.

In the current research we applied the Bayesian analytic approach to a test of the TCM with informative prior values for key model effects derived from a meta-analysis of the TCM [27]. We expected to see a reduced level of uncertainty in the distributions of the parameters of the TCM model specified for the current data when informative priors for key model parameters derived from the meta-analysis are specified, reflected in narrowed credibility intervals, compared to the distributions when non-informative priors are specified. Given that we proposed to extend the TCM to include habit and trait self-control as

predictors of leisure-time physical activity participation, we also capitalized on previous meta-analytic research on self-reported habit [58] and trait self-control [44] to specify informative priors for these parameters in our test of the extended TCM. The approach allows us to use cumulative data from previous research to inform the extension of the model to incorporate additional constructs.

The Present Study

The current study investigated the determinants of lower secondary school students' leisure-time physical activity participation based on an extended TCM. The study adopted survey methods and a five-week prospective design with measures of motivational and social cognition constructs, habit, trait-self-control, and past physical activity participation taken at an initial occasion, and self-reported leisure-time physical activity participation taken at follow-up, five weeks later. In addition to testing effects of the motivational and social cognition determinants from the TCM on students' intentions toward, and actual participation in, leisure-time physical activity, we also tested direct effects of constructs reflecting non-conscious processes as direct determinants of leisure-time physical activity participation, self-reported habit, trait self-control, and attitudes. Hypothesized direct and indirect effects in the proposed model are summarized in Table 1 and Figure 1.

The first premise in which perceived autonomy support from PE teachers is related to autonomous motivation in a PE context is represented by the first hypothesis (H_1). The second premise specifying the trans-contextual effects of autonomous motivation across PE and leisure-time contexts is represented by the second hypothesis (H_2). Perceived autonomy support was also expected to predict autonomous motivation in leisure time directly (H_3), although the majority of effects of this construct on leisure-time physical activity participation was expected to be mediated by the motivational sequence of the model. The third premise that effects of autonomous motivation in leisure time predicts leisure-time physical activity participation through beliefs and intentions from the TPB is represented by effects of autonomous motivation on attitude (H_4), subjective norms (H_5), and perceived behavioral control (H_6), the effects of attitude (H_8), subjective norms (H_9), and perceived behavioral control (H_{10}) on intention, and intention (H_{13}), attitude (H_{14}), and perceived behavioral control (H_{15}) on leisure-time physical activity participation. In addition, direct effects of autonomous motivation in leisure-time on intentions (H_7) and leisure-time physical activity participation (H_{18}) were specified. The model was also extended to include effects of self-reported habit (H_{11}, H_{16}) and trait self-control (H_{12}, H_{17}) on intentions and leisure-time physical activity participation, respectively. Finally, past physical activity behavior was expected to predict leisure-time physical activity participation (H_{19}).

Indirect effects reflecting key mediation effects were also specified. Perceived autonomy support was expected to predict autonomous motivation in leisure time indirectly mediated by autonomous motivation in PE (H_{20}). Autonomous motivation in PE was expected to predict intentions and leisure-time physical activity participation indirectly mediated by autonomous motivation in leisure time and attitude (H_{21}, H_{24}), subjective norms (H_{22}, H_{25}), and perceived behavioral control (H_{23}, H_{26}), with an additional effect of autonomous motivation in PE on leisure-time physical activity participation through autonomous motivation in leisure time and perceived behavioral control only (H_{27}). Autonomous motivation in leisure time was expected to predict intentions and leisure-time physical activity participation indirectly mediated by attitude (H_{28}, H_{31}), subjective norms (H_{29}, H_{32}), and perceived behavioral control (H_{30}, H_{33})

Data were analyzed using a Bayesian path analysis of hypothesized relations among the extended TCM constructs with informative priors taken from meta-analyses. This model was compared to a model with non-informative prior values. We expected the current study to provide further evidence to support the TCM in predicting lower secondary school students' leisure-time physical activity participation, and extend it to encompass effects representing non-conscious processes. Results may inform the development of PE interventions targeting multiple processes that may have efficacy in promoting school students' motivation toward, and actual participation in, leisure-time physical activity participation.

Method

Participants

Participants were lower secondary school students (N = 502, 43.82% female; *M* age = 14.52, *SD* = 0.71) recruited through established links with schools across Jyväskylä, Finland with support from the City Education Department. The University institutional review board and Education Department approved the study protocol prior to data collection. Informed consent was sought from the head teacher of each school, and, subsequently, PE teachers and eligible students' parents or legal guardians via the schools' online administration and communication software or via email or post. Opt-in consent was sought from the head teachers and PE teachers, while opt-out consent was sought from students' parents and legal guardians. Qualified full-time PE teachers teaching regular PE lessons in lower secondary schools were eligible to participate in the study and were asked to select one of their PE classes to take part. Students in grades 7 to 9 (typical ages 13 to 15 years) in lower secondary schools were eligible to participate. Students with existing physical or mental health conditions that prevented participation in PE lessons, regular leisure-time physical activity, or completing surveys were excluded.

Design and Procedure

Data for this study was collected as part of a larger randomized controlled trial (trial registration: ISRCTN39374060. Registered July 24, 2018). The study adopted a cluster-randomized, waitlist control, single-group intervention design with randomization by school. The trial comprised a teacher training phase and an implementation phase; full details of the intervention design and content have been published previously [59]. Secondary school PE teachers (*N* = 29) from 11 secondary schools and their students (*N* = 502) were invited to participate in the study. The pool of potentially eligible students numbered approximately 5000 based on numbers from the 11 schools. Baseline data was collected prior to the teacher training phase and participants completed self-report questionnaires assessing demographic, psychological, and behavioral measures. The baseline data collection period was followed by the teacher training phase (12 hours over two weeks) and the implementation phase (one month), after which post-intervention data was collected comprising the same self-report questionnaires as at baseline. Follow-up data was further collected one, three, and six months post-intervention. The present study used measures

of motivation and social cognition constructs and leisure-time physical activity participation taken at baseline and post-intervention leisure-time physical activity participation controlling for the effects of the intervention at baseline. Data for the present study were collected between September and December 2018.

Measures

Measures of study constructs were adapted from validated self-report instruments used in previous applications of the TCM. Measures included in the surveys were: perceived autonomy support from PE teachers [60]; autonomous motivation derived from items measuring self-determined forms of motivation from the perceived locus of causality scales for the PE and leisure-time physical activity contexts [61]; intentions, attitudes, subjective norms, and perceived behavioral control from the TPB [62]; self-reported habit [42] and trait self-control [63]; and self-reported leisure-time physical activity participation [64]. All self-report measures were translated from English to Finnish using a back-translation process by two bilingual researchers. A summary of each measure follows with complete measures available in Appendix A (supplemental materials).

Perceived autonomy support

Students' perceived autonomy support from their PE teacher was measured using items from the Perceived Autonomy Support Scale for Exercise Settings [PASSES; 60]. The scale comprised 13 items (e.g., "I feel that my PE teacher provides me with choices and options to …") with responses provided on seven-point scales (1 = *strongly disagree* and 7 = *strongly agree*). The scale has demonstrated adequate construct validity and internal consistency in previous research [60, 65].

Autonomous motivation

Autonomous motivation toward in-school and out-of-school physical activities was measured using items from the Perceived Locus of Causality Questionnaire [61]. Two items measured *identified regulation* (e.g., "I do PE/physical activity because it is important to me to do well in PE/physical activity") and two items measured *intrinsic motivation* (e.g., "I do PE/physical activity because it is fun"). Responses were provided on seven-point scales (1 = *not true for me* and 7 = *very true for me*). For each of the PE and leisure-time contexts, a composite autonomous motivation score was computed by averaging scores on the identified regulation and intrinsic motivation items. Measures of autonomous motivation have demonstrated satisfactory construct validity and internal consistency in previous studies [65].

TPB Constructs

Measures of students' attitudes, subjective norms, perceived behavioral control, and intentions with respect to their future participation in leisure-time physical activity were developed according to published guidelines [62]. Attitudes were measured on three items in response to a common stem: "Participating in physical activity in the next five weeks will be…", with responses provided on seven-point scales (e.g., 1 = *unenjoyable* and 7 = *enjoyable*). Subjective norms (e.g., "Most people who are important to me think I should do active sports and/or vigorous physical activities during my leisure time in the next five weeks"), perceived behavioral control (e.g., "I am confident I could do active sports and/or vigorous physical activities during my leisure time in the next five weeks"), and intentions (e.g., "I intend to do active sports and/or vigorous physical activities during my leisure time in the next five weeks") were measured using two items each with responses provided on seven-point scales (e.g., 1 = *strongly disagree* and 7 = *strongly agree*). Previous research has supported the construct validity and internal consistency of these measures within the TCM [65].

Habit

Habit was measured using the Self-Report Behavioral Automaticity Index [42], a short form of the Self-Reported Habit Index [36] which focuses on personal experience of the behavior as 'automatic' and excludes items related to past behavior. The scale comprised four items (e.g., "Physical activity is something I do without thinking") with responses provided on seven-point scales (1 = *completely disagree* and 7 = *completely agree*). The scale has demonstrated satisfactory internal consistency and validity in previous research [42].

Trait self-control

Students' trait self-control was measured using the 10-item Self-Discipline Scale (e.g., "I tend to carry out my plans") from the IPIP-HEXACO scales [66] with responses provided on four-point scales (1 = *not like me at all* and 4 = *very much like me*). Research has demonstrated the internal consistency and predictive validity of this scale in school contexts [67].

Leisure-time physical activity participation

Leisure-time physical activity participation at follow up was measured using the short form of the International Physical Activity Questionnaire [IPAQ; 64]. The introduction statement to the measure asked students to disregard physical activity performed in school. The IPAQ comprises four items recording the frequency (number of days) and duration (minutes per day) of engagement in moderate and vigorous physical activity, walking, and sitting over the past seven days. IPAQ data were processed according to established guidelines [68]. The procedure gives an estimate of physical activity in MET-minutes per week with higher MET-minute values indicating higher level of physical activity engagement. Full details of calculations used to produce physical activity estimates are presented in Appendix B (supplemental materials). The short form of the IPAQ has shown adequate internal consistency and validity and reasonable agreement with the long form in previous research [64].

Data Analysis

The proposed hypotheses of the extended TCM (see Table 1 and Figure 1) were tested using Bayesian path analytic models estimated with the Mplus 8.4 statistical software. Constructs and behavioral variables were manifest variables computed from the mean of the scale items for each construct. We controlled for the effects of the intervention in the model by including effects of a binary variable representing intervention group membership (1 = allocated autonomy support intervention group, 0 = allocated to control group) on follow-up leisure-time physical activity participation. We controlled for effects of gender as a binary variable (0 = female, 1 = male) and age as a continuous variable by estimating effects of these variables on all other constructs in the model. Missing data for the model components were imputed using full information maximum likelihood (FIML) in Mplus.

The Bayesian path models were estimated using a Markov Chain Monte Carlo (MCMC) simulation process using Gibbs' algorithms [56]. We specified 100,000 iterations of which the first half were used as a burn-in phase and the remaining posterior draws used to test model inferences. We adopted Gelman and Rubin's [69] criterion to determine the convergence of the Bayesian estimates with a strict potential scale reduction (PSR) value of 1.01. Two models were estimated. The first was estimated using non-informative prior values for model parameters using the standard default values offered in Mplus for regression coefficients: normal distribution, mean = 0, variance = infinity[1]. The second adopted informative prior values for key parameters in the model derived from three meta-analyses. Priors for relations among TCM constructs were derived from Hagger and Chatzisarantis' [27] meta-analysis. The prior value for the effect of self-reported habit on leisure-time physical activity participation was taken from Gardner et al.'s [58] meta-analysis of self-reported habit in physical activity. Finally, the prior value for the effect of trait self-control on leisure-time physical activity participation was taken from de Ridder et al.'s [44] meta-analysis of trait self-control in health behaviors. Non-informative default priors were specified for the remaining paths.

Fit of the Bayesian models was assessed using posterior predictive checking using recommended criteria based on the goodness-of-fit chi-square comparing the proposed model with the observed data across the replications in the Bayesian simulation [56]: (a) the 95% confidence interval of the difference in goodness-of-fit chi-square values associated with the observed and replicated data, which should have a positive upper bound and a negative lower bound with the interval centered approximately about zero, and (b) the posterior predictive *p*-value (PPP), which should exceed .05 and preferably approach .50 for a well-fitting model. In addition, we also report a series of approximate fit indices equivalent to those reported in frequentist path analysis: the comparative fit index (CFI), Tucker-Lewis index (TLI), and the root mean square error of approximation (RMSEA) computed at each MCMC iteration and their 90% confidence intervals [71]. Cut-off values of .95 or greater for the CFI and TLI, and .06 for the RMSEA, have been proposed as indicative of good model fit. Furthermore, the 90% confidence intervals of each index should ideally exceed the cut-off values.

With respect to model parameters, the Bayesian analysis computes the point estimate and a 95% credibility interval for each proposed model path. The hypothesized effect is considered supported if the posterior credibility interval of the parameter coefficient for the effect does not include zero. In such cases, the posterior probability of a coefficient not including zero is >0.975. In addition, estimates and credibility of indirect effects for the Bayesian models were estimated using Yuan and MacKinnon's [72] method. The Bayesian approach that included informative priors for key relations in the model was expected to improve the precision of the estimates. Comparisons of the models with non-informative and the model that included informative priors for key model relationships were evaluated by comparing the reduction in variance of the parameter estimates as result of the inclusion of informative priors for key model relationships. We therefore computed the extent to which the width of the credibility interval of the parameter estimates decreased in our Bayesian model with informative priors compared to the model with non-informative priors. Data file and Mplus syntax for the analyses are available online: https://osf.io/z8axj.

Results

Preliminary Analyses

Of the participants who completed the initial survey (N = 502), 370 provided complete data at baseline and 298 participants (50% female; M age = 14.51, SD = 0.70) provided data for analysis after the second survey (19.46% attrition rate). Attrition was due to school absences. Percentage of missing data for the psychological constructs over time was low (M = 1.4%; range = 0.0% to 4.0%) and data were found to be missing completely at random according to Little's [73] MCAR test (χ^2 = 63.882, df = 70, p = .683). In addition, there were no significant differences between those who completed study measures at both time points and those who did not on gender distribution, ($\chi^2(1)$ = 0.403, p = .526), age ($t(368)$ = -0.463, p = .643), or baseline physical activity ($t(368)$ = -1.103, p = .271). We also conducted a one-way MANOVA to examine differences in psychological variables between those who completed study measures at both time points and those who did not, which was not significant ($F(9, 360)$ = 0.775, p = .639; Wilks' Λ = .981; partial η^2 = .019). Means, standard deviations, omega internal consistency coefficients [74], and zero-order intercorrelations among study constructs are presented in Table 2. All constructs exhibited adequate internal consistency.

Path Analyses

Bayesian path analytic models using non-informative (Bayesian posterior predictive χ^2 95% CI = [-25.520, 58.347]; PPP = 0.224; CFI = 0.987, 90% CI = [0.968, 1.000]; TLI = .953, 90% CI [0.881, 1.000], RMSEA = 0.048, 90% CI [.000, .076]) and informative priors for key model relationships (Bayesian posterior predictive χ^2 95% CI = [-17.857, 67.360]; prior PPP = 0.389; CFI = 0.982, 90% CI = [0.961, 0.999]; TLI = .918, 90% CI [0.825, 0.996], RMSEA = 0.064, 90% CI [.013, .093]) exhibited adequate goodness-of-fit with the data, although it should be noted that the 90% confidence intervals for the TLI were wider than desirable and included the .95 cut-off value. This index penalizes models of high complexity, indicating a relative lack of parsimony in the model. Parameter estimates and 95% credibility intervals for the analysis with non-informative priors (Model 1) and the analysis including informative priors for key model relationships (Model 2) are presented in Table 3 and Figure 2[1].

Assuming the selected priors derived from meta-analyses were indicative of the population point estimates and distributions of effects among model constructs, we expected that Model 2 would yield greater precision in model parameter estimates compared to Model 1 [72]. This was evaluated by examining

the extent to which the credibility intervals about each parameter estimate differed across the models (Table 3). Results indicated that the width of the credibility intervals was narrowed for a few of the effects in Model 2 relative to Model 1, but not by a substantial margin in most cases. The adequate fit of both models suggest that including informative priors in the analyses for key model relationships did not have a substantial bearing on the pattern of effects in the model. Nevertheless, given that some parameters were more precise, particularly the direct effects of perceived autonomy support on autonomous motivation in PE and autonomous motivation in PE on autonomous motivation in leisure time, and the indirect effects of autonomous motivation in PE on autonomous motivation in leisure time and intention, we elected to evaluate our hypothesis tests based on the model using informative priors (Model 2). If the posterior distribution for each effect, represented by the credibility intervals about the coefficients, did not include zero, then the effect was considered supported and the posterior probability of a non-zero value for the coefficient is >0.975.

In terms of direct effects, we found a non-zero effect of perceived autonomy support in PE on autonomous motivation in PE (H_1; β = 1.520, 95% CI [1.176, 1.874], $p < .001$). There was also a non-zero trans-contextual effect of autonomous motivation in PE on autonomous motivation in leisure time (H_2; β = .609, 95% CI [0.476, 0.772], $p < .001$), and perceived autonomy support in PE also had a non-zero effect on autonomous motivation in leisure time (H_3; β = 0.363, 95% CI [0.166, 0.626], $p < .001$). We also found non-zero effects of autonomous motivation in leisure time on attitudes (H_4; β = .434, 95% CI [0.346, 0.523], $p < .001$), subjective norms (H_5; β = .166, 95% CI [0.010, 0.320], $p = .018$), and perceived behavioral control (H_6; β = .222, 95% CI [0.121, 0.323], $p < .001$). We also found non-zero effects of attitudes (H_8; β = .182, 95% CI [0.076, 0.288, $p < .001$), subjective norms (H_9; β = .118, 95% CI [0.059, 0.178], $p < .001$), and perceived behavioral control (H_{10}; β = .323, 95% CI [0.227, 0.420], $p < .001$) on intentions. Moreover, there were non-zero effects of autonomous motivation in leisure time (H_7; β = .403, 95% CI [0.298, 0.507], $p < .001$) and trait self-control (H_{12}; β = .215, 95% CI [0.031, 0.399], $p < .001$) on intentions, but the effect of habit on intention (H_{11}) was no different from zero. We found non-zero effects of attitude (H_{14}; β = .093, 95% CI [0.034, 0.152], $p = .001$), trait self-control (H_{17}; β = .107, 95% CI [0.007, 0.208], $p = .018$), and past physical activity participation (H_{19}; β = .673, 95% CI [0.518, 0.829], $p < .001$) on leisure-time physical activity participation at follow-up, while effects of intention (H_{13}), perceived behavioral control (H_{15}), habit (H_{16}), and autonomous motivation in leisure time (H_{18}) were no different from zero. All effects were small-to-medium in size.

Focusing on the indirect effects, we found non-zero effects of perceived autonomy support on autonomous motivation in leisure time mediated by autonomous motivation in PE (H_{20}; β = .922, 95% CI [0.625, 1.324], $p < .001$). There were also non-zero effects of autonomous motivation in PE on intentions mediated by autonomous motivation in leisure time and attitude (H_{21}; β = .047, 95% CI [0.019, 0.084], $p < .001$), subjective norms (H_{22}; β = .011, 95% CI [0.001, 0.027], $p = .019$), and perceived behavioral control (H_{23}; β = .043, 95% CI [0.021, 0.074], $p < .001$). Similarly, there were also non-zero indirect effects of autonomous motivation in leisure time on intentions mediated by attitude (H_{28}; β = .078, 95% CI [0.032, 0.131], $p < .001$), subjective norms (H_{29}; β = .019, 95% CI [0.001, 0.044], $p = .019$), and perceived behavioral control (H_{30}; β = .071, 95% CI [0.036, 0.114], $p < .001$). However, indirect effects of autonomous motivation in the PE (H_{24}-H_{27}) and leisure-time (H_{31}-H_{33}) contexts through the social cognition constructs on leisure-time physical activity participation were no different from zero because the intention-behavior relationship was also no different from zero. Finally, effects of the intervention on leisure-time physical activity participation, and effects of age on model constructs, were no different from zero. However, we found non-zero effects of gender on autonomous motivation in PE (β = -.462, 95% CI [-0.795, -0.138], $p = .002$), with girls experiencing higher levels than boys, and leisure time (β = .243, 95% CI [0.018, 0.463], $p = .017$), and attitudes (β = .210, 95% CI [0.017, 0.404], $p = .016$).

Discussion

The purpose of the current research was to examine the determinants of lower secondary school students' leisure-time physical activity participation using an extended version of the TCM [10]. Specifically, the TCM was augmented to include two constructs that reflected non-conscious processes as predictors of leisure-time physical activity participation, self-reported habit [42] and trait self-control [43]. In addition, attitude was also set as a direct predictor of leisure-time physical activity participation, representing a further non-conscious process [49, 51]. Hypothesized relations among the extended TCM constructs were tested using a two-wave prospective survey design in a sample of lower secondary school students. Data were analyzed using two Bayesian path analytic models: one specifying non-informative priors and one in which informed priors for key relations in the model derived from previous meta-analyses were specified. Results indicated adequate fit of both models with the data. Perceived autonomy support predicted autonomous motivation in PE and leisure-time contexts, autonomous motivation in PE predicted autonomous motivation in a leisure-time context, and autonomous motivation in a leisure-time context predicted social cognition constructs (attitudes, perceived behavioral control) and intentions toward leisure-time physical activity participation. There were also indirect effects of perceived autonomy support on autonomous motivation in leisure time mediated by autonomous motivation in PE, and of autonomous motivation in PE and leisure time on intentions through the social cognition constructs. In contrast, there were no effects on leisure-time physical activity participation due to effects of intention and perceived behavioral control that were no different from zero. However, attitudes and trait self-control predicted both intentions and behavior. The application of a Bayesian analytic approach demonstrated that the model was tenable with the model incorporating informative prior knowledge demonstrating marginally more precise parameter estimates.

Overall, current results supported hypotheses relating to the first two premises of the TCM, that is, the premises specifying effects of perceived autonomy support on autonomous motivation in PE, and the trans-contextual effects of autonomous motivation across PE and leisure time context [10, 27]. It also provided support for the effects of autonomous motivation in leisure time on intentions to participate in leisure-time physical activity mediated by the attitude, subjective norm, and perceived behavioral control constructs from the TPB. However, there was scant evidence for the third premise, due to an intention-physical activity participation relationship that was no different from zero. These findings suggest that, in the current sample, the TCM is effective in identifying motivational and social cognition determinants of secondary school students' intentions to participate in leisure-time physical activity, and the processes involved, but not their actual participation. We propose four possible interpretations of the current findings. First, results may raise questions on the effectiveness of the TCM in identifying the determinants of leisure-time physical activity participation. There have been occasions where studies on the motivational and social cognition constructs in multi-theory, integrated models have failed to yield non-zero effects for the primary predicted determinants of

behavior [77, 78]. Nevertheless, such occasions are rare, and are contrary to the substantive body of meta-analytic evidence applying the TCM [27] and other integrated models that have supported effects more broadly and in multiple populations and contexts [79, 80]. Therefore, it may be premature to use the current data as a basis for rejecting the TCM.

A second interpretation may be that some of the hypothesized effects were attenuated due to contextual factors that affected relations among constructs, particularly the intention-behavior relationship. Certainly, there is evidence that other extraneous constructs may moderate the intention-behavior relationship [81]. One possibility is that the current research was conducted in the context of an intervention. However, correlations of the intervention with key model constructs, particularly intentions and follow-up physical activity participation were no different from zero. In fact, the only effects of the intervention on variables from the current study were on perceived autonomy support and attitudes at baseline, and these effects were opposite to the predicted direction and were taken prior to the intervention. Furthermore, we also controlled for intervention effects in the current model, so reported effects were independent of intervention effects. This leaves the possibility of other extraneous constructs attenuating the intention-physical activity participation relationship in the current study. It is possible, for example, that students' intentions were particularly unstable or inconsistent with their subsequent behavior, given research that has confirmed these intention properties moderate these relations [81, 82]. However, this possibility remains speculative as we have no data on intention stability or consistency, nor do we have any contextual or demographic information that would explain such inconsistencies.

A third explanation may be that participation in leisure-time physical activity in the current sample of school students was largely determined by constructs that reflect individual-level non-conscious processes, that is, constructs that impact behavior directly independent of intentions. That the only determinants of leisure-time physical activity participation in the current study were past physical activity participation, attitude, and trait self-control is consistent with this interpretation. Focusing first on the direct effect of trait self-control on behavior, this construct is proposed to reflect non-conscious processes insofar as those endorsing it are purported to exhibit adaptive self-regulatory skills that assist in pursuing goal-directed behaviors and help resist temptations to engage in alternative behaviors that may derail pursuit of the behavior [45-47]. On the surface, such an effect implies that individuals applying such skills must engage in active, effortful decision making to ensure focus on the target behavior and manage distractions, a conscious process. This may be the case for behaviors with which the individual has little experience. However, where the individual has substantive experience and has engaged in such active deliberation over the management of the behavior and application of their skills, they are likely to have well-learned behavioral scripts or schemas stored in memory to manage distractions and maintain behavioral engagement, obviating the need for such conscious deliberation. This is consistent with research suggesting that individuals with good trait self-control are highly effective in managing their environment so as not to be encumbered by distractions and to ensure that the cues to their desired behavior are omnipresent [83]. While this mechanistic explanation is speculative, it may explain the direct effect of trait self-control on behavior in the current model and provides justification to explore the role of this constructs within the TCM.

A fourth and final interpretation is that social environmental factors may have contributed to the weak intention-behavior relationship observed in the current study. The high availability of inactive highly-appealing pastimes available to young people (e.g., computer games) and social norms within families and peer groups to engage in inactive pastimes and forms of transport may have contributed to failure of students to engage in physical activity even if they had autonomous motives and intentions to do so. This is consistent with the current data in which students' average intentions to engage in physical activity in their leisure time was above the scale mid-point (M = 5.651, SD = 1.282). The effects of peer norms are especially strong in this age group, so young people with intentions to be active may find that they are superseded by their need to conform. These premises are consistent with ecological models that stress environmental influences [84], and research suggesting that such influences are important predictors of behavior beyond social cognition determinants [85, 86]. Analogously, if a child has low or no intention to participate in physical activity, they may still be compelled to spontaneously do so if their peer groups decides to have a 'kick about' with a football in their local park. The current study did not measure environmental influences, so such determinants cannot be empirically verified from the current data and should be considered speculative. Nevertheless, it points to the potential importance of incorporating constructs that reflect these environmental determinants within integrated models such as the TCM.

Turning to the direct effect of attitude on leisure-time physical activity participation, current findings are consistent with previous research that has found a direct effect of attitude components on behavior in multiple health contexts [49, 51]. Such effects likely represent spontaneous decisions to engage in a behavior learned through positive or negative affective experiences that coincide with the behavior. As a consequence, the anticipation of rewarding affective responses may be reasons why children and adolescents might spontaneously engage in physical activities outside of school without the need for reasoned decision making. Such an effect has not been identified in previous research adopting the TCM, but has been consistently identified in research applying the TPB in health behavior contexts, including physical activity [51]. These findings suggest that if out-of-school activities are emotionally appealing to children and adolescents and have been experienced as enjoyable in the past, they may be more likely to spontaneously participate in physical activities in future.

With respect to the direct effect of past physical activity behavior, current findings are consistent with the extensive literature reporting consistent effects of past behavior on subsequent behavioral enactment in the context of social cognition theories [39, 87, 88]. In general, research findings indicate that past behavior accounts for the largest proportion of the variance in behavior, and often attenuates effects of other constructs on behavior. The inclusion of past behavior as a behavioral determinant in social cognition models, including integrated theories, is important as it provides an indication of the sufficiency of the theory constructs as an account of behavior [14]. The absence of effects of theory constructs other than past behavior, provides an indication that the theory may be inadequate as a means to explain behavior beyond the stability of the behavior itself. Although in the case of the current research, the exclusion of past behavior did not restore effects of other constructs such as intention on behavior.

So, what might the substantive effect of past behavior represent? Researchers have suggested that past behavior may also model effects of unmeasured constructs in tests of these theories [14, 39]. Given social cognition theories incorporate constructs that reflect reasoned, deliberative processes, past behavior effects have been proposed to model effects of unmeasured constructs representing non-conscious processes. These may include, for example, habits and constructs representing implicit beliefs. The substantive effect of past physical activity behavior on leisure-time physical activity participation in the current study suggests that lower secondary school students' physical activity in their leisure time may be a function of these kinds of constructs. Current findings

suggest, however, that habit may not be among these determinants, given that the independent effect of self-reported habit on leisure-time physical activity participation was no different from zero. Although it must be stressed that the current measure of habit focused exclusively on automaticity, one aspect of habit, and may not have sufficiently captured all habitual influences [89, 90]. The current study did not include measures that capture other aspects of habit such as context stability and accessibility of relevant cues to the behavior [91, 92]. In addition, we did not measure other constructs that may reflect these non-conscious processes, such as implicitly held beliefs developed through past experiences of the behavior covarying with evaluations [38]. Research has suggested that measures of implicit beliefs predict behavior, including physical activity participation, independent of intentions [93-95] and may also mediate effects of past behavior on subsequent behavior [96]. The effects of past behavior in the current study may, therefore, indicate that physical activity behavior in leisure time may be a function of unmeasured constructs reflecting implicit processes, but such an inference is speculative and requires empirical verification.

The current research also illustrates the value of adopting a Bayesian analytic approach to combine prior knowledge of the distributions of model effects with the observed distributions to produce precise estimates and variability among model constructs. This was demonstrated by the narrowing of the credibility intervals about some of the model parameters. Importantly, the data used for the informative priors was highly reliable given they were derived from meta-analyses of multiple studies with large samples sizes. It is, however, also important to note that although the informative priors for the TCM effects were a meta-analysis of studies on samples of school students with similar profile to the participants in the current study [27], priors for the effects of the additional variables, self-reported habit and trait self-control were derived from research from multiple populations and mostly adult samples [44, 58]. Therefore, the populations from the studies on which these priors were based were not directly comparable to the current sample, and that may have been a source of error. Nevertheless, current findings may be of value as a source of informative priors for future applications of the extended TCM. Consistent with the Bayesian approach, the current study should form part of an ongoing iterative research process that yields increasingly precise estimates of effects in the TCM.

Strengths, limitations and recommendations for future research

Strengths of the current study include (1) a focus on the determinants of lower secondary school students' leisure-time physical activity participation, a priority area of research; (2) the application of an extended TCM, an innovative multi-theory approach that provided a priori hypotheses on the relations among the determinants and leisure-time physical activity participation; (3) adoption of a two-wave prospective design using validated measures of model determinants and behavior; and (4) application of Bayesian analytic procedures that enabled utilization of prior knowledge to arrive at precise estimates of TCM effects. However, it is also important to note limitations of the current research that may affect interpretation of the findings and the extent to which they can be generalized.

While we endeavored to incorporate additional constructs representing non-conscious determinants of leisure-time physical activity participation in the current study, our measures did not encompass a full range of candidate determinants. For example, the current study did not include measures of implicit cognition and motivation with respect to school students' leisure-time physical activity participation. Given that measures of constructs such as implicit beliefs and autonomous motivation have been shown to predict behavior directly independent of intentions in adult samples [93, 94, 96, 97], future tests of the extended TCM should consider incorporating measures of these constructs as predictors of leisure-time physical activity participation. This is particularly important given the lack of effects of the intentional or motivational constructs on leisure-time physical activity participation in the current study, and inclusion of implicit beliefs may assist in providing an explanation of the effects of past behavior.

In addition, current data are correlational, which limits the extent to which we could infer causal relations among the extended TCM constructs. As with many model tests, including those of the TCM, causal effects are inferred from theory not the data [27]. Future research should consider the adoption of panel designs that permit modeling of temporal change and direction among TCM constructs over time through cross-lagged effects [20]. In addition, intervention and experimental designs are needed to test the effect of manipulating the constructs found to have a direct effect on leisure-time physical activity participation [98]. For example, interventions targeting attitudes should seek to promote enjoyment and positive affect through positive experiences of physical activity, and interventions targeting self-discipline should seek to provide self-regulatory skills that promote better control over impulses to spend excessive time on leisure-time alternatives to physical activity (e.g., video games, watching television) and identify and barrier management [99].

Conclusions

The current research is the first to test an extended version of the TCM to identify determinants of leisure-time physical activity participation in lower secondary school students. Results indicate that the traditional motivational and social cognition constructs are effective in predicting leisure-time physical activity intentions, but not actual behavior. However, we found direct effects of trait self-control and attitude on leisure-time physical activity participation, suggesting that students' physical activity participation was determined by constructs representing non-conscious processes. A further innovation of the current research is the application of a Bayesian analytic approach to update the effects and variability estimates of TCM model parameters based on previous meta-analytic findings. Results raise questions over the effectiveness of the original TCM constructs in determining leisure-time physical activity participation, at least in the current societal context in which the physical environment may not support engagement in physical activity and offers various competing, non-active alternatives (e.g. video games). However, highlights the potential of including additional constructs representing individual-level non-conscious processes. However, these data should not be considered unequivocal evidence to support rejection of the model as unmeasured moderator variables may have affected model effects. Further replication of the extended TCM predictions in larger samples is warranted.

Declarations

Ethics approval and consent to participate

The study protocol was approved by the research ethics committee of the University of Jyväskylä (ref no. 2017/12/13). Written informed consent was obtained from participating students and their parents prior to data collection.

Consent for publication

All participants provided consent for their deidentified data to be used in research reports and publications arising from this study.

Availability of data and materials

Data file, analysis syntax, and output for the present study are available online: https://osf.io/z8axj.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MSH, MH, TL, NH, MIH, and THT conceived the study and secured funding. MSH, TL, MH, JP, AL, NH, and AL developed the study protocol and design. MH, JP, AL, MSH, MIH, and THT developed the measures. JP and AL collected and collated the data. MSH, KH, JP, and JS analyzed the data and wrote the manuscript. All authors read, commented on, and approved the final manuscript.

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Abbreviations

PE = Physical education

TCM = Trans-contextual model

TPB = Theory of planned behavior

IPAQ = International physical activity questionnaire

PASSES = Perceived autonomy support scale for exercise settings

MET = Metabolic equivalent

MCMC = Markov Chain Monte Carlo

PPP = Posterior predictive p-value

CFI = Comparative fit index

TLI = Tucker-Lewis index

RMSEA= Root mean square error of approximation

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Tables

Table 1 Summary of Hypothesized Direct and Indirect Effects in the Extended Trans-Contextual Model

H	Independent variable	Dependent variable	Mediator(s)	Informative prior values	
				β	σ^2
Direct effects					
H_1	PAS	Aut. mot. (PE)[a]	–	0.42	0.10
H_2	Aut. mot. (PE)	Aut. mot. (LT)[a]	–	0.56	0.17
H_3	PAS	Aut. mot. (LT)[a]	–	0.29	0.18
H_4	Aut. mot. (LT)	Attitude[a]	–	0.60	0.12
H_5	Aut. mot. (LT)	Subjective norm[a]	–	0.26	0.26
H_6	Aut. mot. (LT)	PBC[a]	–	0.51	0.19
H_7	Aut. mot. (LT)	Intention[a]	–	0.31	0.13
H_8	Attitude	Intention[a]	–	0.68	0.09
H_9	Subjective norm	Intention[a]	–	0.42	0.25
H_{10}	PBC	Intention[a]	–	0.63	0.28
H_{11}	Habit	Intention	–	–	–
H_{12}	Self-control	Intention	–	–	–
H_{13}	Intention	Phys. act.[a]	–	0.60	0.20
H_{14}	Attitude	Phys. act.[a]	–	0.43	0.21
H_{15}	PBC	Phys. act.[a]	–	0.43	0.21
H_{16}	Habit	Phys. act.[b]	–	0.43	0.13
H_{17}	Self-control	Phys. act.[c]	–	0.26	0.09
H_{18}	Aut. mot. (LT)	Phys. act.		–	–
H_{19}	Past behavior	Phys. act.		–	–
Indirect effects					
H_{20}	PAS	Aut. mot. (LT)	Aut. mot. (PE)	–	–
H_{21}	Aut. mot. (PE)	Intention	Aut. mot. (LT) Attitude	–	–
H_{22}	Aut. mot. (PE)	Intention	Aut. mot. (LT) Sub. norm.	–	–
H_{23}	Aut. mot. (PE)	Intention	Aut. mot. (LT) PBC	–	–
H_{24}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) Attitude Intention	–	–
H_{25}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) Sub. norm. Intention	–	–
H_{26}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) PBC Intention	–	–
H_{27}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) PBC	–	–

H_{28}	Aut. mot. (LT)	Intention	Attitude	–	–
H_{29}	Aut. mot. (LT)	Intention	Sub. norm.	–	–
H_{30}	Aut. mot. (LT)	Intention	PBC	–	–
H_{31}	Aut. mot. (LT)	Phys. act.	Attitude Intention	–	–
H_{32}	Aut. mot. (LT)	Phys. act.	Sub. norm. Intention	–	–
H_{33}	Aut. mot. (LT)	Phys. act.	PBC Intention	–	–

Note. [a]Informative prior value taken from Hagger and Chatzisarantis' (2016) meta-analysis of the trans-contextual model; [b]Prior value taken from Gardner et al.'s (2012) meta-analysis of self-reported habits; [c]Prior value taken from de Ridder et al.'s (2012) meta-analysis of trait self-control. H = Hypothesis; PAS = Perceived autonomy support; Aut. mot. = Autonomous motivation; PE = Physical education context; LT = Leisure-time context; PBC = Perceived behavioral control; Sub. norm = Subjective norm; Phys. act = Self-reported leisure-time physical activity participation; Past. Beh. = Past leisure-time physical activity behavior.

Table 2 Descriptive Statistics and Zero-Order Intercorrelations for the Extended Trans-Contextual Model Constructs, Behavior Measure, and Socio-Demographic and Control Variables

Variable	w	*M*	SD	1	2	3	4	5	6	7	8	9	10	11	12
1. Perceived autonomy support (PE)	.912	5.681	0.867	–											
2. Autonomous motivation (PE)	.888	5.647	1.314	.447***	–										
3. Autonomous motivation (LT)	.921	5.876	1.253	.391***	.614***	–									
4. Intention	.890	5.651	1.282	.294***	.479***	.733***	–								
5. Attitude	.805	6.070	1.006	.300***	.393***	.582***	.591***	–							
6. Subjective norms	.815	4.769	1.451	.106	.204***	.189**	.315***	.189**	–						
7. PBC	.756	6.030	1.018	.262***	.253***	.391***	.576***	.429***	.175**	–					
8. Habit	.851	5.127	1.373	.262***	.472***	.650***	.566***	.402***	.162**	.360***	–				
9. Self-control	.875	2.914	0.542	.316***	.496***	.478***	.477***	.345***	.141*	.324***	.454***	–			
10. Past physical activity behavior	.912	3.696	0.373	.151*	.254***	.524***	.507***	.335***	.167**	.368***	.492***	.284***	–		
11 Physical activity	.888	3.604	0.470	.102	.229***	.355***	.351***	.342***	.121*	.206**	.313***	.282***	.575***	–	
12. Intervention	–	–	–	-.141*	.067	-.061	-.046	-.124*	-.024	-.049	.023	.012	.066	.052	–
13. Gender	–	–	–	.086	-.103	.003	.006	.099	-.042	-.073	-.149*	-.087	-.151**	-.069	-.007
14. Age	–	14.506	0.704	.051	.007	.056	.085	.098	.033	.085	.009	-.067	.002	-.042	-.237*

Note. PE = Physical education context; LT = Leisure-time context; PBC = Perceived behavioral control; Past physical activity behavior = Past leisure-time physical activity behavior; Physical activity = Self-reported leisure-time physical activity participation.

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$.

Table 3 Parameter Estimates (β) with 95% Credibility Intervals for Hypothesized Effects from the Bayesian Path Analyses of the Extended Trans-Contextual Model for School and Out-Of-School Science Activities

H	Independent variable	Dependent variable	Mediator(s)	Model 1			Model 2			%diff
				β	95% CrI		β	95% CrI		
					LL	UL		LL	UL	
Direct effects										
H_1	PAS	Aut. mot. (PE)†	–	2.683***	1.850	3.457	1.520***	1.176	1.874	-56.57
H_2	Aut. mot. (PE)	Aut. mot. (LT)†	–	0.683***	0.516	0.887	0.609***	0.476	0.772	-20.22
H_3	PAS	Aut. mot. (LT)†	–	0.190**	0.034	0.378	0.363***	0.166	0.626	33.72
H_4	Aut. mot. (LT)	Attitude†	–	0.432***	0.342	0.521	0.434***	0.346	0.523	-1.12
H_5	Aut. mot. (LT)	Sub. norm†	–	0.163*	0.007	0.320	0.166*	0.010	0.320	-0.96
H_6	Aut. mot. (LT)	PBC†	–	0.220***	0.119	0.321	0.222***	0.121	0.323	0.00
H_7	Aut. mot. (LT)	Intention†	–	0.411***	0.305	0.517	0.403***	0.298	0.507	-1.42
H_8	Attitude	Intention†	–	0.165**	0.058	0.274	0.182***	0.076	0.288	-1.85
H_9	Sub. norm	Intention†	–	0.118***	0.058	0.178	0.118***	0.059	0.178	-0.83
H_{10}	PBC	Intention†	–	0.325***	0.228	0.422	0.323***	0.227	0.420	-0.52
H_{11}	Habit	Intention	–	0.057	-0.029	0.143	0.058	-0.028	0.143	-0.58
H_{12}	Self-control	Intention	–	0.216*	0.032	0.400	0.215*	0.031	0.399	0.00
H_{13}	Intention	Phys. act.†	–	-0.001	-0.062	0.060	0.000	-0.061	0.061	0.00
H_{14}	Attitude	Phys. act.†	–	0.092**	0.033	0.151	0.093**	0.034	0.152	0.00
H_{15}	PBC	Phys. act.†	–	-0.030	-0.086	0.026	-0.029	-0.085	0.026	-0.89
H_{16}	Habit	Phys. act.†	–	-0.005	-0.051	0.041	-0.004	-0.050	0.042	0.00
H_{17}	Self-control	Phys. act.†	–	0.104*	0.002	0.207	0.107*	0.007	0.208	-1.95
H_{18}	Aut. mot. (LT)	Phys. act.	–	-0.017	-0.079	0.045	-0.019	-0.081	0.043	0.00
H_{19}	Past beh. (LT)	Phys. act.	–	0.676***	0.521	0.829	0.673***	0.518	0.829	0.97
Indirect effects										
H_{20}	PAS	Aut. mot. (LT)	Aut. mot. (PE)	1.827***	1.113	2.733	0.922***	0.625	1.324	-56.85
H_{21}	Aut. mot. (PE)	Intention	Aut. mot. (LT) Attitude	0.048**	0.016	0.090	0.047***	0.019	0.084	-12.16
H_{22}	Aut. mot. (PE)	Intention	Aut. mot. (LT) Sub. norm.	0.012*	0.000	0.031	0.011*	0.001	0.027	-16.13
H_{23}	Aut. mot. (PE)	Intention	Aut. mot. (LT) PBC	0.048***	0.022	0.085	0.043***	0.021	0.074	-15.87
H_{24}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) Attitude Intention	0.000	-0.003	0.003	0.000	-0.003	0.003	0.00
H_{25}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) Sub. norm. Intention	0.000	-0.001	0.001	0.000	-0.001	0.001	0.00
H_{26}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT) PBC Intention	0.000	-0.003	0.003	0.000	-0.003	0.003	0.00
H_{27}	Aut. mot. (PE)	Phys. act.	Aut. mot. (LT)	-0.004	-0.015	0.004	-0.004	-0.013	0.004	-10.53

			PBC							
H_{28}	Aut. mot. (LT)	Intention	Attitude	0.071**	0.024	0.123	0.078***	0.032	0.131	0.00
H_{29}	Aut. mot. (LT)	Intention	Sub. norm.	0.018*	0.001	0.043	0.019*	0.001	0.044	2.38
H_{30}	Aut. mot. (LT)	Intention	PBC	0.070***	0.035	0.114	0.071***	0.036	0.114	-1.27
H_{31}	Aut. mot. (LT)	Phys. act.	Attitude Intention	0.000	-0.005	0.005	0.000	-0.005	0.005	0.00
H_{32}	Aut. mot. (LT)	Phys. act.	Sub. norm. Intention	0.000	-0.001	0.001	0.000	-0.001	0.001	0.00
H_{33}	Aut. mot. (LT)	Phys. act.	PBC Intention	0.000	-0.005	0.005	0.000	-0.005	0.005	0.00

Note. †Parameters with informative priors. Model 1 = Bayesian path model with non-informative priors; Model 2 = Bayesian path model including informative priors; H = Hypothesis; β = Parameter estimate; 95% CrI = 95% credibility interval of path coefficient; %diff = Percent difference in 95% credibility interval of path coefficients of path analysis including informative priors for specified model relationships compared to analysis using non-informative priors (negative numbers indicate a narrowing of credibility intervals when using informative priors); PAS = Perceived autonomy support; Aut. mot. = Autonomous motivation; PE = Physical education contexts; LT = Leisure-time context; PBC = Perceived behavioral control; Sub. norm = Subjective norm; Phys. act = Self-reported leisure-time physical activity participation; Past. Beh. = Past leisure-time physical activity behavior. $^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

Figures

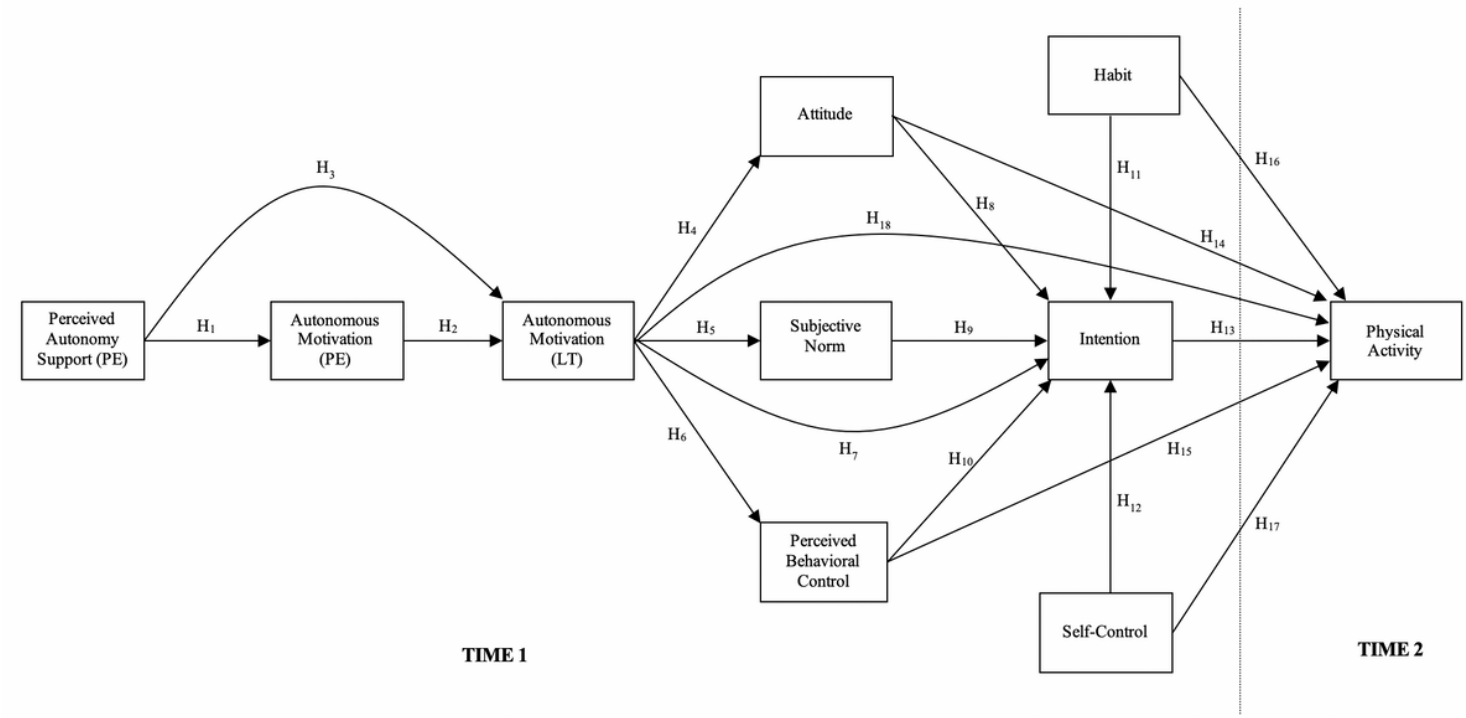

Figure 1

The hypothesized relations among constructs of the extended trans-contextual model.

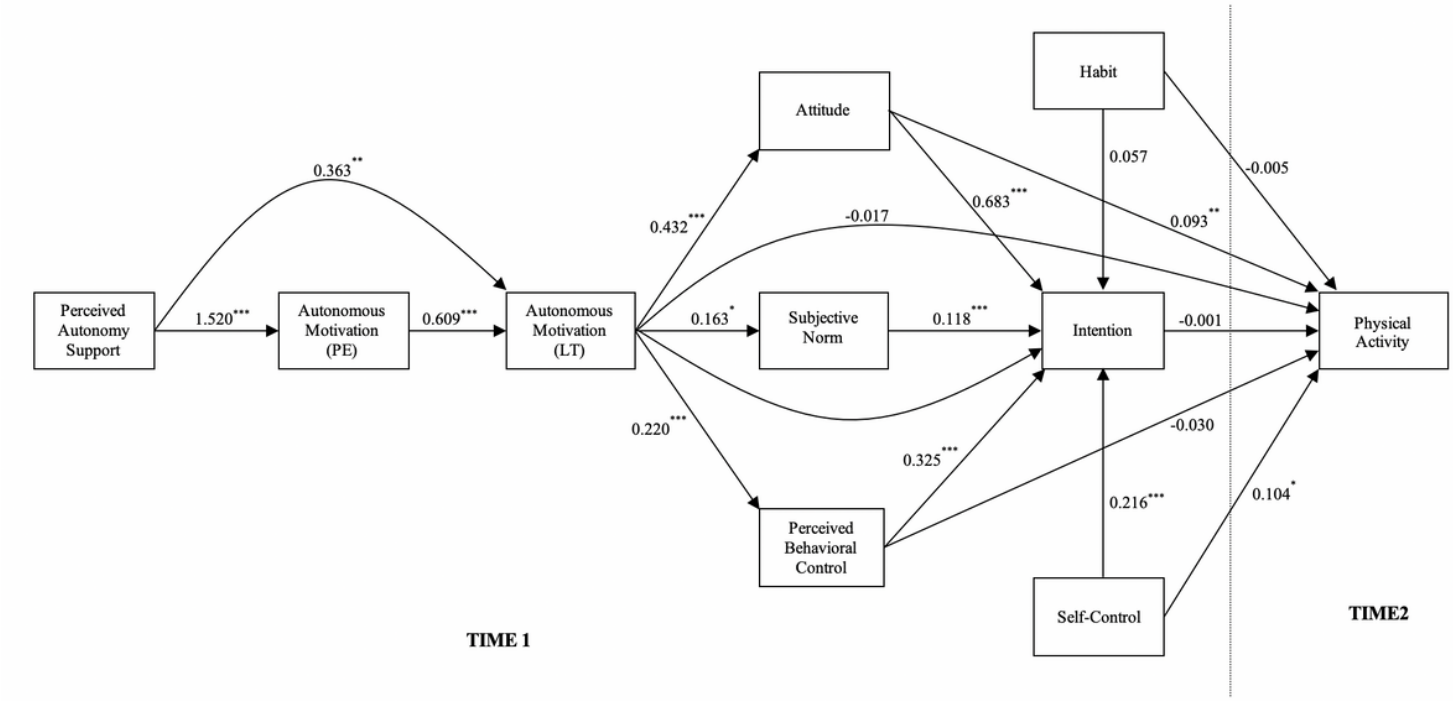

Figure 2

Parameter estimates from the Bayesian path analysis of the extended trans-contextual model including informative priors. PE = Physical education context; LT = Leisure time context. Model parameters omitted for clarity: past physical activity behavior→perceived autonomy support, β = .388, p = .003; past physical activity behavior→autonomous motivation (PE), β = .243, p = .144; past physical activity behavior→autonomous motivation (LT), β = 1.164, p < .001; past physical activity behavior→attitude, β = .199, p = .097; past physical activity behavior→subjective norms, β = .338, p = .105; past physical activity behavior→perceived behavioral control, β = .599, p < .001; past physical activity behavior→intention, β = .293, p = .021; past physical activity behavior→habit, β = 1.765, p < .001; past physical activity behavior→self-control, β = 0.404, p < .001; past physical activity behavior→physical activity behavior, β = .673, p < .001.

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