

HANNA KALAJAS-TILGA

Trans-contextual model of motivation  
predicting change in physical activity  
among Estonian school students





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Institute of Sport Sciences and Physiotherapy, Faculty of Medicine, University of Tartu, Tartu, Estonia

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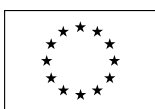
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## LIST OF ORIGINAL PUBLICATIONS

This thesis basis on the listed papers, which are referred to by Roman Numerals in the following:

- I. Kalajas-Tilga, H., Koka, A., Hein, V., Tilga, H., & Raudsepp, L. (2020). Motivational processes in physical education and objectively measured physical activity among adolescents. *Journal of Sport and Health Science*, 9(5), 462–471. <https://doi.org/10.1016/j.jshs.2019.06.001>.
- II. Kalajas-Tilga, H., Hein, V., Koka, A., Tilga, H., Raudsepp, L., & Hagger, M. S. (2022). Application of the trans-contextual model to predict change in leisure time physical activity. *Psychology & Health*, 37(1). <http://dx.doi.org/10.1080/08870446.2020.1869741>.
- III. Kalajas-Tilga, H., Hein, V., Koka, A., Tilga, H., Raudsepp, L., & Hagger, M. S. (in press). Trans-contextual model predicting change in out-of-school physical activity: A one-year longitudinal study. *European Physical Education Review*.

**Paper I, II and III.** Hanna Kalajas-Tilga had primary responsibility for leading the design of the studies, coordinating, and implementing data collection, performing statistical analyses, and drafting the manuscripts.

# 1. INTRODUCTION

Physical activity is associated with several health benefits (Poitras et al., 2016), long-term positive impact on health (Abrigani et al., 2019) and is considered to prevent several diseases (Reiner et al., 2013). However, the vast majority of European (Kantanista et al., 2021; Van Hecke et al., 2016) including Estonian (Mäestu et al., 2018) children and adolescents do not meet the official guidelines of physical activity – an average of 60 min of moderate-to-vigorous physical activity per day across the week (Bull et al., 2020). Furthermore, a marked decrease in the levels of physical activity participation during the transition from childhood to adolescence is demonstrated (Chong et al., 2020). The promotion of physical activity among adolescents at an early age is a public health priority in many nations (Guthold et al., 2018). Researchers have, therefore, aimed to identify the psychological determinants of physical activity and the processes by which they relate to behaviour to provide evidence to develop behavioural interventions to improve adolescents' participation in physical activity (Hagger et al., 2020). Research applying the trans-contextual model has identified that perceived autonomy support in physical education (PE) context leads to higher self-reported physical activity outside of school among adolescents through autonomous motivation, social cognition beliefs, and intentions toward physical activity (Hagger & Chatzisarantis, 2012; 2016).

The trans-contextual model is a multi-theory model that integrates constructs and hypothesis from self-determination theory (Deci & Ryan, 1985), Vallerand's hierarchical model of intrinsic and extrinsic motivation (Vallerand, 1997), and the theory of planned behaviour (Ajzen, 1991). The model is an integrated approach to identify the psychological determinants of young people's physical activity participation, with a focus on determinants in two different contexts: PE and leisure-time physical activity. The model specifies the mechanisms by which students' perceptions of autonomy support from their PE teachers relate to their motivation toward, and actual participation in, physical activity in a leisure-time context (Hagger et al., 2003). Most studies of the trans-contextual model have used prospective designs and predicted physical activity behaviour over short periods. Only a few have used a longitudinal design where model constructs have been measured at several points in time to allow the modelling of change (Hutmacher et al., 2020; Polet et al., 2020). Furthermore, there is a dearth of literature applying the model that has adopted non-self-report measures of physical activity, such as accelerometer-based devices (Hagger & Chatzisarantis, 2016).

The main objective of the present study was to test the trans-contextual model of motivation among adolescents using both self-reported and accelerometer-based out-of-school physical activity as an outcome, and to investigate the influence of different motivational regulations on adolescents' actual physical activity. Firstly, a model of motivational processes based on self-determination theory was used to evaluate the processes which influence adolescents' moderate-



to-vigorous physical activity. Secondly, a trans-contextual model of motivation using residual change scores was used to test the effects of changes in the psychological constructs of the trans-contextual model on changes in adolescents' outside of school moderate-to-vigorous physical activity using both self-reported and non-self-reported physical activity. Finally, the long-term predictive validity of the trans-contextual model of motivation was tested over a one-year period.

## 2. LITERATURE REVIEW

### 2.1. Theoretical framework

Trans-contextual model of motivation (Hagger et al., 2003) serves as the theoretical framework for the current work. The trans-contextual model of motivation merges components from self-determination theory (Deci & Ryan, 1985; 2000), the theory of planned behaviour (Ajzen, 1985; 1991) and the hierarchical model of motivation (Vallerand, 1997). The theory was developed to explain the psychological processes by which students transfer motivation in PE into physical activity behaviour in leisure-time (Hagger et al., 2003). PE lessons can provide students with skills and competence to engage in health-related physical activity during their leisure time (Ntoumanis, 2001).

Trans-contextual model has been extensively used in educational setting and especially in PE context. The model has found considerable empirical support specifically regarding the relationship between autonomous motivation in PE context and autonomous motivation in outside of school physical activity (Hagger et al., 2003, 2009; Pihu et al., 2008; Standage et al., 2012). In addition, the model has found support also in other domains, such as math lessons (Hagger et al., 2015), science (Hagger & Hamilton, 2018), sports (Chan et al., 2011; Chan & Hagger, 2012a), rehabilitation (Chan et al., 2009) and injury prevention at work (Chan & Hagger, 2012b).

Trans-contextual model proposes three central propositions from the integration of the aforementioned theories. The first key tenet of the model is that students' perceptions of support for autonomous forms of motivation based on self-determination theory (Deci & Ryan, 1985) by teachers in the educational environment (e.g., PE teachers in PE lessons) will be related to students' autonomous motivation in that concrete context. The second tenet of the trans-contextual model suggests that forms of motivation with respect to activities in an educational context (e.g., school PE classes) will be transferred to forms of motivation with respect to similar activities in other contexts (e.g., physical activity during leisure time). Vallerand's (2007) hierarchical model forms the basis of this prediction. Vallerand's model proposes that cross-contextual interplay occurs between motivation at the contextual level. The third tenet of the model is that students' autonomous motivation toward activities in a leisure time out-of-school context is related to their future participation in those activities through sets of beliefs and intentions. The integration of the theory of planned behaviour with self-determination theory provides the basis for this prediction.

In addition to the environment created by PE teachers in fostering students' motivation toward PE (e.g., Girard & Lemoyne, 2018), research has demonstrated that perceived autonomy support from peers and parents in the out-of-school contexts is also positively associated with autonomous motivation towards behaviour in that context (González-Cutre et al., 2014; Hagger et al., 2009).

### 2.1.1. Self-determination theory

Self-determination theory (Deci & Ryan, 1985), a well-investigated macro-theory of human motivation, has been extensively used in educational settings (Niemiec et al., 2009), including PE context (Standage et al., 2005). Based on the self-determination theory, humans strive to satisfy their three basic psychological needs for autonomy (i.e., to experience behaviour as volitional and independent), competence (i.e., to experience efficiency in action), and relatedness (i.e., sense of connection with the important others), which are complementary. Fulfilment versus thwarting of the psychological needs determine the quality of motivation and engagement in a particular activity (Deci & Ryan, 2000).

Self-determination theory proposes a motivational continuum, ranging from intrinsic motivation to external regulation depending on the level of autonomy that humans may have for participating in a certain activity. Intrinsic motivation refers to highly autonomous behaviours where the activity is carried out due to its inherent fulfilment rather than for a certain result. Intrinsic motivation is the most long-lasting form of motivation (Ryan & Deci, 2000). Identified regulation refers to behaviours that are highly valued and performed out of choice and to acquire self-endorsed outcomes. Introjected regulation refers to behaviours that individuals perform out of a sense of obligation, guilt or worry or to achieve social recognition. External regulation refers to activities that are carried out in order to avoid sanctions or to receive a reward (Deci & Ryan, 2000). According to self-determination theory, fulfilling basic psychological needs in a given activity is proposed to be the key factor in promoting autonomous motivation (i.e., intrinsic motivation and identified regulation), whereas failing to satisfy these needs will likely result in controlled motivation (i.e., introjected and external regulations; Ryan & Deci, 2000).

Central to the self-determination theory is that social factors (e.g., autonomy-supportive behavior from significant others such as teachers, parents and peers) could build individuals' motivation toward a certain activity by satisfying their psychological needs (Deci & Ryan, 2000; Ryan & Deci, 2017). An autonomy-supportive PE teacher would be curious how students solve a given exercise and also help them if necessary. Students, in turn, would most likely feel they can choose the way to continue (i.e., autonomy satisfaction), are likely to feel more positive about improving their skills (i.e., competence satisfaction), and feel that their teacher cares for them (i.e., relatedness satisfaction; Haerens et al., 2015). Studies conducted in PE context have shown that if teachers demonstrate autonomy-supportive behaviour, then students most likely report higher psychological need satisfaction which results in increased autonomous motivation towards PE (Standage et al., 2005; Haerens et al., 2015; Koka, 2014; Koka & Hagger, 2010; Wang, 2017).

### **2.1.2. Vallerand's hierarchical model of intrinsic and extrinsic motivation**

Vallerand (1997) has proposed a hierarchical model which demonstrates the processes by which contextual factors influence the perceived locus of causality. The key tenet of the model is that there exists a cross-contextual interplay so that intrinsic motivation in one context (i.e., school PE) can affect intrinsic motivation in another (i.e., leisure-time) context. Therefore, the promotion of physical activity in school during PE lesson can lead to participation also in related activities in another context. Likewise, if autonomy support is not provided within the educational context and intrinsic motivation is thwarted, it is transferred also to leisure-time (Vallerand, 2000).

### **2.1.3. The theory of planned behaviour**

The theory of planned behaviour (Ajzen, 1985) has been used to explain volitional and intentional behaviour. According to the theory, intention is the most proximal and strongest predictor of human behaviour. Intentions reflect deliberative plans to do a certain behaviour in a concrete context and time. It is proposed that intentions mediate the relationship between attitudes (reflect an individual's orientation toward participating in a behaviour), subjective norms (reflect perceived social pressure from significant others considering their behaviour) and perceived behavioural control (PBC; reflect the impact of perceived capacities and obstacles toward engaging in the behaviour) on behaviour. In addition, PBC is considered also to have a direct effect on behaviour. The theory of planned behaviour has found support in many meta-analysis (Armitage & Conner, 2001; Hagger et al., 2002) and explains variance in intention and behaviour but it is not complete (Hagger, Chatzisarantis & Biddle, 2002). It has been therefore suggested to incorporate other constructs from the self-determination theory to explain better its situation-specific constructs (Hagger et al., 2003).

### **2.1.4. The integration of the theories within the trans-contextual model**

The reason for integrating the social-cognition theories to form the trans-contextual model is based on the premise that the theories are complementary and therefore provide an explanation of the unexplained processes within each theory (Deci & Ryan, 1985). The integration of self-determination theory, the Vallerand's hierarchical model and the theory of planned behaviour is based on three premises. Firstly, it is expected that motivation which is related to basic psychological needs is involved in action to do a certain activity (Deci & Ryan, 2000). Secondly, it is thought that generalized, context-level motivation from self-determination theory forms the basis of more specific, situation-level evaluations

regarding future behaviour in the theory of planned behaviour (Vallerand, 1997). Thirdly, autonomous motivation from self-determination theory reflects the subjective degree of internality of a behaviour for an individual but the theory of planned behaviour reflects an individual's expectancies towards future behaviour (Chatzisarantis et al., 1997).

## **2.2. The longitudinal studies of the trans-contextual model**

Previous studies of the trans-contextual model have used correlational, prospective designs where model constructs are measured at an initial point in time and physical activity measured at a subsequent point in time. The results of these studies support the core premises of the trans-contextual model (Hagger & Chatzisarantis, 2009; 2012; 2016). In addition to the three key tenets that were mentioned before, the trans-contextual model proposes several other propositions, for example, controlled motivation in school context would be transferred to out-of-school context, controlled motivation in out-of-school context predicts subjective norms, and perceived autonomy support from peers and parents predicts students' autonomous motivation in out-of-school context. These propositions have found support in previous tests of the model (Hagger & Chatzisarantis, 2016; Hagger & Hamilton, 2018; Hagger et al., 2009). This data has some utility in identifying potential correlates of behavioural outcomes, however, they do not account for the natural change in constructs that occurs over time. Such change may be the result of individuals' reassessment of their beliefs due to new information appearing. Residual change scores have been proposed to be a useful method in order to measure change in constructs over time while controlling for their covariance stability (Gollob & Reichardt, 1987; Prochaska et al., 2008). Using residual change score approach researchers can make stronger claims concerning the value of the model in accounting for change in study constructs over time by controlling for the effect of each model construct on itself over time.

Previously, Polet et al. (2020) have found additional support for the key hypothesis of the trans-contextual model by using a residual change score approach which enabled modelling of change within the trans-contextual model constructs and physical activity behaviour over three months' time using a three-wave prospective design. Polet et al. (2020) showed the efficacy of the model in predicting change in students' autonomous motivation in PE and leisure-time by change in perceived autonomy support from PE teachers and change in intentions and participation in self-reported leisure-time physical activity. The residualized change score approach accounts for the stability (change) in study constructs across several time points taking into account the naturally occurring change in constructs over time (Rowan et al., 2017). This approach used within the trans-contextual model has given the opportunity to account for dynamic changes, as opposed to static, of motivational and social cognition constructs determining out-of-school physical activity over a longer time period.

There is a relative dearth of studies done on the long-range predictive validity of the trans-contextual model beyond a few weeks. Previous meta-analyses have demonstrated that the intention-behaviour relationship is consistent with a long time gap between intention and behaviour measures (Hagger et al., 2018; McEachan et al., 2011). A cross-lagged panel design based on the integration of self-determination theory and the theory of planned behaviour showed that autonomous motivation predicts the subsequent social cognition constructs and intentions from the theory of planned behaviour, and not vice-versa, supporting this key directional relationship within the model in a sport injury context (Chan et al., 2020). In addition, a study conducted in physical activity context found significant reciprocal relationships between autonomous motivation in PE and leisure-time autonomous motivation over a six-months period (Hutmacher et al., 2020). One of the aims of the current work was to provide more robust and reliable data on the long-range predictive validity of the trans-contextual model and to test the pattern of relationships over a full year. Modelling change in the trans-contextual model constructs has value because it tests whether the model is effective in accounting naturally occurring change in its constructs over time, rather than providing a static account of constructs measured at a particular point in time, which may change as new information appears.

### **2.3. Psychological determinants of physical activity measured by self-reports**

The majority of research done in investigating the relationships within self-determination theory and relationships within trans-contextual model have used self-reported measures to evaluate adolescents' out-of-school physical activity (Grasten & Watt, 2017; Zhang et al., 2011; Hagger et al., 2009; Hagger & Chatzisarantis, 2016). It has been demonstrated in a recent meta-analysis that students' perception of PE teachers' autonomy-supportive behaviour is positively correlated with students' self-reported physical activity (Hagger & Chatzisarantis, 2016). Self-reported measures are thought to be practical and user-friendly to apply and are generally more accepted by the participants than non-self-report measures (Adams et al., 2005). Previous research testing the self-determination theory and trans-contextual model which have used self-reported measures of physical activity have found positive relationships between psychological variables and students' out-of-school physical activity (Grasten & Watt, 2017; Hagger & Chatzisarantis, 2012; 2016; Zhang et al., 2011).

## **2.4. Psychological determinants of physical activity measured by accelerometer-based devices**

Measuring students' physical activity via accelerometers or using self-reports can produce very different results within the associations between psychosocial variables and physical activity (Kavanaugh et al., 2015). For instance, different psychosocial variables such as physical activity enjoyment were found to be significantly related only with self-reported physical activity and not with non-self-report measures (Kavanaugh et al., 2015). At the same time there is evidence stating that self-reported and non-self-reported measures are correlated in studies among children (Wang et al., 2016) and adolescents (Magalhaes et al., 2017).

Only a few cross-sectional studies (Standage et al., 2012; Wang, 2017) have investigated the relationships between psychosocial and motivational variables (i.e., perceived autonomy support from significant others, fulfilment of basic psychological needs, and motivation) and adolescents' non-self-reported physical activity. Previous research has found that perceived autonomy support from the PE teachers (Standage et al., 2012; Wang, 2017), parents (Vierling et al., 2007; Wang, 2017) and peers (Wang, 2017) has a direct effect on adolescents' psychological need satisfaction, which in turn has a direct effect on autonomous motivation. Furthermore, autonomous motivation has been shown to have a direct effect on students' physical activity measured by pedometers (Standage et al., 2012; Vierling et al., 2007) and accelerometers (Wang, 2017). However, Sebire et al. (2013) have demonstrated that only intrinsic motivation mediates the relationship between psychological needs and moderate-to-vigorous physical activity of children. The inclusion of each motivational regulation would provide us with deeper insight into adolescents' motives for engaging in physical activity.

Although a great amount of trans-contextual studies has relied on self-reported physical activity assessment, it has been stated that self-report methods can lead to inaccurate results due to over or underestimation of true energy expenditure and rates of inactivity (Prince et al., 2008) and recall bias (Adams et al., 2005) which may contribute substantially to error variance and common method variance. These measures may have led to inflation of effects between trans-contextual model constructs and behaviour in previous studies. Therefore, it has been suggested that studies should rely on other than only self-reported methods when measuring physical activity. For example, a more objective assessment of physical activity would be to use accelerometer-based devices, to reduce bias and increase precision in behavioural prediction when testing the model (Hagger et al., 2005). The current work aimed to test the trans-contextual model using both self-reported and accelerometer-based devices to measure adolescents' physical activity during their out-of-school time.

### 3. OBJECTIVES OF THE STUDY

The overall objective of the present study was to test the trans-contextual model of motivation among Estonian adolescents by using a longitudinal design and both self-reported and accelerometer-based physical activity as an outcome.

The specific aims of the present study were to:

1. test how students' perceptions of autonomy support from PE teachers predict accelerometer-based moderate-to-vigorous physical activity through basic psychological needs and autonomous and controlled forms of motivation.
2. test the trans-contextual model of motivation while accounting for change in model constructs over time using residual change scores.
3. examine the effects of the trans-contextual model of motivation over a one-year time period using residual change scores and both self-reported and accelerometer-based out-of-school physical activity as an outcome.

In this study, it was hypothesized that students' perceived autonomy support from the PE teacher is positively and indirectly related to accelerometer-based moderate-to-vigorous physical activity through psychological need satisfaction, intrinsic motivation, and identified regulation in PE (H1). Based on the tenets of the trans-contextual model it was expected that change in perceived autonomy support have direct effects on change in autonomous motivation in PE (H2). Further, it was expected that changes in autonomous motivation and controlled motivation in PE have direct effects on changes in autonomous and controlled motivation in leisure-time, respectively (H3). In addition, changes in perceived autonomy support from peers and parents were expected to predict change in autonomous motivation in leisure-time (H4). Change in autonomous motivation in leisure-time was expected to predict changes in attitudes (H5) and PBC (H6), whereas change in controlled motivation was expected to predict change in subjective norms (H7). Changes in attitudes (H8), subjective norms (H9), and PBC (H10) were expected to predict changes in intentions, and changes in intentions (H11) and PBC (H12) were expected to predict change in behaviour (both in self-reported physical activity and accelerometer-based physical activity).

Regarding indirect effects, it was hypothesized that change in autonomous motivation in leisure time predicts change in intention mediated by change in attitude and change in PBC (H13). Furthermore, it was hypothesized that change in autonomous motivation in leisure time predicts change in self-reported leisure time physical activity and accelerometer-based physical activity mediated by changes in attitude, PBC and intentions (H14).

Finally, it was expected that hypotheses of the trans-contextual model will be supported over a one-year period.



## 4. METHODS

### 4.1. Participants and research design

The sample of the present study was recruited from basic and secondary schools from three different cities in Estonia. Invitation via e-mail to participate in the study was sent to all Estonian-speaking public schools (except for special schools) in three different cities in Estonia (Tartu, Pärnu and Rakvere). All the measures were administered at school in a classroom setting, except part of the third wave of the paper III where the participants finished the study on-line.

In paper I the final study sample comprised of 397 students ( $M_{\text{age}} = 13.16$ ;  $SD = .91$ ; range = 11–15 years). A total of 277 girls (69.8%) and 120 boys (30.2%) participated in the study. In paper I participants completed self-reported measures of perceived autonomy support from the PE teacher, basic psychological need satisfaction, autonomous and controlled forms of motivation in PE, and wore an accelerometer-based device for one week. Paper I adopted a cross-sectional design.

In paper II the final study sample comprised of 331 students ( $M_{\text{age}} = 13.1$ ;  $SD = .99$ ; range = 11–15 years). There were 240 girls (72.5%) and 91 (27.5%) boys participating in the study. The study adopted a three-wave design where the measures of the trans-contextual model were completed at Time 1 and Time 2, five weeks apart. Self-reported physical activity was measured also at Time 3, five weeks after Time 2. Accelerometer-based physical activity was measured for seven days after Time 1 and Time 3. All measures were completed twice to enable the modelling of change in study constructs.

In paper III the final study sample comprised of 265 students ( $M_{\text{age}} = 13.23$ ;  $SD = .96$ ; range = 11–15 years). Out of the participants 196 were girls (76.6%) and 69 boys (23.4%). The study adopted a longitudinal three-wave design (please see Appendix A). Due to the pandemic virus (COVID-19) 129 participants out of 265 were forced to finish the final study on-line which restricted them wearing the accelerometer-based device at the second data collection occasion. Therefore, for the test of the model with self-reported physical activity as the dependent variable (Model 1) the sample comprised 265 participants, whereas for the test of the model with physical activity measured by accelerometers as the dependent variable (Model 2) the sample comprised 136 participants. An auxiliary analysis was performed on the model with self-reported physical activity as the dependent variable on participants ( $n = 136$ ) whose results were not affected by the introduction of lockdown restrictions for COVID-19.

## **4.2. Measures**

### **4.2.1. Perceived autonomy support**

In paper I, II and III students' perceived autonomy support from PE teachers was measured using a short form of the Perceived Autonomy Support Scale for Exercise Settings (PASSES; Hagger et al., 2007).

In paper II and III additional sources of autonomy support (i.e., peer and parent) were measured using the aforementioned scale. Each subscale contained four items (e.g., "I feel that my PE teacher/parents/friends provide me with choices, options, and suggestions about whether to do physical activity") with responses provided on seven-point scales (1 = strongly disagree and 7 = strongly agree). Previous studies have shown the PASSES to be a valid and reliable measure and has been used previously in Estonian context (e.g., Hagger et al., 2007; 2009).

### **4.2.2. Basic psychological need satisfaction**

In paper I students' perceptions of their need satisfaction for autonomy, competence and relatedness were assessed by three need satisfaction subscales from the Basic Psychological Need Scale and Need Frustration Scale (BPNSNF; Chen et al., 2015) adapted and validated for PE (Haerens et al., 2015). Each subscale consisted of four items and was presented with a common stem, which reads "During the PE lesson...", followed by the set of items: need satisfaction for autonomy (e.g., "...I felt that the exercises reflect what I really want"), competence (e.g., "...I felt capable at what I did"), and relatedness (e.g., "...I felt that the class members I care about also cared about me") with responses provided on seven-point scales (1 = strongly disagree and 7 = strongly agree). BPNSNF has been shown to be a valid and reliable measure (Haerens et al., 2015) and has been used previously in Estonian context (Tilga et al., 2020a).

### **4.2.3. Autonomous and controlled motivation towards physical education**

In Paper I, II and III students' autonomous and controlled forms of motivation toward PE were assessed using an adapted version of the perceived locus of causality questionnaire (Goudas et al., 1994). The scale had four subscales consisting of two items preceded by a common stem: "I do PE...". The stem was followed by sets of items measuring each regulation subscale: intrinsic motivation (e.g., "...because PE is fun"), identified regulation (e.g., "...because it is important to me to do well in PE"), introjected regulation (e.g., "...because I would feel bad if the teacher thought that I was not good at PE"), and external regulation (e.g., "...so that the teacher won't yell at me") with responses provided on seven-point scales (1 = strongly disagree and 7 = strongly agree).

In paper II and III average scores on the intrinsic motivation and identified regulation subscale items were used to form the autonomous motivation construct, and average of scores on the introjected regulation and external regulation items were used to form the controlled motivation construct. A perceived locus of causality questionnaire for PE has been shown to be a valid and reliable measure (Hagger et al., 2005; Polet et al., 2020; Standage et al., 2012) and has been used in Estonian context (Tilga et al., 2021).

#### **4.2.4. Leisure-time autonomous and controlled motivation**

In paper II and III an adapted version of Ryan and Connell's (1989) measure of perceived locus of causality for leisure time was used to measure participants' autonomous and controlled motivation during leisure time. The scale had four subscales consisting of two items for each autonomous motivation regulation style. Participants were presented with a common stem: "I do physical activity during my free time...". The stem was followed by items for the intrinsic motivation (e.g., "...because I enjoy doing physical activity"), identified regulation (e.g., "...because I value the benefits of physical activity"), introjected regulation (e.g., "...because I feel bad about myself if I don't do physical activity"), and external regulation (e.g., "...because I feel under pressure from people I know to do physical activity") subscales with responses provided on seven-point scales (1 = strongly disagree and 7 = strongly agree). The autonomous motivation construct was indicated by calculating the average of scores on the intrinsic motivation and identified regulation subscale items, and controlled motivation construct was indicated by calculating the average of scores on the items for the introjected regulation and external regulation subscales. Perceived locus of causality questionnaire has shown to be a valid and reliable measure (e.g., Hagger et al., 2005; Polet et al., 2020) and has been used in Estonian context (Tilga et al., 2021).

#### **4.2.5. The constructs of the theory of planned behaviour**

In paper II and III measures of the theory of planned behaviour constructs were developed based on guidelines by Ajzen (2003). Students' intentions were measured by two items (e.g., "I intend to do active sports and/or vigorous physical activities during my leisure time in the next 5 weeks"). Students' attitude was measured using three 7-point semantic differential scales with bipolar adjectives: bad-good, unenjoyable-enjoyable, and useless-useful in response to the common stem: "Participating in active sports and/or vigorous physical activities during my leisure time in the next 5 weeks is ...". Students' subjective norms were measured by two items (e.g., "Most people close to me expect me to do active sports and/or vigorous physical activities during my leisure time for the next 5 weeks"). Students' PBC was measured by two items (e.g., "How much control do you have over doing active sports and/or vigorous physical activities in my leisure time in the next 5 weeks"). The measures of the constructs of the theory of planned

behaviour have shown to be valid and reliable among school children and has been used previously in Estonian context (e.g., Pihu et al., 2008).

#### **4.2.6. Accelerometer-based physical activity**

In paper I, II and III students' moderate-to-vigorous physical activity was measured using the Actigraph GT3X (ActiGraph LLC, Pensacola, FL, USA). The participants were assigned to wear the accelerometer on their waist for seven consecutive days, and to remove the device only for sleeping and water-based activities (e.g., bathing, swimming). The data files were downloaded using ActiLife software (Version 6.13.3; Actigraph LLC). The sampling interval was set at 15 s. Accelerometer data were considered valid if over 600 min (10 hours) of recorded data per day at least four days out of seven were present. Zero counts of 60 consecutive min were classified as non-wear time. The physical activity intensity level as indicated by the accelerometers was measured using Evenson et al. (2008) cut-off points which has been used to evaluate the level of physical activity during adolescence (Hinckson et al., 2017). Evenson et al. (2008) cut-off points were used to calculate minutes spent in moderate-to-vigorous physical activity ( $\geq 2296$  counts/min). In paper I, II and III the output of the accelerometer indicates the average min of moderate-to-vigorous physical activity spent per day, weighted equally by each valid day. Moderate-to-vigorous physical activity in out-of-school time consisted of all sports and other vigorous activities participants performed outside of school hours. Physical activity data collected during the hours the participants spent at school were excluded from the analyses.

In paper II students' out-of-school moderate-to-vigorous physical activity was measured twice, at wave one and at wave three. In paper III students' out-of-school moderate-to-vigorous physical activity was measured three times, at Time 1 (waves one and three) and at Time 2 (wave three). Residual change score of participants' physical activity measured at Time 1 was considered as participants' past behaviour.

#### **4.2.7. Self-reported physical activity**

In paper II and III students' self-reported physical activity during leisure time was assessed at all time points using an adapted version of Godin and Shepherd's (1985) leisure time exercise questionnaire. Students responded on two items: "How frequently have you participated in vigorous physical activities during your leisure time in the course of the past five weeks for at least 20 minutes at a time?" with responses reported on a 6-point scale (1 = never and 6 = all of the time) and "In the course of the past five weeks, how often on average, have you participated in vigorous physical activities during your leisure time for at least 20 minutes at a time?" with responses reported on a 6-point scale (1 = not at all and 6 = most days per week). The content of the items used (i.e., a minimum of 20 minutes of vigorous physical activity daily) were based on the guidelines of American

College of Sport Medicine. Before answering to these two items students were presented with the definition of vigorous physical activity, which included all active sports and physical activities (e.g., sports training, practices, competition, continuous swimming, running etc.), but not sedentary sports (e.g., pool, darts) or walking to school. This measure has been used in previous studies to evaluate physical activity (Hagger et al., 2003; 2005; 2009; Polet et al., 2020) and has been used also previously in Estonian context (e.g., Hein et al., 2020; Pihu et al., 2008; Tilga et al., 2020b).

### **4.3. Research procedure**

In all cases, the relevant school administrators gave permission to conduct the study in their school. Students, and their parents gave a written informed consent to participate in the study. The students were informed that their responses reflected their opinions, that their responses can be different from others, and that there were no correct or incorrect answers. After completing the questionnaires each participant received an accelerometer-based device according to the study design together with an instruction how to use the device. Questionnaires were completed anonymously and matched using an individual code with numbers and letters based on participants' initials, birth date, gender, class, and accelerometer-based device number.

The study was in accordance with the Declaration of Helsinki and approved by Research Ethics Committee of the University of Tartu (273/T-5).

### **4.4. Statistical procedures**

In all cases descriptive data was analyzed using IBM SPSS 23.0 (IBM Corp., Armonk, NY, USA). In paper I and II additional data analyses were conducted using IBM SPSS AMOS Version 23.0 (IBM Corp., Armonk, NY, USA). In paper III the proposed model was tested using variance-based structural equation modelling (VB-SEM), which is also known as partial least squares analysis, using the Warp PLS v7.0 software (Kock, 2015).

In Paper I and II data were screened for missing values and distributional properties based on Tabachnick and Fidell (2007), and in Paper III arithmetic mean imputation was used to impute missing data. Regarding normal univariate distribution, the values for asymmetry (between -2 to +2) and kurtosis (between -7 to +7) were considered acceptable (Byrne, 2010). Statistics (means and standard deviations) and correlations for all study variables were computed and Cronbach's alphas were calculated.

In paper I structural equation modelling was used to test the direct, indirect, and specific indirect pathways from perceived autonomy support to accelerometer-based moderate-to-vigorous physical activity through psychological needs and different forms of motivation. Due to the complementarity of the basic

psychological needs, the need for autonomy, competence, and relatedness were subsumed into a single, higher-order construct (Hagger et al., 2006). More precisely, three first-order latent factors (i.e., autonomy, competence, and relatedness need satisfaction) that had their respective items as indicators served as indicators for a higher-order need satisfaction latent factor. The bootstrap-generated bias-corrected confidence approach was used to investigate the mediated relationships between study variables (Byrne, 2010; Preacher & Hayes, 2008). The specific indirect effect was considered statistically significant when the 95% confidence intervals excluded zero. Confidence intervals (95%) were produced by bootstrapping with 5000 re-samples (Paper I and II).

In paper II a path analysis of the hypothesized relationships of two models with different outcome variables (i.e., self-reported physical activity and non-self-reported physical activity) was performed. Study hypotheses were tested using path analysis with residual change scores to account for the stability (change) in study constructs across two time points. Residual change scores for each variable were calculated by regressing scores for variables measured at Time 2 on scores measured at Time 1, except self-report and accelerometer-based measures of physical activity where variable scores were calculated by regressing Time 3 scores on Time 1 scores. In the main analysis Time 2 scores of self-reported measure were not used to mirror the results with the accelerometer-based device. The effects of age and gender were controlled for by including these as covariates when computing the residual change score for each variable (Paper II and III).

In paper III partial least squares analysis was performed to test the hypothesized relationships using residual change scores. Residual change scores for each variable were calculated by regressing scores for variables measured at Time 2 wave two on scores measured at Time 2 wave one, on scores measured at Time 1 wave two, and on scores measured at Time 1 wave one. Accelerometer-based scores were calculated by regressing scores measured at Time 2 wave three on scores measured at Time 1 wave three and on scores measured at Time 1 wave one. Self-reported physical activity residual change scores were calculated in a similar manner including all possible measured scores (i.e., six time points).

In paper I and II the fit of the model was evaluated using the following indices: the  $\chi^2$  coefficient, the comparative fit index (CFI), Bentler–Bonett non-normed fit index (NNFI), and root mean square error of approximation (RMSEA) and its 90% confidence interval (Hu & Bentler, 1995). Values exceeding .90 for the CFI and NNFI, and below .08 for the RMSEA, with narrow confidence intervals, are indicative of acceptable model fit.

In paper III the fit of the model was evaluated using multiple criteria: the goodness-of-fit (GoF) index with values of .100, .250, and .360 corresponding to small, medium, and large effect sizes, respectively (Tenenhaus et al., 2005), the average variance inflation factor (AVIF) value for model parameters which is expected to be less than 5.000 (Kock, 2018a), and average path coefficient (APC) and average  $R^2$  (ARS) which are both expected to be significantly different from zero for an adequate model. Hypothesized mediation effects were tested by calculating indirect effects using a 'Stable 3' method recommended by Kock (2018b).

## 5. RESULTS

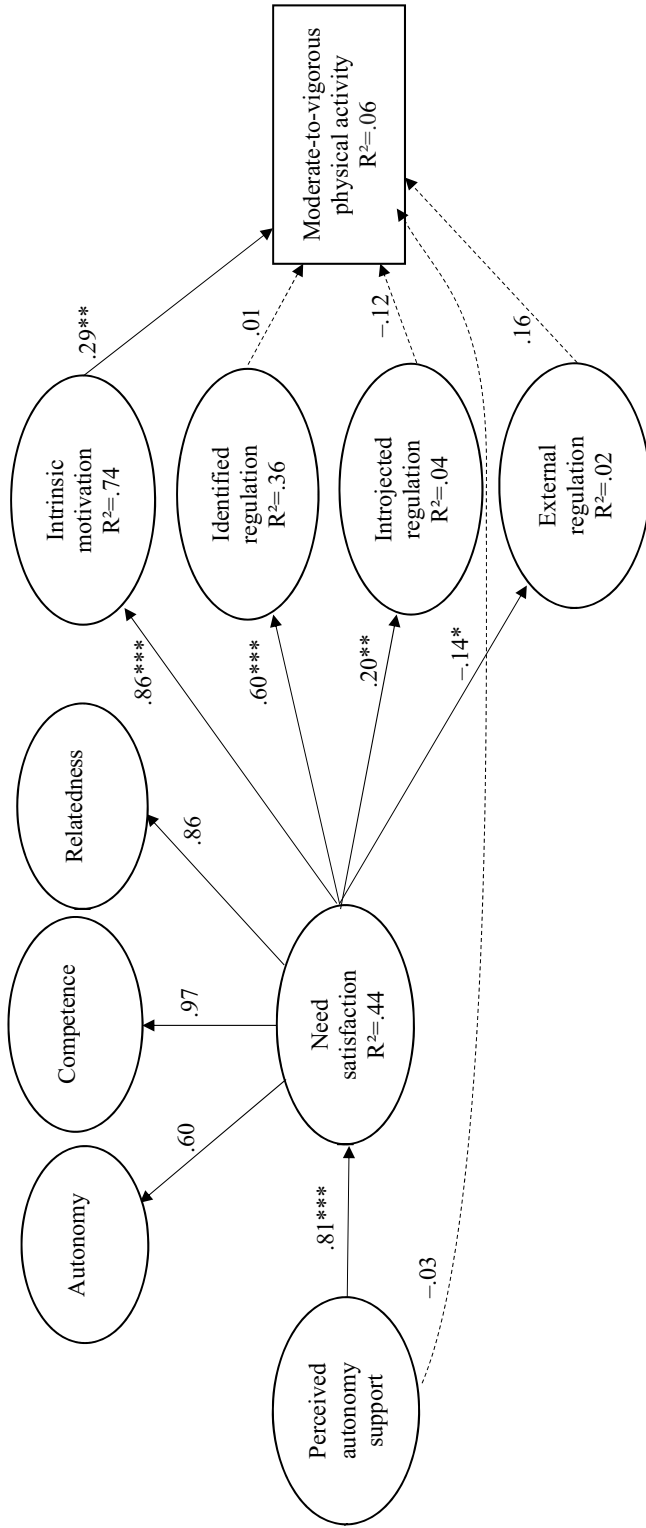
### 5.1. The relationship between perceived autonomy support from the physical education teacher and adolescents' accelerometer-based physical activity through need satisfaction and motivation (Paper I)

Descriptive statistics, alpha coefficients for all measures, and correlations among latent study variables and accelerometer-based moderate-to-vigorous physical activity are presented in Table 1 (see Paper I). The measurement model of all nine latent constructs and 25 indicators showed an acceptable fit to the data ( $\chi^2 = 639.406$ ,  $df = 252$ ; CFI = .932; NNFI = .919; RMSEA = .062; RMSEA 90% CI = .056 – .068).

42.07% of the students provided seven valid days of accelerometer data, 71.79% provided six valid days, and 91.69% provided five valid days. Students' average accelerometer wear-time was  $6.00 \pm 1.26$  days, with an average of  $841.02 \pm 63.99$  min/day. On average, participants who provided four valid days of accelerometer data spent 58.39 min ( $SD = 24.17$ ) in moderate-to-vigorous physical activity a day. Only 2.5% of students met 60 min moderate-to-vigorous physical activity a day recommendation, while 14.6% of students did not meet the recommendation on any of the days. In addition, 17.4%, 19.9%, 19.4%, 12.1%, 8.3%, and 5.8% of students met the recommendation on one, two, three, four, five, and six days, respectively.

Figure 1 demonstrates direct effects from perceived autonomy support from the PE teacher to accelerometer-based moderate-to-vigorous physical activity through psychological needs and different forms of motivation. The results revealed that adolescents' perception of PE teacher's autonomy-supportive behaviour predicted significantly and positively adolescents' perceived psychological need satisfaction, which, in turn predicted significantly and positively intrinsic motivation, identified and introjected regulation. The relationship between psychological need satisfaction and external regulation was significant, but negative. Out of the motivational regulations only intrinsic motivation predicted significantly and positively accelerometer-based moderate-to-vigorous physical activity. The direct relationship between perceived autonomy support from the PE teacher and accelerometer-based physical activity was non-significant.

The results demonstrated a significant and positive indirect effect from perceived autonomy support to intrinsic motivation ( $\beta = .70$ ,  $p = .001$ ), identified regulation ( $\beta = .48$ ,  $p = .001$ ), and introjected regulation ( $\beta = .16$ ,  $p = .012$ ) through the psychological needs. There was no significant indirect effect from perceived autonomy support to external regulation ( $\beta = -.11$ ,  $p = .066$ ) through the psychological needs. There was a specific indirect effect from perceived autonomy support to moderate-to-vigorous physical activity measured by accelerometer-based device through perceived need satisfaction and intrinsic motivation ( $\beta = .53$ ,  $p = .004$ ).



**Figure 1.** The structural equation model measuring the relationships between perceived autonomy support and moderate-to-vigorous physical activity (MVPA) through need satisfaction and motivation.

*Note.* Four specific indirect effects of perceived autonomy support on MVPA were tested through i) need satisfaction and intrinsic motivation, ii) need satisfaction and identified regulation, iii) need satisfaction and introjected regulation, iv) need satisfaction and external regulation. In addition, four indirect effects of perceived autonomy on motivational regulations through need satisfaction were tested. Solid lines indicate significant relationships and dotted lines indicate non-significant relationships; For visual simplicity covariances between all forms of motivations are not shown. Covariances of the disturbance terms were:  $r_{\text{intrinsic motivation-identified regulation}} = .17$ ,  $r_{\text{intrinsic motivation-introjected regulation}} = .00$ ,  $r_{\text{intrinsic motivation-external regulation}} = -.25^{**}$ ,  $r_{\text{identified regulation-introjected regulation}} = .50^{***}$ ,  $r_{\text{identified regulation-external regulation}} = .05$ ,  $r_{\text{introjected regulation-external regulation}} = .54^{***}$ .  $*p < .05$ .  $**p < .01$ .  $***p < .001$ .



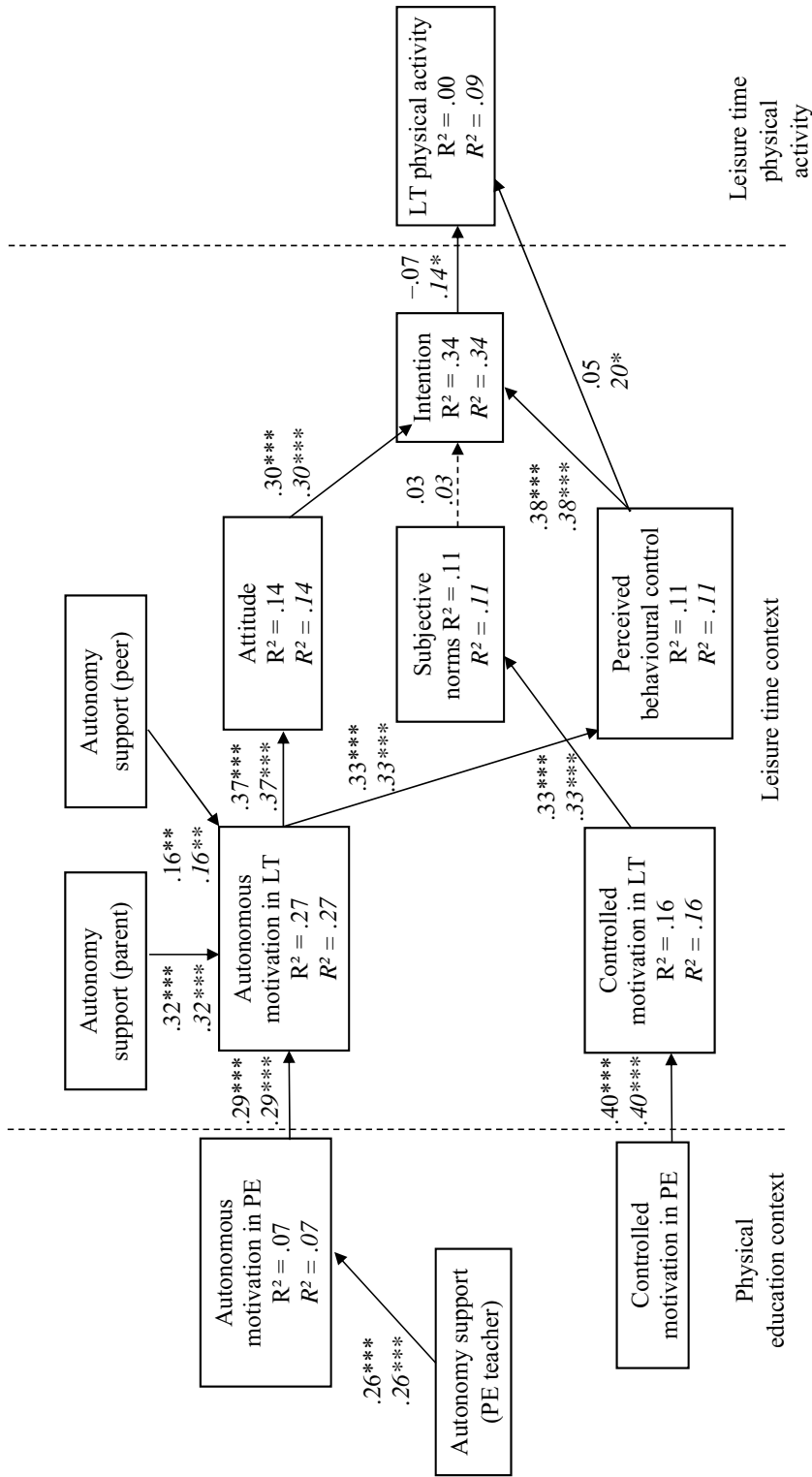
There was no significant specific indirect effect through need satisfaction and identified regulation ( $\beta = .02$ ,  $p = .908$ ), through need satisfaction and introjected regulation ( $\beta = -.07$ ,  $p = .269$ ), and through need satisfaction and external regulation ( $\beta = -.04$ ,  $p = .200$ ). All the indirect effects of the model are presented in Table 2 (see Paper I). The structural equation model that was tested demonstrated an acceptable fit to the data ( $\chi^2 = 642.464$ ,  $df = 257$ ; CFI = .932; NNFI = .921; RMSEA = .062; RMSEA 90% CI = .054 – .067).

## **5.2. The effects of changes in the psychological constructs of the trans-contextual model in changes of adolescents' out-of-school physical activity (Paper II)**

The descriptive statistics and intercorrelations for residual change scores, and alpha coefficients for study variables at each time point are presented in Table 2 (see Paper II). All alpha values exceeded  $>.70$  except for the subjective norm ( $\alpha = .64$  and  $.65$ , at Time 1 and Time 2, respectively) and controlled motivation in PE ( $\alpha = .67$  and  $.65$ , at Time 1 and Time 2, respectively) constructs.

Figure 2 shows the results of the path analysis testing the relationships of the trans-contextual model. The results revealed that change in perceived autonomy support from PE teachers had a statistically significant direct effect on change in autonomous motivation in PE ( $\beta = .26$ ,  $p = .001$ ), which, in turn had a significant direct effect on change in autonomous motivation in a leisure time context ( $\beta = .29$ ,  $p = .001$ ). Similarly, change in controlled motivation in PE had a significant direct effect on change in controlled motivation in leisure time ( $\beta = .40$ ,  $p = .001$ ). Change in perceived autonomy support from parents and peers had significant direct effects on the change in autonomous motivation in leisure time ( $\beta = .32$ ,  $p = .001$  and  $\beta = .16$ ,  $p = .005$ , respectively). Change in autonomous motivation in leisure time context had a statistically significant direct effect on change in attitude ( $\beta = .37$ ,  $p = .001$ ) and PBC ( $\beta = .33$ ,  $p = .001$ ). Change in controlled motivation in leisure time had a significant direct effect on the change in subjective norms ( $\beta = .33$ ,  $p = .001$ ). Change in attitude ( $\beta = .30$ ,  $p = .001$ ) and PBC ( $\beta = .38$ ,  $p = .001$ ) had significant direct effects on change in intention.

Regarding physical activity behaviour, change in intention had a statistically significant direct effect on changes in physical activity measured by self-report ( $\beta = .14$ ,  $p = .017$ ) but not by accelerometer-based devices ( $\beta = -.07$ ,  $p = .338$ ). Similarly, change in PBC had a significant direct effect on physical activity measured by self-report ( $\beta = .20$ ,  $p = .002$ ) but not by accelerometer-based devices ( $\beta = .05$ ,  $p = .515$ ).



**Figure 2.** Results of a path analysis testing trans-contextual model predictions for leisure time moderate-to-vigorous physical activity measured by accelerometer-based devices and self-reports.

*Note.* All variables were residual change scores. Change scores for all study variables were calculated by regressing the score of each variable measured at Time 2 on its score measured at Time 1, with the exception of the leisure-time physical activity variable for which the Time 3 score was regressed on Time 1 score. Upper values for the path and  $R^2$  coefficients are for physical activity measured by accelerometer-based devices and the lower line in italics are for physical activity measured by self-report. For clarity, the error covariances among the attitude, subjective norms, and perceived behavioural control constructs, the perceived autonomy support constructs, and motivational constructs have been omitted. PE = Physical education context; LT = Leisure-time context. \* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ .

Indirect effects of the model are depicted in Table 3 (see Paper II). The effect of the change in perceived autonomy support from the PE teacher on change in autonomous motivation in leisure time was mediated by change in autonomous motivation in PE ( $\beta = .07, p = .001$ ). The effect of change in perceived autonomy support from parents ( $\beta = .12, p = .001$ ) and peers ( $\beta = .06, p = .005$ ) on change in attitude was mediated by change in autonomous motivation in leisure time. The effect of change in perceived autonomy support from parents ( $\beta = .11, p = .001$ ) and peers ( $\beta = .05, p = .005$ ) on change in PBC was mediated by change in autonomous motivation in leisure time. The effect of change in autonomous motivation in PE on the change in intention was mediated by change in autonomous motivation in leisure time and change in attitude ( $\beta = .03, p = .001$ ), and by change in autonomous motivation in leisure time and change in PBC ( $\beta = .04, p = .0001$ ). The effect of change in autonomous motivation in leisure time on change in intention was mediated by change in attitude ( $\beta = .13, p = .001$ ) and change in PBC ( $\beta = .14, p = .001$ ).

The indirect effect of the change in autonomous motivation in leisure time on self-reported physical activity was mediated by change in attitude and change in intention ( $\beta = .13, p = .001$ ), and by change in PBC and change in intention ( $\beta = .14, p = .001$ ). The effect of change in attitude ( $\beta = .04, p = .017$ ) and PBC ( $\beta = .05, p = .017$ ) on the change in self-reported physical activity was mediated by change in intention. There were no indirect effects of change in attitude ( $\beta = -.02, p = .26$ ) and PBC ( $\beta = -.03, p = .25$ ) on change in physical activity measured by accelerometer-based devices.

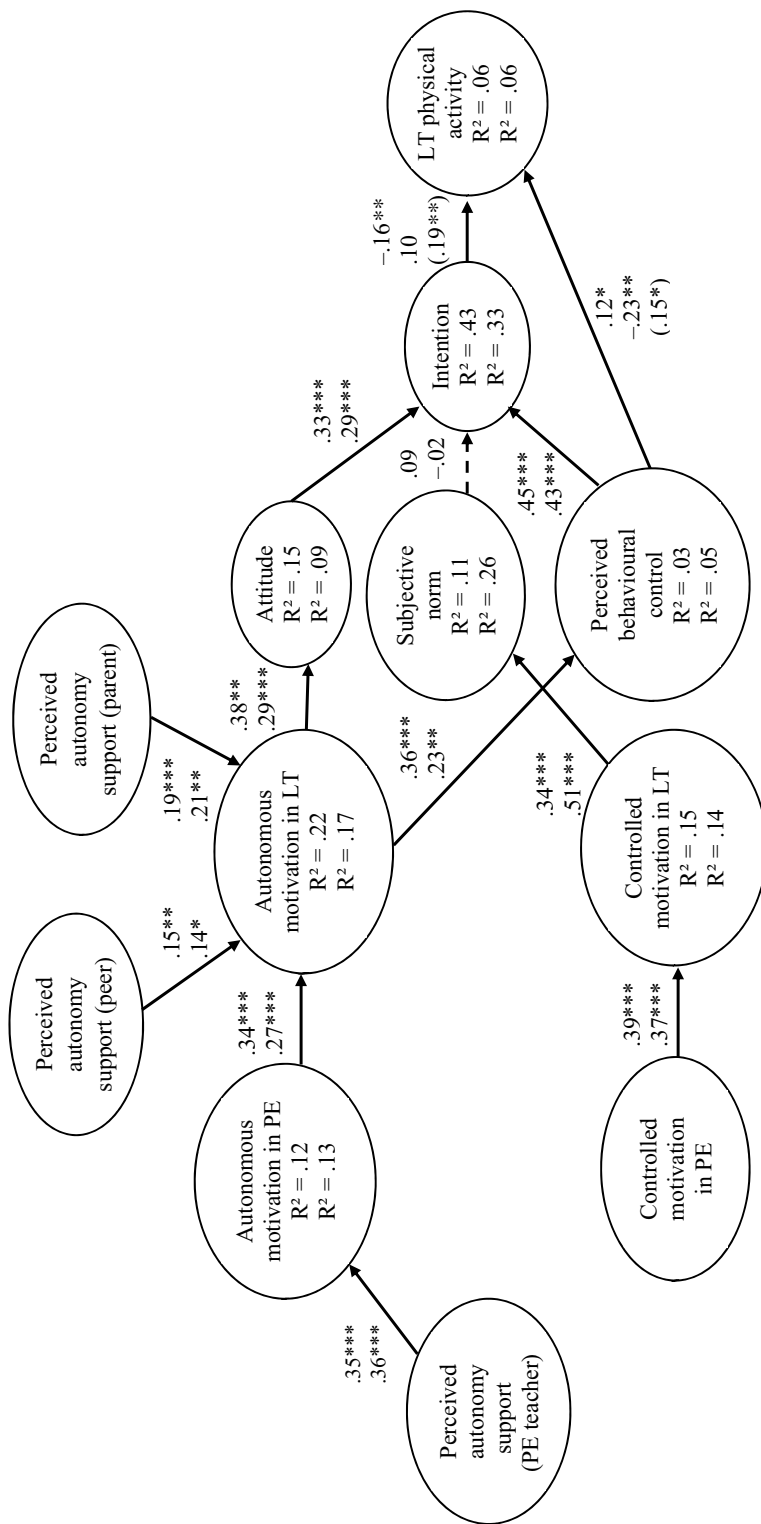
The model which predicted self-reported physical activity ( $\chi^2 = 73.22, df = 41, p < .001$ ; CFI = .95.; NNFI = .92; RMSEA = .049; RMSEA 90% CI = .030–.067) and the model which predicted accelerometer-based physical activity ( $\chi^2 = 75.01, df = 41, p < .001$ ; CFI = .95.; NNFI = .92; RMSEA = .050; RMSEA 90% CI = .032–.068) both yielded an acceptable fit to the data.

### **5.3. The long-term predictive validity of the trans-contextual model in accounting for variance in adolescents' out-of-school physical activity (Paper III)**

Intercorrelations of the study variables are presented in Table 1 (see Paper III). According to the GoF statistics, Model 1 (GoF Index = .397; APC = .265,  $p = .001$ , ARS = .158,  $p = .002$ ; AVIF = 1.135) and Model 2 (GoF Index = .394; APC = .266,  $p = .001$ , ARS = .155,  $p = .016$ ; AVIF = 1.094) demonstrated acceptable overall fit to with the data.

Regarding the results of students' physical activity measured by accelerometers, during the first data collection occasion participants spent on average 57.26 min (SD = 21.24) in moderate-to-vigorous physical activity a day at wave one and 63.98 min (SD = 21.30) at wave three. On the second data collection occasion they spent 47.04 min (SD = 20.08) in moderate-to-vigorous physical activity a day.

Figure 3 demonstrates the direct effects for Model 1 (N = 265) and Model 2 (N = 136). The results demonstrated that change in perceived autonomy support from PE teachers had a statistically significant direct effect on change in autonomous motivation in PE in Model 1 ( $\beta = .35, p < .001$ ) and Model 2 ( $\beta = .36, p < .001$ ). Change in autonomous motivation in PE had a significant direct effect on change in autonomous motivation in a leisure-time context in Model 1 ( $\beta = .34, p < .001$ ) and Model 2 ( $\beta = .27, p < .001$ ). Change in controlled motivation in PE had a significant direct effect on change in controlled motivation in a leisure-time context in Model 1 ( $\beta = .39, p = .001$ ) and Model 2 ( $\beta = .37, p < .001$ ). Change in perceived autonomy support from parents and peers had significant direct effects on the change in autonomous motivation in a leisure-time context in Model 1 ( $\beta = .19, p = .001$  and  $\beta = .15, p = .007$ , respectively) and Model 2 ( $\beta = .21, p = .007$  and  $\beta = .14, p = .046$ , respectively). Change in autonomous motivation in a leisure-time context had a statistically significant direct effect on change in attitude and PBC in Model 1 ( $\beta = .16, p = .004$ ;  $\beta = .38, p = .001$ , respectively) and Model 2 ( $\beta = .29, p < .001$ ;  $\beta = .23, p = .002$ , respectively). Change in controlled motivation in leisure-time had a significant direct effect on the change in subjective norm in Model 1 ( $\beta = .34, p = .001$ ) and Model 2 ( $\beta = .51, p < .001$ ). Change in attitude and PBC had significant direct effects on change in intention in Model 1 ( $\beta = .33, p = .001$  and  $\beta = .45, p = .001$ , respectively) and Model 2 ( $\beta = .29, p < .001$  and  $\beta = .43, p < .001$ , respectively). Subjective norms had no statistically significant effects on intention in either model. Change in PBC had a significant direct effect on physical activity measured by self-report in Model 1 ( $\beta = .12, p = .021$ ), while change in PBC had a significant and negative direct effect on accelerometer-based physical activity in Model 2 ( $\beta = -.23, p = .003$ ). Change in intention had a statistically significant but negative direct effect on change in physical activity measured by self-report in Model 1 ( $\beta = -.16, p = .004$ ), but not on physical activity measured by accelerometer-based devices in Model 2 ( $\beta = .10, p = .111$ ). Results of the auxiliary analysis in the sample of 136 participants with self-reported physical activity as the dependent variable, however, revealed a positive direct effect of change in PBC ( $\beta = .15, p = .035$ ) and intention ( $\beta = .19, p = .012$ ) on self-reported physical activity. The indirect effects of Model 1 and Model 2 are presented in Table 2 (see Paper III). The results revealed a statistically significant indirect effect of change in perceived autonomy support from the PE teacher on change in autonomous motivation in leisure-time through change in autonomous motivation in PE in Model 1 ( $\beta = .12, p = .003$ ), but not in Model 2 ( $\beta = .10, p = .054$ ). In addition, there was an indirect effect of change in perceived autonomy support from parents on change in attitude through change in autonomous motivation in leisure-time in Model 1 ( $\beta = .07, p = .046$ ), but not in Model 2 ( $\beta = .06, p = .157$ ). There was an indirect effect of change in PBC ( $\beta = -.07, p = .048$ ), but not attitude ( $\beta = -.05, p = .113$ ), on change in self-reported physical activity in Model 1 through change in intention, although the indirect effect for PBC on physical activity was negative in sign. The effect of change in autonomous motivation in leisure-time on change in intention was mediated by change in attitude and PBC in Model 1 ( $\beta = .20, p = .001$ ) and Model 2 ( $\beta = .18, p = .013$ ).



**Figure 3.** Standardized path coefficients for the longitudinal structural equation model testing change in trans-contextual model predictions for leisure-time self-reported and out-of-school moderate-to-vigorous physical activity measured by accelerometers.

*Note.* All variables represented in the diagram are residualised change scores. Values printed on the upper line are for the model with physical activity measured by self-report ( $N = 265$ ) and values printed on the lower line are for the model with physical activity measured by accelerometer-based devices ( $N = 136$ ). Values in parentheses represent the results of the auxiliary analysis where physical activity was measured by self-report ( $N = 136$ ). Paths between past behaviour and the study constructs are not shown for clarity. PE = Physical education context; LT = Leisure-time context. \* $p < .05$ . \*\* $p < .01$ . \*\*\* $p < .001$ .

Finally, results of the auxiliary analysis for the model with self-reported physical activity as the dependent variable of participants whose results were not affected by COVID-19 revealed that the effect from change in PBC on change in self-reported physical activity was not statistically significant ( $\beta = .08, p = .089$ ). In model 2 there were no indirect effects of change in attitude ( $\beta = .03, p = .314$ ) and PBC ( $\beta = .04, p = .232$ ) on change in physical activity measured by accelerometer-based devices.

## 6. DISCUSSION

### 6.1. The relationship between perceived autonomy support from the physical education teacher and adolescents' accelerometer-based physical activity through need satisfaction and motivation (Paper I)

The analysis demonstrated that perceived autonomy support from the PE teachers fosters fulfilling adolescents' psychological needs, which, in turn, were positively associated with intrinsic motivation, identified regulation, and introjected regulation, whereas negatively with external regulation among Estonian adolescents. However, only intrinsic motivation was found to be positively and significantly related to accelerometer-based moderate-to-vigorous physical activity.

Results support one of the main tenets of self-determination theory (Deci & Ryan, 2000) and previous studies conducted in PE context (Haerens et al., 2015; Standage et al., 2005; 2012; Vierling et al., 2007; Koka et al., 2014; Wang, 2017) demonstrating that autonomy supportive environment created by PE teachers is not directly related to autonomous motivation but through the satisfaction of the basic psychological needs. In line with the theory (Hagger et al., 2009) and previous studies in the field of PE (Ntoumanis, 2001; Sebire et al., 2013), psychological need satisfaction was positively and significantly related to intrinsic motivation and identified regulation. However, the results revealed also a positive and significant association between the psychological needs and introjected regulation. Some previous studies (Sebire et al., 2013; Standage et al., 2003; 2005) confirm this finding of a positive relationship with even greater magnitude between need satisfaction and introjected regulation. This finding could be attributed to the fact that students may participate in PE to avoid being isolated from other students as proposed by Ntoumanis (2001). In addition, students who rely on introjected regulation, might be engaged in PE due to feeling obligated to do so (Standage et al., 2005). Furthermore, it could be that the whole concept of introjected regulation is too abstract for early adolescence to detect. The development of personality at that age is still incomplete and recognizing and comprehending feelings of guilt and shame requires more advanced self-perception and cognitive development (Harter, 1999; Repinski et al., 2002).

The results demonstrated that only intrinsic motivation towards PE, but not identified regulation, is related to adolescents' accelerometer-based moderate-to-vigorous physical activity. Intrinsic motivation is considered to be a more autonomous form of motivation compared to identified regulation. Hence, a significant relationship is more likely to be emerged between intrinsic motivation and moderate-to-vigorous physical activity being a positive adaptive outcome (Ryan & Deci, 2017). In addition, intrinsic motivation is often believed to be the focal variable when examining different forms of motivation influencing physical activity behaviour leading to long term engagement (Zhang et al., 2011). This

finding is supported by previous studies measuring adolescents' and children daily physical activity (Dishman et al., 2015; Sebire et al., 2013; Owen et al., 2013).

In the current analysis, the model accounted for 6% of the variance in adolescents' accelerometer-based moderate-to-vigorous physical activity. This finding is in accordance with previous studies where non-self-reported physical activity measures were used (Sebire et al., 2013; Vierling et al., 2007; Wang, 2017). The reason why psychological constructs fail to capture more variance in adolescents' accelerometer-based moderate-to-vigorous physical activity within this and previous studies could be attributed to the fact that adolescents' physical activity was measured during a short time-period which might not reflect so precisely their everyday physical activity. In addition, the current study measured adolescents' motivation in PE to predict their daily moderate-to-vigorous physical activity, although, other factors such as students' motivation towards leisure-time physical activity could also influence students' daily physical activity engagement. Higher predictive power of various psychological constructs on self-reported physical activity have been shown in studies using self-reported measures of physical activity (Grasten & Watt, 2017; Zhang et al., 2011). The difference in the variance explained by self-report and non-self-reported physical activity measures could come from adolescents overestimating their physical activity level in self-reported measures (Prince et al., 2008) and due to recall problems (Kohl, et al., 2000).

The analysis revealed only one significant indirect pathway from perceived autonomy support to accelerometer-based moderate-to-vigorous physical activity through perceived satisfaction of the psychological needs and intrinsic motivation, confirming hypothesis H1. Previous studies (Standage et al., 2012; Vierling et al., 2007; Wang, 2017) investigating this pathway have failed to show this, probably due to using a composite variable of autonomous motivation (Wang, 2017) or a single measure of relative autonomy index (Standage et al., 20012; Vierling et al., 2007). The unique role of each motivational regulation can emerge if each motivational regulation is investigated separately. This finding is in line with Zhang et al. (2011) who found that need support from PE teachers is positively related to the students' psychological need satisfaction, intrinsic motivation in PE and self-reported physical activity participation during the time spent both at school and outside of school. The current results extend previous research (Standage et al., 2012; Vierling et al., 2007; Wang, 2017) by showing the unique contribution of each motivational regulation on adolescents' moderate-to-vigorous physical activity within the motivational sequence. This finding enables researchers to better understand the associations between PE teachers' perceived autonomy support, adolescents' fulfilment of the psychological needs, motivation in PE and accelerometer-based moderate-to-vigorous physical activity.



## **6.2. The effects of changes in the psychological constructs of the trans-contextual model in changes of adolescents' out-of-school physical activity (Paper II)**

Results of the current study confirm some of the key hypotheses of the trans-contextual model (Hagger & Chatzisarantis, 2012; 2016) using residual change scores. More precisely, effects of perceived autonomy support on autonomous motivation in PE (H2), the trans-contextual relationship between autonomous and controlled motivation between PE and leisure time physical activity contexts (H3), the effect from change in autonomous motivation in leisure-time on changes in attitudes (H5) and on PBC (H6), the effect from change in controlled motivation in leisure-time on change in subjective norms (H7), the effect from change in attitudes (H8), and PBC (H10) predicted changes in intentions, and the effect from change in leisure-time autonomous motivation predicted change in intention through attitude and PBC (H13).

Change in autonomous motivation in leisure time predicted change in self-reported leisure time physical activity mediated by changes in attitude, PBC and intentions. However, these effects were not supported for outside of school physical activity measured by accelerometer-based devices. So, hypotheses H14 was only partly confirmed. Generally, the pattern of effects is in line with previous studies using the model (Gonzales-Cutre et al., 2014; Hagger & Chatzisarantis, 2016; Hagger et al., 2009; Pihu & Hein, 2007). These findings showed whether the model effects hold when accounting for inter-individual change in motivation, beliefs, and behaviour in the model over time. The results showed that the current model predictions in the trans-contextual model largely hold when accounting for stability demonstrating the effectiveness of the model in explaining change in the constructs over time.

The current results support the relevance of including parents' and peers' autonomy support in the trans-contextual model. The results demonstrated that change in perceived autonomy support from peers and parents predicted change in autonomous motivation in leisure time (H4). According to Hagger et al. (2009), this finding suggests that other sources of autonomy support are also important in influencing adolescents' decision-making processes. However, it is important to note that autonomy support from PE teachers in a separate context, still had pervasive influence on autonomous motivation for physical activities in leisure time, and beliefs and intentions toward, and actual participation in, physical activity in that context, even when autonomy support from other sources was included.

Contrary to the trans-contextual model predictions, results demonstrated that change in subjective norms did not predict the change in intention as was hypothesized (H9). Similarly, change in controlled motivation in leisure time and subjective norms did not mediate the relationship between change in controlled motivation in PE and change in intention. Similar results of relatively small or no effects of subjective norms on intentions have been found also in previous studies

(Hagger et al., 2003; 2006; 2009; Hagger & Chatzisarantis, 2016), suggesting a rather peripheral influence of subjective norms and controlled motivation in the model compared to autonomous motivation, attitudes and PBC (Hagger et al., 2002).

Results showed that change in intentions (H11) and PBC (H12) were the proximal determinants of physical activity change only for the self-reported physical activity and not for accelerometer-based physical activity. These findings are consistent with previous conventional prospective studies without modelling change and using self-reported physical activity measurement (Hagger & Chatzisarantis, 2012; 2016). The reason for the non-significant relationship between change in intention and PBC and change in accelerometer-based physical activity may be due to some measurement issues of the study which could have influenced the results. The lack of correspondence between the psychological constructs and the accelerometer-based device measure could be one of the problems. It is necessary that measures of constructs like intentions and attitudes correlate well with behavioural measures regarding the individual performing the behaviour, the action, the context and time (Ajzen, 1991). In the current study, the self-report measure of physical activity corresponded strongly with the psychological measures according to the aforementioned criteria. However, the measure of accelerometer-based physical activity and the psychological measures had problems with correspondence, which may have influenced the results. The accelerometer-based measure was only worn by the participants over a one-week census period, which is common practice due to the high cost and logistical difficulties. Furthermore, the accelerometer-based measure included incidental form of physical activity (e.g., active transport, household chores) in addition to leisure-time physical activity while the psychological variables made reference exclusively to leisure-time physical activity.

### **6.3. The long-term predictive validity of the trans-contextual model in accounting for variance in adolescents' out-of-school physical activity (Paper III)**

The analysis showed that several key trans-contextual model (Hagger & Chatzisarantis, 2016) relationships hold over a full year in Model 1 and Model 2. The findings support the relationship between perceived autonomy support and students' autonomous motivation in PE over a full year (H2), the relationship between autonomous and controlled forms of motivation across contexts over a full year (H3), the relationship between change in autonomous motivation in leisure-time and change in attitudes (H5) and PBC (H6) over a full year, the relationship between change in controlled motivation and change in subjective norms (H7) over a full year, the relationship between change in attitudes and change in intentions (H8) over a full year, the relationship between change in PBC and change in intention (H10) over a full year, and the indirect relationship

between autonomous motivation in leisure-time and intentions through attitude and PBC over a full year (H13). Previous prospective model tests have confirmed these relationships in the PE (Hagger et al., 2005, 2009) and other educational contexts (Hagger et al., 2015; Hagger & Hamilton, 2018).

The results confirmed the importance on peers' and parents' perceived autonomy support within the trans-contextual model over a full year (H4). The relevance of peers' and parents' autonomy support on adolescents' motivation towards physical activity over shorter time periods have been demonstrated also in previous studies (Tilga et al., 2018; Wang 2017).

These results demonstrate that peers' and parents' autonomy support is a consistent predictor of adolescents' physical activity through constructs of the trans-contextual model over a longer period (i.e., one-year). Future intervention would do well in including peers' and parents' autonomy support in addition to PE teachers' autonomy support to influence adolescents' motivation, beliefs about physical activity, and out-of-school physical activity.

Change in subjective norms did not predict change in intention, so H9 was rejected. Subjective norms seem to have minor effects in the model compared to attitudes and PBC. Similar results have been found in previous studies (Hagger et al., 2009; Hutmacher, et al., 2020).

Change in PBC had a significant direct effect on change in self-reported physical activity (H12) in Model 1, however the same effect was negative in Model 2 where accelerometer-based physical activity was used. The positive relationship between PBC and self-reported physical activity is consistent with postulates of the trans-contextual model and with previous studies (e.g., Hutmacher et al., 2020). Interestingly, also a negative effect between PBC and self-reported physical activity have been demonstrated earlier by Polet et al. (2020) applying the model. One possible explanation for this contradictory finding might be that students inaccurately assess their perceived control. Students' control estimates may coincide with their personal evaluations of their capability, which is more likely in line with their self-reported physical activity, but it may be inaccurate when it is related to activity measured by non-self-report means.

Another surprising result was the negative relationship between change in intention and change in self-reported physical activity. In this case H11 must be rejected. This finding is contrary to previous trans-contextual model research (Hagger et al., 2018; McEachan et al., 2011). However, a possible reason for this finding may be related to the timing of the study. Specifically, part of the study period fell in the spring of 2020 when very strict COVID-19 restrictions were implemented. During the first wave of data collection participants might have declared an intention to be physically active, but due to the unexpected movement restrictions, were not able to carry out their plans, so their predictions were inaccurate due to these unexpected restrictions. An auxiliary analysis was done with participants whose study period was unaffected by the implementation of the COVID-19 restrictions to examine in detail this option. As expected, the results demonstrated a significant and positive relationship between change in

intention and change in self-reported physical activity which is in line with previous studies (Hagger & Chatzisarantis, 2016; Polet et al., 2020).

In contrast to previous trans-contextual model research (Hagger & Chatzisarantis, 2016), and previous research investigating the long-term relationship between intention and physical activity behaviour (Raudsepp et al., 2010) using self-reported physical activity, current results failed to demonstrate a relationship between change in intention and change in out-of-school accelerometer-based physical activity (H11). This counterintuitive finding might be related to the lack of correspondence between the psychological constructs and the accelerometer-based device. Furthermore, the psychological measures made specific reference to leisure-time physical activity whereas the accelerometer-based device measured more types of activity which leads to weak behavioural correspondence within the measures.

## 7. PRACTICAL IMPLICATIONS

Considering the importance of PE teachers', peers' and parents' autonomy-supportive behaviour on adolescents' autonomous motivation some specific recommendations can be given. In order to enhance adolescents' physical activity a special focus should be on increasing their intrinsic motivation rather than relying on other forms of motivational regulations. Students' pure enjoyment in engaging in physical activity should be supported to increase their daily physical activity. This could be done by adopting an autonomy-supportive behaviour to fulfil students' basic psychological needs, which, in turn enhances their intrinsic motivation and actual physical activity behaviour. In addition, PE teacher should for example give students the opportunity to choose between activities (autonomy satisfaction), provide them with assignments which are executable (competence satisfaction) and show interest in what the students are doing (relatedness satisfaction) (Paper I). The longitudinal design and the use of residual change scores permitted evaluation of whether the trans-contextual model is effective over time while accounting for change in motivational outcomes and out-of-school physical activity behaviour. Autonomy-supportive behaviour of the PE teacher, peers and parents form the basis of students' autonomous motivation towards physical activity in PE lesson and during out-of-school time (Paper II and III). Therefore, teachers, peers and parents should adopt autonomy supportive behaviours to promote students' autonomous motivation. Autonomy-supportive behaviour can consist of providing choice and positive feedback to the students, avoiding controlling language and contingencies, and showing interest towards the students and their activities. The current study provides strong evidence suggesting that any external influence that affects change in autonomous motivation could lead to change in associated variables.

## 8. LIMITATIONS OF THE STUDY

Although, the present study provided valuable findings regarding the longitudinal test of the trans-contextual model and students' accelerometer-based physical activity measurement, there are also several limitations of the current research that should be acknowledged. First, although device-based measurement to assess adolescents' physical activity is considered a preferred method over self-reported measures (Hagger et al., 2005), it has its limitations. Accelerometer-based devices have to be removed for aquatic activities and they do not measure physical activity while cycling on a stationary bicycle and while weight-lifting. Furthermore, they capture all bodily movements including chores at home and transportation which do not precisely go under the "leisure" category. Future studies could use diary format together with accelerometers to provide converging estimates of physical activity (Van Hoya et al., 2014).

Secondly, the participants of the current work were mainly female which may limit the generalizability of the findings. However, in Paper II and III gender was controlled in the analysis which means that observed effects are unlikely to have adversely affected by gender variations. Thirdly, in Paper II and III there was a measurement correspondence issue between measures of study constructs and physical activity measured by accelerometer-based devices. Fourth, it is important to highlight that the data of the current work is correlational and therefore does not allow to infer causality. Future studies could use experimental intervention designs to infer causality. Fifth, in Paper II and III two time points were used to estimate change over time. It would be recommended to use multiple time points to have a better estimation of change over time. Furthermore, in Paper III the final sample was relatively small. Future longitudinal studies should replicate the results in larger samples by taking into account the large drop-out rate while planning the study and find ways to retain participants in the study. Finally, in order to receive a more objective assessment of students' autonomy support future studies could complement the study design by including an externally-referenced assessment of autonomy support from the three socializing agents rather than relying only on perceived autonomy support.

## 9. CONCLUSIONS

1. Perceived autonomy support from the PE teacher is indirectly related to students' daily accelerometer-based moderate-to-vigorous physical activity through basic psychological needs and intrinsic motivation.
2. Key predictions of the trans-contextual model including the prediction of change in adolescents' autonomous motivation in PE and leisure-time, intention, and self-reported physical activity hold, but not the prediction of change in physical activity measured by accelerometer-based device.
3. Over a one-year period, the key effects of the trans-contextual model hold for the model with physical activity measured by self-report, but not for the model with physical activity measured by accelerometer-based device.

The core hypotheses of the study were confirmed, except for H9 – the change from subjective norms to change in intention and H11 and H12 in accelerometer-based models where no relationship emerged between change in PBC and physical activity and change in intention and physical activity.

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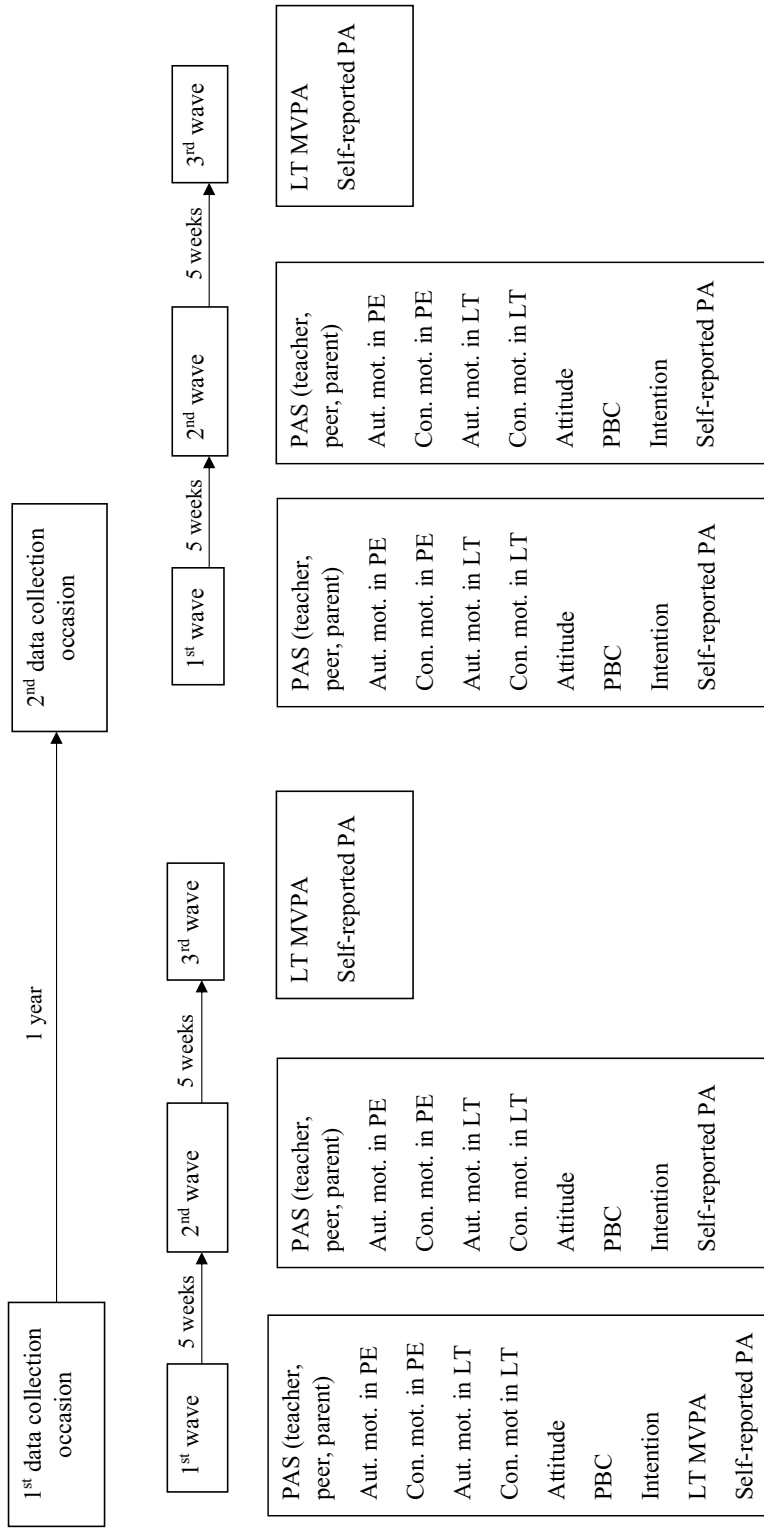
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Appendix A. The longitudinal study design.

PAS = Perceived autonomy support; Aut.mot. = Autonomous motivation; Con.mot. = Controlled motivation; PE = Physical education context; LT = Leisure-time context; PBC = Perceived behavioural control; PA = Physical activity; MVPA = Moderate-to-vigorous physical activity measured by accelerometers.

## SUMMARY IN ESTONIAN

### **Eesti kooliõpilaste kehalise aktiivsuse muutuste prognoosimine kasutades trans-kontekstilist motivatsioonimudelit**

Piisav kehalise aktiivsuse tase aitab ennetada mitmeid passiivse elustiiliga seotud haiguseid (Reiner et al., 2013) ja on oluline üldise tervise seisukohast (Poitras et al., 2016). Vaatamata sellele ei täida enamuse lastest ja noortest Maailma Terviseorganisatsiooni (Bull et al., 2020) soovitus olla mõõduka kuni tugeva intensiivsusega kehaliselt aktiivne vähemalt 60 minutit iga päev ühe nädala lõikes (Kantanista et al., 2021; Van Hecke et al., 2016). Lisaks sellele on leitud, et laste kehalise aktiivsuse tase väheneb veelgi jõudes lapseeas noorukiikka (Chong et al., 2020). Teadlased on proovinud tuvastada psühholoogilisi tegureid, mis võiksid aidata suurendada laste osalemist kehalistes tegevustes (Hagger et al., 2020). On leitud, et olulisel kohal noorte kehalise aktiivsuse prognoosimisel on tajutud autonoomsuse toetus kehalise kasvatusõpetajate, kaasõpilaste ja vanemate poolt, mis omakorda mõjutab nende autonoomset motivatsiooni, uskumusi, kavatsust olla kehaliselt aktiivne ja seeläbi ka noorte eneseraporteeritud kehalise aktiivsuse taset (Hagger & Chatzisarantis, 2012; 2016). Nende seoste uurimise aluseks on teoreetilise raamistikuna kasutatud trans-kontekstilist motivatsioonimudelit (Hagger & Chatzisarantis, 2003), mis hõlmab endas enesemääratlemise teooria (Deci & Ryan, 1985), Vallerandi hierarhilise mudeli (Vallerand, 1997) ja planeeritud käitumise teooria komponente (Ajzen, 1991). Valdav osa varasemaid trans-kontekstilise motivatsioonimudeli uuringuid kehalise kasvatusõpetuse kontekstis on vaadeldud kehalist aktiivsust lühikese aja jooksul ning kasutanud noorte kehalise aktiivsuse hindamiseks eneseraporteeritud küsimustikke.

Käesoleva töö peamiseks eesmärgiks oli testida trans-kontekstilist motivatsioonimudelit kehalise kasvatusõpetuse kontekstis pikema aja jooksul hinnates noorte vaba aja kehalist aktiivsust nii eneseraporteeritud küsimustikega kui ka kiirendusanduritega. Lisaks käsitleb käesolev töö erinevate motivatsiooniregulatsioonide seost noorte kiirendusanduritega mõõdetud kehalise aktiivsusega koolivälisel ajal ning samuti trans-kontekstilise motivatsioonimudeli komponentide seoste kehtivust ühe aasta möödudes.

Käesolev töö koosneb kolmest uuringust. Esimeses uuringus osales 397 õpilast vanuses 11–15 aastat, kelle hulgas oli 277 tüdrukut ja 120 poissi. Esimene uuring põhines enesemääratlemise teorial, kus uuriti erinevate motivatsiooni regulatsioonide seost õpilaste tajutud autonoomsuse toetuse ja kiirendusanduritega mõõdetud koolivälise aja kehalise aktiivsusega. Tulemustest selgus, et kõige olulisem vahendaja õpilaste tajutud autonoomsuse toetuse ja nende kehalise aktiivsuse vahel on sisemine motivatsioon.

Teise ja kolmanda uuringu eesmärgiks oli testida trans-kontekstilise motivatsioonimudeli komponentide seoste dünaamilist kehtivust kasutades erinevaid ajalisi intervalle. Selleks mõõdeti kõiki tunnuseid mõlemas uuringus kahel korral. Hinnati õpilaste tajutud autonoomsuse toetust kehalise kasvatusõpetaja poolt



kehalise kasvatuses tunnis, tajutud autonoomsuse toetust eakaaslaste ja vanemate poolt vaba aja kontekstis, õpilaste autonoomset ja kontrollitud motivatsiooni kehalises kasvatuses ja vabal ajal, planeeritud käitumise teooria komponente (hoiakud, subjektiivsed normid, tajutud käitumuslik kontroll ja kavatsus) ja õpilaste eneseraporteeritud ja kiirendusanduritega mõõdetud kehalist aktiivsust väljaspool koolitunde. Kolmandas uuringus teostati aastase vahega kaks kolmelainelist uuringut samade vaatlusalustega. Teises uuringus osales 331 õpilast vanuses 11–15 aastat, kellest 240 olid tüdrukud ja 91 poisid. Kolmandas uuringus osales 265 õpilast vanuses 11–15 aastat, kelle hulgas oli 196 tüdrukut ja 69 poissi.

Teise uuringu tulemustest selgus, et trans-kontekstiline motivatsioonimudel võimaldab prognoosida noorte vaba-aja autonoomset motivatsiooni, kavatsust olla kehaliselt aktiivne ja eneseraporteeritud kehalist aktiivsust, kuid mitte kiirendusanduritega mõõdetud kehalist aktiivsust võttes arvesse seoste dünaamikat ühe kuu jooksul. Kolmanda uuringu tulemustest selgus, et trans-kontekstiline motivatsioonimudel ennustab noorte vaba-aja autonoomset motivatsiooni, kavatsust olla kehaliselt aktiivne ja eneseraporteeritud kehalist aktiivsust, kuid mitte kiirendusanduritega mõõdetud kehalist aktiivsust võttes arvesse seoste dünaamikat ühe aasta jooksul.

Käesoleva töö tulemused näitasid, et trans-kontekstilise motivatsioonimudeli tunnuste vahelised seosed on stabiilsed ehk kehtivad ajas võttes arvesse seoste dünaamikat nii ühe kuu kui ka ühe aasta möödudes. Tulemustest selgus, et kehalise kasvatuses õpetaja poolt pakutud autonoomsuse toetus kehalise kasvatuses tunnis on seotud noorte autonoomse motivatsiooniga kehalise kasvatuses tunnis, mis omakorda kandub üle vaba-aja konteksti. Vaba-aja autonoomne motivatsioon on aga seotud noorte kavatsusega olla kehaliselt aktiivne ja nende eneseraporteeritud kehalise aktiivsusega pärast koolitunde võttes arvesse seoste dünaamikat ajas nii ühe kuu kui ka ühe aasta möödudes. Käesolevas töös ei ilmnenud aga seost õpilaste kavatsusega olla kehaliselt aktiivne ja kiirendusanduritega mõõdetud kehalise aktiivsuse vahel koolivälisel ajal. Vaatamata sellele ilmnes statistiliselt oluline seos kiirendusanduritega mõõdetud päevase kehalise aktiivsuse ja sisemise motivatsiooni vahel esimeses uuringus, mis iseloomustab kehalise kasvatuses õpetajapoolse autonoomsuse toetuse pakkumise olulisust õpilastele, mis mõjutab nende psühholoogilisi põhivajadusi ja selle kaudu õpilaste sisemist motivatsiooni.

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