

Exploring the moderating effects of anticipated effort on
real-time physical activity behaviour:

An ecological momentary assessment study

by

Ryan Tian Xing Chen

A thesis

presented to the University of Waterloo

in fulfilment of the

thesis requirement for the degree of

Master of Science

in

Kinesiology and Health Sciences

Waterloo, Ontario, Canada, 2026

© Ryan Tian Xing Chen 2026

Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Introduction

Regular physical activity (PA) provides many positive physical and mental health outcomes. Despite the well-known benefits of PA, most Canadian adults are not meeting current 24-hour Canadian movement guidelines (Ross et al., 2020). According to the Theory of Planned Behaviour (Ajzen, 1991), intention is theorized as a direct predictor of behaviour. Yet, a notable intention-behaviour gap exists where people fail to translate PA intention to PA behaviours. Newer dual process theories such as The Theory of Effort Minimization in Physical Activity (TEMPA; Cheval & Boisgontier, 2021) include consideration for the dynamic nature of people's physical and psychological states. The TEMPA also further includes consideration for people's evolved automatic tendencies to minimize physical effort. Prior research examining the effects of effort on PA behaviour has relied on cross sectional or single-timepoint experimental designs that lack ecological validity. Furthermore, previous research does not distinguish effort to *prepare* to engage in PA from effort to engage in PA. The present study leveraged ecological momentary assessment (EMA), a novel data capturing technique aimed to maximize ecological validity through repeated sampling of participants in real-time and real-world contexts.

Objective and Hypothesis

The objective of this study is to examine the effects of intention on PA behaviour, the effects of anticipated effort to prepare to engage in PA on PA behaviour, and the moderating effects of anticipated effort to prepare to engage in physical activity on the intention-behaviour relationship. It is hypothesized that intention will positively predict PA behaviour, that anticipated effort to prepare to engage in PA will negatively predict PA behaviour, and that anticipated effort to prepare to engage in PA will moderate the intention-behaviour relationship in that as anticipated effort increases, the intention-behaviour gap widens.

Methods

Emerging adults ($N=124$; mean age = 22.47 years) were recruited and completed EMA surveys four times daily for seven days, reporting PA intention and anticipated effort to prepare to engage in PA. Participants wore Fitbit Versa 4 PA monitoring devices on their non-dominant wrist to passively measure PA behaviour as MVPA minutes 120-min epoch following each survey. Multilevel mixed-effects models were conducted, and within-person and between-person effects were disaggregated to test the hypotheses.

Results

An intention-to-behaviour gap of 41.5% was observed over the duration of the study. Results showed that intention positively predicted PA behaviour and anticipated effort to prepare to engage in PA negatively predicted PA behaviour. Furthermore, within-person and between-person effects of anticipated effort were significant in moderating the intention-behaviour relationship. Within-person effects moderated the intention-behaviour relationship in that as participants reported anticipated effort higher than their own average, the intention-behaviour relationship was weaker. Against hypotheses, the intention-behaviour relationship was stronger for participants reporting higher average anticipated effort compared to others.

Conclusion

These findings suggest that anticipated effort is a dynamic construct capable of predicting PA behaviour and moderating the intention-behaviour relationship in real-time and in real-world environments. While anticipated effort to prepare to engage in PA remains to be a validated construct, it remains a promising target for future research targeting PA behaviour change.

Acknowledgements

To my beloved friends, cherished lab mates, and supportive mentors I have made along this journey. Thank you all so very much for your companionship and guidance. You all are what makes the day-to-day life on campus so bright.

To my supervisor, Dr. Sheereen Harris. Thank you for taking a chance on me and taking me in as your first graduate student. I don't think you'll ever know the depth to which you have and are shaping me as a person. Thank you for your constant guidance, reassurance, and curated challenges. You keep me growing and excited as a student. I look forward to learning from you for as long as you'll let me.

To my committee members, Dr. Michelle Ogrodnik and Dr. Matthew Kwan. Your feedback, support, and mentorship have made me feel supported and have encouraged me to grow. It has been comforting knowing you two are watching over and rooting for me alongside Dr. Harris.

To my loving family, Mom, Dad, Ricky, and Rebecca. Thank you for the encouragement and the life lessons along the way. Thank you for always putting my well-being and my dreams above all else and for helping me along when the student life gets crazy.

Finally, to my partner Julia. Every single day I cherish this journey that we're able to take together. Through ups and downs, through Guelph and Waterloo, through MScs and PhDs, I'm glad we're in this together.

Table of Contents

Author's Declaration.....	ii
Abstract	iii
Acknowledgements.....	v
List of Figures	viii
List of Tables	ix
List of Abbreviations	x
Introduction.....	1
Physical activity among emerging adults.....	1
Common Barriers to PA.....	2
What is the intention-behaviour gap?.....	3
Perceived effort as a barrier	4
Theoretical Framework	7
Ecological Momentary Assessment	9
Methods.....	13
Participants and Recruitment	13
Study Design and Procedures.....	13
Compliance and Remuneration	14
Measures.....	16
Data analysis	17
Data Preparation.....	17
Intention-behaviour coupling.....	17
Time-varying predictors of intention and anticipated effort.....	18
Primary Analysis.....	18
Results.....	20
Descriptive Statistics	20
Missing Data	22
Time-Varying Effects on Intention and Anticipated Effort	23
Primary Analysis	27
Discussion.....	35
Intention-behaviour Coupling	35

Effects of Time on Anticipated Effort.....	39
Within-person and Between-person effects of Anticipated Effort on Intention-behaviour Coupling.....	40
Theoretical Implications.....	42
Practical Implications.....	45
Strengths and Limitations.....	47
Future Directions.....	50
Conclusion.....	51
References.....	52
Appendix A: Baseline Demographic Measures.....	67
Appendix B: International Physical Activity Questionnaire	68
Appendix C: Study Reference Sheet.....	70
Appendix D: Sensitivity Analysis Results.....	77

List of Figures

Figure 1 The Theory of Effort Minimization in Physical Activity. Reprinted from Cheval, B., & Boisgontier, M. P. (2021). The Theory of Effort Minimization in Physical Activity. Exercise and Sport Sciences Reviews, 49(3), 168–178. https://doi.org/10.1249/jes.00000	8
Figure 2 Average anticipated effort by day of week and time of day.....	24
Figure 3 Average intention by day and time. Note. Error bars represent ± 1 SD.....	25
Figure 4 A Johnson-Neyman plot indicating the region of significance for the moderating effect of within-person anticipated effort on within-person intention and behaviour	29
Figure 5 Predictive margin with 95% CIs for the within-person intention*within person anticipated effort interaction.	31
Figure 6 A Johnson-Neyman plot indicating the region of significance for the moderating effect of between-person anticipated effort on between-person intention and behaviour	32
Figure 7 Predictive margin with 95% CIs for the between-person intention*between-person anticipated effort to prepare to engage in physical activity interaction.	34

List of Tables

Table 1 Descriptive Statistics for Participant Characteristics	20
Table 2 Results from linear mixed-effects models predicting intention and anticipated effort to prepare to engage in physical activity using time-varying EMA data.....	26
Table 3 Results from multi-level mixed effects model predicting moderate-to-vigorous intensity physical activity 120-min epoch following the survey using EMA data.....	27
Table 4 Results from simple slopes analysis of within-person anticipated effort on the within-person intention and MVPA 120-min epoch relationship.	30
Table 5 Results from simple slopes analysis of between-person anticipated effort on the between-person intention and MVPA 120-min epoch relationship.....	33

List of Abbreviations

CAD	Canadian dollar
CI	Confidence interval
CORTO	Contextual, One-Item, Repeated, Timely, Open-ended
EMA	Ecological Momentary Assessment
JIT	Just-in-Time
JITAI	Just-in-Time Adaptive Intervention
MPAC	Multi-Process Action Control (Model)
MVPA	Moderate-to-vigorous physical activity
OR	Odds ratio
PA	Physical activity
PACES	Physical Activity Enjoyment Scale
PES	Physical Effort Scale
REB	Research Ethics Board
SD	Standard deviation
SE	Standard error
TEMPA	The Theory of Effort Minimization for Physical Activity
TPB	Theory of Planned Behaviour
WEIRD	Western, Education, Industrialized, Rich, Democratic

Introduction

Regular physical activity (PA) is well known to improve the quality of life and life expectancy by reducing risk of all-cause mortality and negative health outcomes (Löllgen et al., 2009; Marquez et al., 2020). Previous reviews have shown that engaging in PA can also lead to beneficial mental health outcomes such as improved self-esteem, reduced anxiety, reduced depressive symptoms, and improved mood (Raglin, 1990; Sani et al., 2016; Singh, 2023). In a study conducted by Fredriksson et al. (2018), the majority of the adult sample ($N=615$) indicated perceiving PA to be either beneficial (7.2%) or very beneficial (92.5%) to their health. This suggests that most adults are aware that engaging in PA provides health benefits. Despite the numerous physical and psychological benefits of PA and despite general awareness of health benefits of engaging in PA, most Canadian adults are insufficiently active with only 16% of Canadian adults reaching the recommended movement guidelines of engaging in at least 150 minutes of moderate to vigorous physical activity (MVPA) per week (Clarke et al., 2019). This poses a challenge to public health where most adults are missing out on the numerous benefits that PA offers (Booth et al., 2012).

Physical activity among emerging adults

Emerging adulthood refers to the time period between the late teens through to the mid-to-late twenties (Arnett, 2000). This period represents a major life transition as people begin to experience some characteristics of adulthood such as greater autonomy or independent living; however, they have not yet reached certain milestones typically associated with adulthood such as working a full-time job (Koenig et al., 2024). Regarding PA behaviours, the transition from adolescence to emerging adulthood is marked by a notable decline in PA for most people. While 24.4% of Canadian youth are meeting recommended guidelines of 60-minutes of MVPA per day

(Roberts et al., 2017), this decreases to the previously mentioned 16% of Canadian adults are reaching the recommended movement guidelines of engaging in at least 150 minutes of MVPA per week (Clarke et al., 2019). These findings are particularly concerning, given adults have a lower criteria than youth to be considered sufficiently active. While 61.1% of post-secondary students are meeting Canadian MVPA guidelines compared to 16% of Canadian adults overall (Weatherson et al., 2021), longitudinal studies following adolescents transitioning into emerging adulthood highlight that upwards of 64% of emerging adults become inactive or stay inactive during this time (Kwan et al., 2012; Aira et al., 2021). The dramatic decline in PA seen during and after this transition marks emerging adulthood as a time in which negative changes occur to PA behaviour. Understanding predictors of PA during this time may help stave off subsequent declines as emerging adults transition to adulthood supporting overall health and well-being throughout the lifespan.

Common Barriers to PA

PA declines as adolescents transition into emerging adulthood as emerging adulthood presents people with new sets of barriers to engage in PA, ultimately leading to lower rates of engagement (Anjali & Sabharwal, 2018). Common barriers to engaging in PA among emerging adults include personal barriers such as lack of energy, time, knowledge, and self-efficacy (Anjali & Sabharwal, 2018). Emerging adults most commonly report a lack of options for PA facilities or that PA facilities are too far and offer poor hours (Idowu et al., 2024). First-year university students within Canada also attribute declines in PA behaviour to over-crowded facilities, lack of peer influence, and disrupting school routines (Thomas et al., 2019). Arnett and colleagues (2014) theorized that this transition in life is characterized by instability, as living arrangements and relationships are oftentimes changing, as well as identity exploration where

people are taking on new goals and experiences that may compete with PA behaviour. The instability and competing goals characteristic of emerging adulthood may make it difficult for PA behaviour to be maintained.

What is the intention-behaviour gap?

Many psychological theories have been developed to provide an organized framework and explain what informs behaviour (Rhodes et al., 2019). One commonly applied theory is Ajzen's (1991) Theory of Planned Behaviour (TPB), which suggests that the most proximal determinant of behaviour is intention, which is informed by one's attitudes, subjective norms, and perceived behavioural control (Ajzen, 1991). The TPB also theorizes a direct link between one's perceived behavioural control on behaviour (Ajzen, 1991). While behaviour being predicted by intention has widely been accepted in theory, meta-analyses show that intention has small to medium sized effects on many health-related behaviours such as PA, substance use, and diet (Armitage & Conner, 2001; Hagger & Hamilton, 2023). The gap observed in people's intention to engage in PA and their actual PA behaviours has been coined the intention-behaviour gap, describing the common failure to translate PA intention to action (Faries, 2016). A meta-analysis conducted by Feil et al. (2023) aimed at quantifying the size of the intention-behaviour gap found that among 29,600 individuals across all age groups, 72% intended to engage in regular PA but only 52% of those individuals were successfully achieving PA guidelines. In other words, 48% of people were unsuccessful at translating their intentions into PA behaviour.

The intention-behaviour gap has been observed for decades, and ongoing research aims to understand and close this gap by identifying and targeting moderators to this association (Feil et al., 2023; Rhodes & de Bruijn, 2013). For example, Rhodes and colleagues (2021) conducted a

meta-analysis examining 78 potential moderators to explain the intention-behaviour gap, and 10 were found to have a significant interaction. Moderators such as intention stability, affective attitude, and anticipated regret were found to be significant such that higher levels of these moderators were associated with improved intention-behaviour coupling (Rhodes et al., 2021). The only moderator with a negative association found by Rhodes et al. (2021) was goal conflict. Goal conflict describes the challenges associated with simultaneous pursuit of more than one goal and higher levels of goal conflict is associated with worse intention-behaviour coupling (Bray & Harris, 2025). With only 10 of 78 moderators showing an association between intention and behaviour, much of the intention-behaviour gap remains unexplained. Thus, to understand why people are unable to translate intentions to behaviour, identifying additional moderators is warranted.

Perceived effort as a barrier

Common perceived barriers to engaging in PA such as lack of motivation, skill, time, and convenience have been identified (Farah et al., 2021; Godin et al., 2009; Herazo-Beltrán et al., 2017; Koh et al., 2022; Salmon et al., 2003). Emerging adults specifically note additional barriers associated with transportation and creating time and energy to be able to engage in PA (Idowu et al., 2024; Thomas et al., 2019). An underlying theme amongst many commonly cited barriers to PA is that each one requires overcoming either mental or physical effort to engage in subsequent PA. Effort is defined as the “the intensification of either mental or physical activity in the service of meeting some goal. Related to, but distinct from, demand or difficulty, which corresponds to a property of the stimulus not of the organism” (Inzlicht et al., 2018, p. 338). Lack of time to exercise may require physical and mental effort to eliminate competing tasks to create time and schedule PA around competing priorities such as work, school, or maintaining

personal relationships. In general, there is increased mental and physical effort associated with the processes required to engage in a bout of PA in the case that it is not convenient, such as if the facility is far or if PA requires certain equipment not readily available. In this instance, mental effort in the form of problem solving and physical effort in the form of actual preparation are required. Thus, research examining the role of effort in relation to PA may help understand why intentions do not always translate to PA behaviour.

In a cross-sectional study, Bourque et al. (2025) used a survey to assess the relationship between effortful self-control and self-reported weekly levels of MVPA among adults ($N = 603$, $M_{age} = 38.6$ years). Within the study, effortful self-control referred to the deliberate exertion of mental effort to overcome temptations to achieve a valued goal. For example, effortful self-control must be employed when someone has the goal to engage in PA by going on a walk later in the day but must overcome the temptation of the less effortful option to remain sedentary by going on their phone instead. The researchers found that effortful self-control had a negative association with self-reported MVPA. In other words, when participants self-reported experiencing greater deliberate effort required to engage in MVPA, participants engaged in less self-reported weekly MVPA.

A similar association was observed in an experimental study conducted by Harris and Bray (2021) that measured anticipated effort and subjective evaluations of PA, and their effect on PA decision-making. Harris & Bray (2021) recruited 84 emerging adults and randomized them to complete either a higher mentally fatiguing task or a lower mentally fatiguing task. Anticipated effort to engage in PA and motivation to engage in PA were measured before and after completing the mental fatigue manipulation. Participants were then asked whether they wanted to engage in an exercise task or non-exercise task for 20-minutes. Results showed higher

perceived anticipated effort for a bout of PA lowered motivation to engage in PA, which, in turn, impacted an individual's decision to engage in PA. In other words, greater anticipated effort increased the likelihood of participants selecting a sedentary task rather than an exercise task indirectly through changes in motivation.

A limitation within this area of research is the unclear operationalization of *perceived effort* in relation to PA. Specifically, effort associated with overcoming perceived barriers to PA may include barriers to engaging in the behaviour itself (i.e., injury, feeling tired, lack of skill), barriers to preparing to exercise (i.e., distance from facility), or both (i.e., lack of motivation, lack of time, weather; Godin et al., 2009; Herazo-Beltrán et al., 2017; Koh et al., 2022). As previous measures assessing perceived effort to engage in PA have been double-barreled in nature (e.g., “How difficult is it to get yourself to get ready and start physical activity”; Bourque et al., 2025), the unique effects of people’s evaluations of anticipated effort to get ready/prepare for PA and evaluations of anticipated effort to engage in PA remains unknown. It would be valuable to measure them independent of one another to determine if each impacts the likelihood of engaging in PA the same way.

Collectively, results from Bourque and colleagues (2025) and Harris and Bray (2021) indicate that effort-related processes are associated with self-reported weekly PA and acute decision-making within an experimental paradigm. Therefore, it is possible that perceived effort could help explain the intention-behaviour gap, such that greater perceived effort requirements are associated with engaging in less PA even in the presence of an intention to engage in PA, acting as a moderator of the intention-behaviour gap.

Theoretical Framework

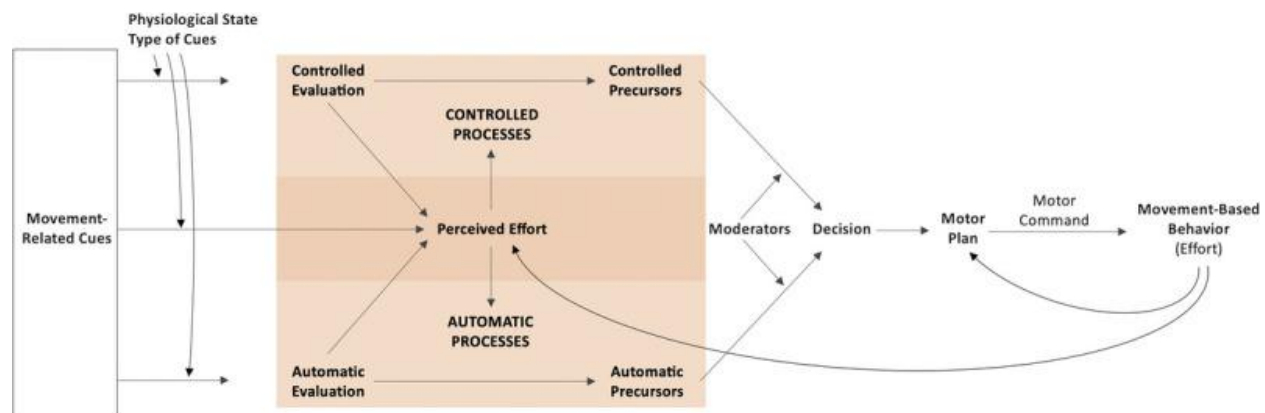
Traditional social-cognitive theories such as the TPB are limited as intention and reasoned action are poised as proximal predictors of behaviour in these models but the presence of the intention-behaviour gap suggests that behaviour is also informed by other variables. Specifically, critiques of social-cognitive theories highlight its over-reliance on the individual to enact change while simultaneously ignoring non-conscious factors that predict behaviour (Rhodes et al., 2019). Within recent years, new theories have been developed to explain PA behaviour in a more dynamic way than traditional social-cognitive theories and models. Dual process models outline influences from both slower, controlled (i.e., reflective, deliberate thinking) and faster, automatic (i.e., reflexive, non-conscious) cognitive processes on behaviours such as PA (Cheval & Boisgontier; Rhodes et al., 2019). For example, a decision to engage in PA can be informed by controlled influences such as long-term reasoned goals and intentions surrounding PA but can also be informed by automatic influences such as momentary emotional desires or aversions to engage in PA.

The Theory of Effort Minimization in Physical Activity (TEMPA) is a dual process model that explains behaviour as being governed by both automatic and controlled processes (Figure 1; Cheval & Boisgontier, 2021). According to the TEMPA, automatic processes inform PA behaviour decision making through learned associations of PA with positive or negative affective reactions. Thus, movement cues and physiological state cues automatically form an affective evaluation of engaging in PA. Controlled processes inform PA behaviour decision making through reasoned intentions to engage in PA which are also subject to movement cues. The TEMPA includes additional consideration that humans have evolved to evaluate PA effort costs and automatically favor more energy efficient behaviors. Cheval and Boisgontier (2021)

further suggest that perceived effort is an antecedent of the decision to engage in PA or not such that for an anticipated bout of PA, lower expected effort triggers automatic responses to prepare for the behaviour and higher expected effort will inhibit preparation and require more controlled processes to overcome the effort required. Effort is theorized to impact both controlled and automatic processes to impact PA decision making by impacting intentions and affective evaluations, respectively.

Figure 1

The Theory of Effort Minimization in Physical Activity. Reprinted from Cheval, B., & Boisgontier, M. P. (2021). The Theory of Effort Minimization in Physical Activity. Exercise and Sport Sciences Reviews, 49(3), 168–178. <https://doi.org/10.1249/jes.00000>



While perceived effort is primarily considered a behavioural cost associated with decisions to engage in PA, it can also serve as a tool to regulate PA behaviour (Cheval et al., 2025). Specifically, Cheval et al. (2025) proposed that perceived effort shapes behavioural regulation through effort-related processes before, during, and after PA engagement. Before PA engagement, anticipated perceived effort is evaluated as a cost and weighed against the benefits of PA. The balance between perceived costs and benefits of the behaviour affects choice such that people will choose to engage in a behaviour such as PA where the benefits outweigh the costs, including perceptions of effort as a behavioural cost. During PA, perceived effort is minimized through optimization processes where actions are completed at lower energy costs

when possible. Finally, perceived effort is used after PA engagement as a source of value to justify the cost of engaging in PA and is used to inform anticipated perceived effort for future bouts of PA. Thus, based on theorizing from the TEMPA, anticipated effort can be optimized by either increasing perceived benefits of PA, decreasing perceived costs of PA, or both (Cheval & Boisgontier, 2021).

Ecological Momentary Assessment

An important limitation of existing studies examining the role of perceived effort on PA is that they typically rely on survey-based or experimental methods. These methodologies lack external validity as they try to measure behaviour in a controlled research environment and oftentimes at a single moment in time. To address this limitation, ecological momentary assessment (EMA) is a methodology that allows for the measurement of people's dynamic psychological states in real time and in people's naturalistic environments (Shiffman et al., 2008; Dunton, 2017). EMA involves the resampling of participants' current experiences by sending brief surveys to their personal devices multiple times per day that can be completed while they are in their naturalistic environments. These data can also be paired with other measures such as MVPA by equipping the participant with an accelerometer or commercial activity monitor. Data from EMA surveys and MVPA data can then be paired to detect associations between factors in real-time.

For example, Bray and Harris (2025) conducted an EMA study that investigated the moderating effects of goal conflict on short-term PA intention-behaviour coupling. In this study, 100 emerging adults completed EMA surveys 4 times a day for 7 days while they wore a wrist-worn accelerometer to track minute level MVPA data. Participants reported their intention to engage in PA within the few hours following the survey as well as their experienced goal conflict

with engaging in PA. Researchers analyzed the 180-minute epoch following the survey and examined the moderating effects of goal conflict on the intention-behaviour relationship. Results showed a significant within-person effect of goal conflict where participants were less likely to engage in at least 10 minutes of MVPA in the 180-min epoch following the survey prompt when they experienced higher goal conflict than their typical average. EMA allows for more ecologically valid measurements, minimizes recall bias, and can measure more sensitive processes that impact behaviour. EMA could be used to examine the effects of anticipated effort to prepare to engage in PA in the intention-to-behaviour gap as they happen in real-time.

Aligning with Bourque and colleagues' (2025) recommendation of separating the effort to engage in PA from the effort to prepare to engage in PA, separate questions can be generated and asked within an EMA context. Measures can be adapted from Bourque et al. (2025) to separately measure the effort associated with effort to engage in PA and effort to prepare to engage in PA. However, due to the constant resampling of measures as well as the in-the-moment nature of EMA, the methodology is recommended only for measures that are expected to be dynamic (Rhodes & Kwan, 2025). Rhodes & Kwan (2025) created a utilization guide for EMA measurements which recommends measures expected to be stable should be measured less frequently while measures expected to be dynamic should be measured more frequently. For example, "affective judgements" towards PA, defined as the evaluation of perceived pleasure of a behaviour or behavioural experience, is not recommended for EMA as it is assumed to be more static in nature and take a long time to change. One's anticipated effort to *engage in PA* reflects how strenuous and difficult an individual thinks a PA session may be. This is consistent with many aspects of the construct of "perceived capability" which is defined "as the perceptions of ability, capacity, or competence to perform a behaviour interdependent of motivation" (Williams

& Rhodes, 2016). The construct of "perceived capability" is not recommended for EMA as the capability to engage in PA is not expected to change abruptly outside of some specific clinical populations (Rhodes & Kwan, 2025). However, the anticipated effort to *prepare to engage in PA* may be more dynamic in nature as it reflects an individual's in-the-moment context and the barriers that they face to in preparation of subsequent PA. This is consistent with the construct of "ongoing perceived opportunity" outlined by Rhodes & Kwan (2025) representing one's perceptions of accessibility in social and environmental contexts and would be appropriate to measure using EMA as it is considered an ongoing reflective process.

Statement of the problem

The decline of PA among adolescence as they transition into adulthood remains a public health concern as people miss out on the health benefits of engaging in PA. While intentions can inform PA behaviour, the intention-behaviour gap is widely recognized and highlights the limitations of translating PA intentions to PA behaviour (Rhodes & de Bruijn, 2013). Numerous studies have investigated moderators to the intention-behaviour gap (Feil et al., 2023; Rhodes & de Bruijn, 2013; Rhodes et al., 2021) but none have operationalized and investigated the role of effort to prepare to engage in PA on PA behaviour or as a moderator of the intention-behaviour gap. Effort related processes remain theoretically relevant in the space of PA decision making research as an integrated cost to PA behaviour (Cheval & Boisgontier, 2021). Using EMA, the moderating role of anticipated effort to prepare to engage in PA on the intention-behaviour gap can be investigated by sampling and measuring people in real-time and naturalistic environments.

Study Purpose and Hypotheses

The purpose of this study is to leverage EMA to determine real-time intention-behaviour coupling within an emerging adulthood population for comparison with the existing literature. Furthermore, the study aimed to determine the momentary effects of anticipated effort to prepare to engage in PA on device-assessed PA. Finally, the study aimed to evaluate the effects of anticipated effort to prepare to engage in PA as a moderator of the intention-PA behaviour gap in real-time. It was hypothesized that a positive association between intentions and behaviour would be observed such that higher PA intentions would be associated with greater minutes of MVPA. Additionally, it was hypothesized that a negative association between anticipated effort and behaviour would be observed such that higher anticipated effort to prepare to engage in PA would be associated with fewer minutes of MVPA. Finally, it was hypothesized that anticipated effort to prepare to engage in PA would moderate the association between intention and PA behaviour such that the positive association between PA intention and MVPA would be weaker under conditions of higher anticipated effort and stronger under conditions of lower anticipated effort.

Methods

Participants and Recruitment

Participants who are between the ages of 18 and 29, have access to a cellular device with data, willing to wear the PA monitor, and willing to download the Pathverse and Fitbit apps on their phones were recruited to participate. As the data collection for this study was nested within a larger project, participants were also required to be available for a 6-month follow-up data collection period. The “power simmixd” program in STATA estimated a sample size of 103 participants to achieve 80% power based on an α value of .05 for a small interaction effect size and assuming a 70% compliance across both T1 and T2 based on previous EMA research (Harris & Bray, 2023). Assuming an 80% attrition between the initial and follow-up data collection periods, 124 participants were recruited. Participants were recruited through posters around the University of Waterloo and Kitchener-Waterloo area, social media posts, and word of mouth. Researchers replied to emails from interested participants to provide the letter of information and confirm study eligibility. Once deemed eligible for the study, participants were prompted to schedule a 60 minute in-person orientation in the research lab space. This study was reviewed and received ethics clearance through a University of Waterloo Research Ethics Board (REB #47778).

Study Design and Procedures

This study leveraged smartphone-delivered EMAs to assess self-reported PA intentions and anticipated effort in real-time (Shiffman et al., 2008). Orientation sessions were available for up to three participants at once where a researcher reviewed the letter of information and answered any questions from participants. Next, participants completed an online baseline survey via Qualtrics which included informed consent followed by a demographics questionnaire. Once the baseline survey was completed, participants were given a Fitbit Versa 4

activity monitor, charger, study information packet including instructions on, and an activity log. Researchers provided details regarding the study procedure, device use, device care, and common troubleshooting before assisting participants in downloading the Pathverse app (Liu et al., 2022) and Fitbit app on their personal smartphones. Participants were instructed to wear the activity monitor on their non-dominant wrist for as much time as they could over the next seven days apart from showering and charging. Each participant was given unique username and login to access a secure, personalized Pathverse account and were shown how to sync their Fitbit data to Pathverse. To ensure the account was set up correctly, a test-prompt was administered to each participant, which insured that notifications could be received. Participants then completed a shortened version of the EMA survey to ensure they understood the questions and how to input their answers with various question types.

EMA surveys were delivered four times a day at random times for each participant based on their self-selected preferred sleep/wake schedule (Schedule 1: (1) 8:00–9:30am, (2) 11:30am–1:00pm, (3) 3:00–4:30pm, and (4) 6:30–8:00pm; Schedule 2: (1) 9:00–10:30am, (2) 12:30–2:00pm, (3) 4:00–5:30pm, and (4) 7:30–9:00pm; Schedule 3: (1) 10:00–11:30am, (2) 1:30–3:00pm, (3) 5:00–6:30pm, and (4) 8:30–10:00pm). Participants were notified to each survey with a notification from the Pathverse app. Each EMA survey took an estimated 2–3 minutes to complete. After the 7-day data collection, participants were sent an email to book a debrief meeting to return the study equipment and receive remuneration.

Compliance and Remuneration

While EMA may improve the external validity of results, researchers are not able to control whether or not participants complete surveys. Previous research shows that compliance typically declines over the course of studies as short as seven days long (Delobelle et al., 2025;

Jones et al., 2018; Tonkin et al., 2023). Several measures were taken to encourage high compliance amongst participants.

Three different schedule options were offered based on self-selected typical sleep/wake schedule which was done to ensure participants were not missing prompts due to surveys being available outside of their typical waking hours. In addition, we aimed to minimize participant burden through several avenues. First, EMA surveys were restricted to 4 times per day and designed to take no longer than 2-3 minutes to complete based on pilot testing. Second, the survey within the Pathverse app were available for 30 minutes to allow participants to complete the prompt even if they were occupied at the moment of receiving the initial prompt. Third, compliance checks were completed daily by members of the research team with progress update emails being sent at the end of day 3 or 4 of the study protocol to let participants know how many prompts they have completed to encourage continued engagement throughout the study period. Finally, participants were sent reminder to sync their device with the Pathverse app on day 3 or 4 of the study and after the final EMA survey. Researchers completed a final device sync check in person at the study debrief session to ensure all available data were synced. To ensure the Fitbit could continuously collect data, reminders were sent on day 3 or 4 of the study to charge the device overnight to ensure that the device did not lose power throughout the study.

Remuneration followed an incentive structure to further encourage individuals to complete as many prompts as possible where participants earned \$2 CAD per completed prompt. To encourage participants to complete as many EMA surveys as they can to increase compliance, participants were offered an additional \$15 CAD bonus for completing $\geq 75\%$ of the surveys. Following this structure, participants could earn up to \$71 CAD for participating in this study. Participants also had access to a log of completed EMA surveys on their Pathverse app in

the case that they wanted to check how many surveys they had completed. During the study debrief session, participants returned the Fitbit device, received compensation via e-transfer, and signed a remuneration confirmation form.

Measures

Demographic factors. Participants were asked to respond to a series of demographic questions including age, gender, race, and year of study/education level at baseline.

Intention. Intention was measured with EMA using a single item presented on a 7-point scale. Participants were presented with the phrase “I intend to be physically active for 10+ minutes sometime within the next hour”. Response options ranged from 1 (Strongly disagree) to 7 (Strongly agree; Maher et al., 2017; Bray & Harris, 2025).

Anticipated effort to prepare to engage in PA. Anticipated effort was measured with EMA using a horizontal sliding scale similar to a Visual Analogue Scale (Wewers & Lowe, 1990). Adapted from Bourque et al. (2025), participants were asked “Within the next hour, how much effort do you feel it will take to get ready to engage in physical activity?” The response continuum included the anchors of 0 “no effort at all” on the left to 100 “maximal effort” on the right.

Device-assessed moderate-to-vigorous intensity physical activity. MVPA minutes in the 120-min epoch following the survey was assessed using the wrist-worn Fitbit Versa 4. Fairly active and very active minutes were calculated through device assessed metabolic equivalents (METs) and were summed to obtain MVPA. Active minutes for non-step based PA was calculated through device measured heart rate. Intensity cut-points and MET thresholds calculated by Fitbit are not publicly disclosed.

Data analysis

Data Preparation

Age and self-reported physical activity levels measured at baseline were summarized as mean and standard deviations. Gender and race were summarized as frequencies. EMA survey responses for intention and anticipated effort to prepare to engage in physical activity were summarized as means and standard deviations. MVPA data within the 120-min epoch following each EMA survey prompt were summarized as means and standard deviations. Wear time statistics were calculated using minute-level heart rate data recorded by the Fitbit Versa 4. Valid wear time was determined based on heart rate being detected within each minute. Wear time was summarized as frequency counts for non-wear (0 minutes of wear), 1-59 minutes of wear, 60-119 minutes of wear, and full wear (120 minutes).

Analyses of missing data were conducted using a logistic regression to determine if age, gender, race, time of day (morning, late morning/early afternoon, mid/late afternoon, and evening), day of week (Monday through Sunday), day of study (day 1 through 7), self-reported weekly physical activity levels, or MVPA 60 minutes surrounding (i.e., 30 minutes prior and 30 minutes after) the prompt would impact the likelihood of answering the prompt. Missing responses were coded as 0 and non-missing responses were coded as 1. All analyses were conducted using R version 4.5.2.

Intention-behaviour coupling.

To determine intention-behaviour coupling, the 7-point scale for intention was converted to a binary variable as done previously (Harris & Bray, 2025; Maher et al., 2017). Intention responses from 1 to 4 were converted to “no intention” (coded as 0) while responses above the midpoint of the scale from 5 to 7 were converted to “intention” (coded as 1). Similarly, MVPA minutes within the 120-min epoch were converted to binary variables where observations with

<10 min were converted to “not active” (coded as 0) while observations with ≥ 10 mins of MVPA were converted to “active” (coded as 1). The conversion of intention and behaviour to binary variables was used to calculate frequency counts of intention-behaviour coupling.

Time-varying predictors of intention and anticipated effort.

Within-day and within-week changes in intention and anticipated effort were examined by computing means and standard deviations for each variable for each timepoint and day of week. Patterns for both variables were visually inspected prior to conducting a formal test to determine the effects of time-varying predictors on intention and anticipated effort.

Separate two-level (observations nested within people) linear mixed-effects models were computed to determine the effects of time of day, day of week, and day of study on intentions and anticipated effort. Time of day and day of week were treated as categorical time variables as changes throughout the day and across the week were not expected to be linear. For time of day, Time 1 (morning) served as the reference category that Time 2 (afternoon), Time 3 (early evening), and Time 4 (late evening) were compared against. For day of week, all days of the week are compared against Monday. Day of study was treated as a continuous time variable to examine whether anticipated effort and intentions would change the longer participants were enrolled in the study.

Primary Analysis.

A two-level mixed effects model was computed to account for multiple observations (Level 1) nested within each participant (Level 2). The *lmer* function in R was used to assess the relationship between (1) intention and MVPA, (2) anticipated effort to prepare to engage in physical activity and MVPA, and (3) the moderating effect of anticipated effort to prepare to

engage in physical activity on the intention-behaviour relationship. Participant age, gender identity, and self-reported weekly levels of MVPA were included as covariates in the model.

Between-person effects (i.e., how one person's average score differed from the averages of other participants) and within-person effects (i.e., how one person's momentary score differed from the rest of their own scores) were disaggregated prior to being included in the model (Curran & Bauer, 2011). The between-person effect for each variable was calculated by computing the mean of the prompt-specific scores for each variable for each person (person-specific mean) and the within-person effect was calculated by subtracting the person-specific mean from each person's prompt-specific score. Both between-person and within-person effects were included as predictors into the mixed effect model. Observations were only included in the analyses if participants responded to the EMA prompt and had a non-zero wear time recorded for the 120-min epoch following the EMA prompt. A sensitivity analysis was conducted for the primary analysis to see if results differed when including observations with full wear time (i.e., 120-min) compared with observations with non-zero wear time (i.e., > 0-min). To maximize available data, results from analyses including non-zero wear time are presented. Differences in interpretation from the sensitivity analysis are noted where relevant. The alpha criterion for all analyses was $p < .05$.

Results

Descriptive Statistics

A complete description of participant characteristics can be found in Table 1. Briefly, the mean age of the participants was 22.5 ($SD = 3.5$) years and most (85.5%) of the participants were enrolled in a post-secondary degree at the time of the study. Fifty-seven percent of participants identified as female ($n = 71$) and 40.3% identified as white ($n=50$). Participants self-reported engaging in a high level of weekly physical activity self-reporting 363.67 ($SD = 326.11$) minutes of MVPA per week.

Table 1
Descriptive Statistics for Participant Characteristics

Baseline Characteristics	<i>M (SD)</i>	<i>n</i>	%
Age	22.47 (3.18)		
Self-Report Weekly Physical Activity	363.67 (326.10)		
Gender			
Male		50	40.3
Female		71	57.3
Non-Binary		3	2.4
Race			
Black		8	6.5
East Asian		28	22.6
Latino		5	4.0
Middle Eastern		4	3.2
South Asian		9	7.3
Southeast Asian		8	6.5

White	50	40.3
Mixed Race	8	6.5
Other	3	2.4
Prefer not to say	1	0.8
Education - Enrolled		
Undergraduate – Year 1	22	20.8
Undergraduate – Year 2	13	12.3
Undergraduate – Year 3	8	7.5
Undergraduate – Year 4+	19	17.9
Graduate – Master’s program	35	33.0
Graduate – Doctoral/Professional program	9	8.5
Education - Completed		
Secondary school diploma (or equivalent)	3	16.7
Certificate of apprenticeship/trades or other qualification	1	5.6
College diploma, CEGEP, or other non-university institution	3	16.7
University certificate, diploma, or degree (Bachelors, Masters, PhD)	11	61.1

Note. Percentages may not sum to 100 due to rounding. *M*=Mean, *SD* = Standard deviation.

EMA survey compliance rate was high with participants responding to 3,004 (86.5%) of surveys being sent. Across all observations, participants on average reported low-moderate intention ($M = 2.45$, $SD = 1.90$), based on a possible range of 1-7 and moderate anticipated effort

to prepare to engage in physical activity ($M = 56.93$, $SD = 30.14$), based on a possible range from 0-100. Participants spent on average 7.06 ($SD = 15.81$) minutes engaging in MVPA during the 120-min epoch following each EMA survey. Participants achieved 120 minutes of wear time during 2,681 (77.2%) of observations, 60-119 minutes of wear time during 496 (14.3%) of observations, and 1-59 minutes of wear time during 177 (5.1%) of observations. Participants reported 0 minutes of wear time for 118 (3.4%) of observations. EMA surveys were submitted for 84 of those 118 observations without corresponding MVPA data due to activity monitor non-wear.

Missing Data

A total of 3,472 EMA prompts were scheduled for delivery across the study. Four hundred and sixty-eight (13.5%) surveys were not answered. Participants self-reported that 38 (8.1%) of missed surveys were due to technical errors/malfunctions with the Pathverse app. The logistic regression revealed that the likelihood of missing surveys was not dependent on age, gender, race, day of week, day of study, self-reported weekly physical activity levels, or MVPA 60 minutes surrounding the prompt ($ps > .05$). Prompts sent at the second ($OR=1.37$, 95% CI [1.04, 1.90], $p=0.025$), third ($OR=1.32$, 95% CI [1.01, 1.73], $p=0.046$), and fourth ($OR=1.59$, 95% CI [1.20, 2.11], $p=.001$), timepoint were more likely to be answered than the first prompt of the day. Seventeen percent of surveys sent during the first timepoint of the day were missed compared to 12.8% at timepoint 2, 13.2% at timepoint 3, and 11.4% at timepoint 4. There were no missing intention or anticipated effort scores across the answered EMA surveys as both questions were mandatory to complete.

Intention-Behaviour Coupling

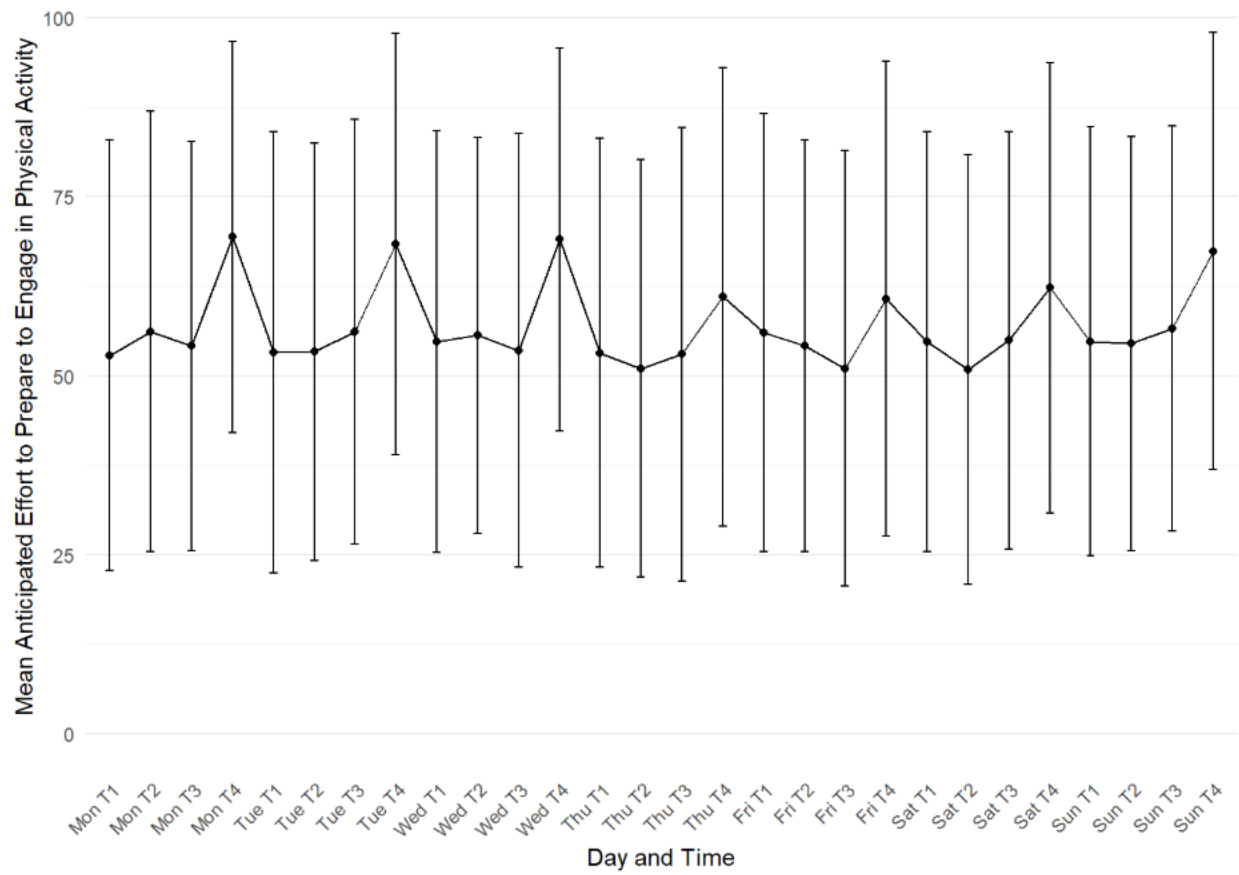
When converting intention and MVPA within the 120-min epoch following each EMA survey from continuous variables to discrete variables, a total of 552 observations were removed for missing the EMA survey ($n = 434$), activity monitor non-wear ($n = 84$), or both ($n = 34$). Participants' responses were coded as “intention” in 497 (17.0%) observations and as “no intention” in 2,423 (83.0%) observations. MVPA within the 120-min epoch following each survey was coded as “active” in 722 (24.7%) observations and coded as “inactive” in 2,198 (75.3%) observations. Overall, during observations where participants had an intention to engage in physical activity, they were active during 58.5% ($n = 291$) of observations but were unsuccessful in translating those intentions to behaviour during 41.5% ($n = 206$) of observations. When participants did not have an intention to engage in physical activity, they were active during 17.8% ($n = 431$) of observations and inactive during 82.2% ($n = 1,992$) of observations.

Time-Varying Effects on Intention and Anticipated Effort

To visualize within-day and within-week changes in intention and anticipated effort, mean values were calculated separately for each variable based on time of day and day of week. Results are visualized in Figure 2 and 3, respectively.

Figure 2

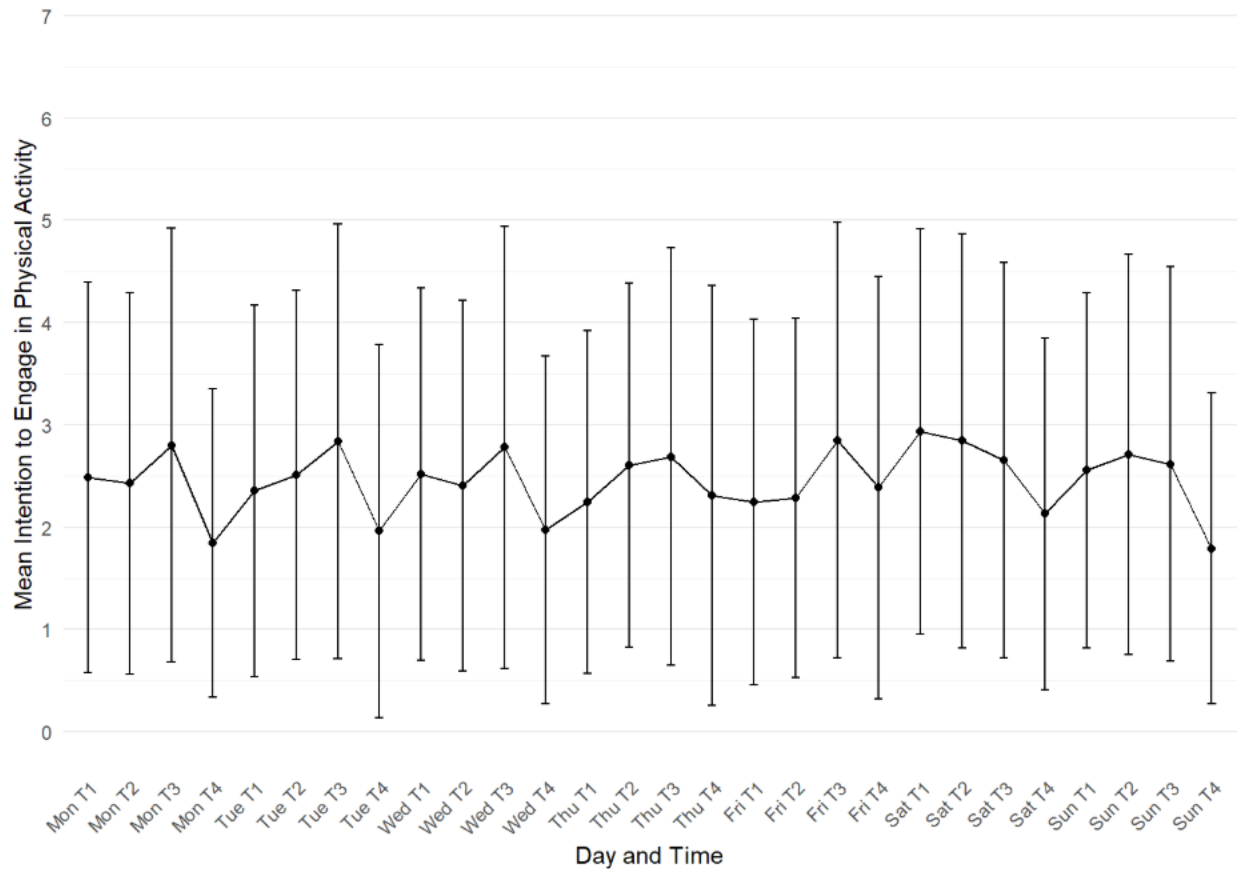
Average anticipated effort by day of week and time of day.



Note. Error bars represent ± 1 SD

Figure 3

Average intention by day and time. Note. Error bars represent ± 1 SD



Results from the linear mixed-effects models using time-varying EMA factors to predict intention and anticipated effort to prepare to engage in physical activity are presented in Table 2. Results show no effect of the day of the week on intention or anticipated effort. A significant effect of time within study was observed for both intention ($b = -0.05$, $SE = 0.02$, $p = .01$) and anticipated effort ($b = 1.15$, $SE = 0.25$, $p < .01$) suggesting that across the duration of the study, intention decreased and anticipated effort increased. Time of day showed significant effects on intention with participants reporting higher intention at Timepoint 3 (early evening; $b = 0.25$, $SE = 0.09$, $p = .007$) and lower intention at Timepoint 4 (late evening; $b = -0.433$, $SE = 0.092$,

$p < .001$) compared to Timepoint 1 (morning). Time of day also showed significant effects on anticipated effort as participants reported higher scores at Timepoint 4 (late evening; $b=11.29$, $SE = 1.312$, $p < .001$) compared to Timepoint 1.

Table 2

Results from linear mixed-effects models predicting intention and anticipated effort to prepare to engage in physical activity using time-varying EMA data.

	Intention			Anticipated Effort		
	Estimate	SE	p	Estimate	SE	p
Intercept	2.659	0.145	<.001	49.47	2.359	<.001
Time 2	0.040	0.092	0.663	-0.341	1.317	0.796
Time 3	0.247	0.092	0.007	0.099	1.319	0.940
Time 4	-0.433	0.092	<.001	11.29	1.312	<.001
Day 2	0.019	0.122	0.874	-0.105	1.735	0.952
Day 3	0.002	0.121	0.986	0.354	1.727	0.838
Day 4	0.026	0.122	0.833	-2.295	1.736	0.186
Day 5	-0.002	0.124	0.870	-0.958	1.766	0.588
Day 6	0.130	0.126	0.302	-0.006	1.797	0.997
Day 7	-0.016	0.124	0.895	0.966	1.763	0.584
Day of study	-0.045	0.017	0.009	1.153	0.246	<.001

Primary Analysis

Model estimates, standard error, and p -values for the primary analysis are presented in Table 3. The multi-level mixed effects model included 2,920 observations. Results revealed significant within person effects of intentions ($b = 3.48$, $SE = 0.20$, $p < .01$) and anticipated effort ($b = -0.04$, $SE = 0.01$, $p < .01$) suggesting participants engaged in more MVPA in the 120-minute period following the survey when they experienced higher intention than their own mean score or lower anticipated effort than their own mean score. Between-person effects were significant for anticipated effort ($b = -0.20$, $SE = 0.08$, $p = .02$) but not intention ($b = -2.89$, $SE = 1.83$, $p = .12$), suggesting participants that on average experienced higher levels of anticipated effort compared to their peers engaged in less MVPA in the 120-min period following the EMA prompt but no differences in MVPA were observed for participants who on average reported greater intention. While there was no effect of age or self-reported weekly MVPA on MVPA ($ps < .05$) there was a significant effect of gender where participants who identified as men were more active on average compared to participants who identified as women ($b = -3.58$, $SE = 0.84$, $p < .001$).

Table 3

Results from multi-level mixed effects model predicting moderate-to-vigorous intensity physical activity in the 120-min epoch following the survey using EMA data

	Estimate	SE	p
Intercept	18.630	5.464	0.001
Within-person intentions	3.478	0.185	<.001
Within-person anticipated effort	-0.036	0.012	0.002
Within-person intentions*anticipated effort	-0.041	0.005	<.001

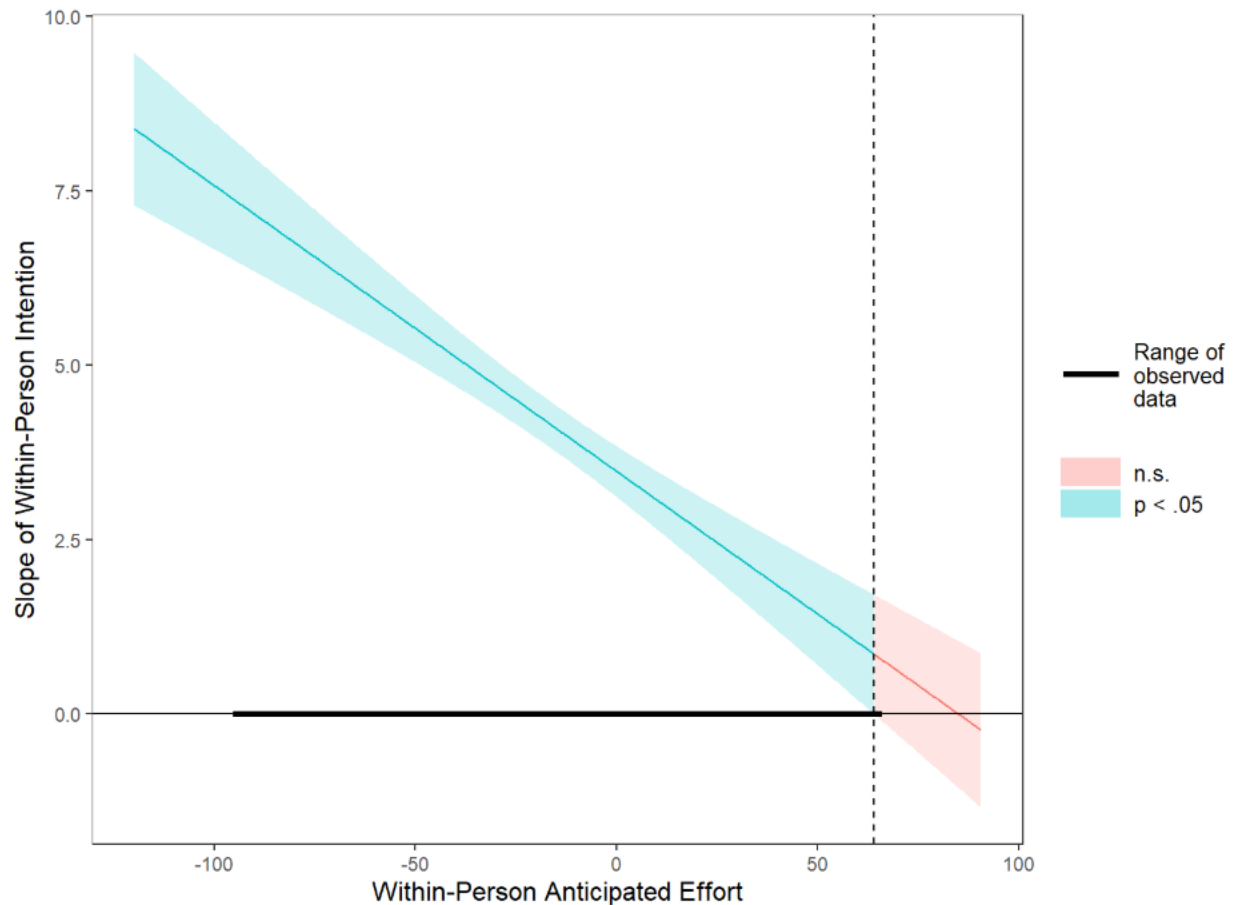
Between-person intentions	-2.893	1.827	0.116
Between-person anticipated effort	-0.203	0.078	0.018
Between-person intentions*anticipated effort	0.071	0.033	0.032
Age	-0.060	0.132	0.651
Gender Identity	-3.624	0.849	<.001
Self-report Weekly MVPA	0.001	0.001	0.458

Note. Gender Identity, Man = 0, Woman = 1, Non-Binary = 2, Another Identity = 3.

The model revealed a significant within-person intention X anticipated effort interaction ($b = -0.04$, $SE = 0.004$, $p < .001$). To decompose the significant interaction, the Johnson-Neyman technique (Bauer & Curran, 2005) was conducted to determine the range of observations in which within-person effects of anticipated effort were significant in moderating the association between within-person intention and MVPA in the 120-min epoch following the survey. The Johnson-Neyman plot for the within-person interaction is shown in Figure 4. The moderating effect of within-person anticipated effort was significant for all scores below 64.10 meaning the effect was significant across nearly the full observed range of the data ($N = 3,004$ observations, $M = 0.00$, $SD = 23.41$, $min = -94.59$, $max = 65.26$). Only within-person anticipated effort measures between 64.10 and 65.26 fall outside the region of significance ($n = 1$ observation).

Figure 4

A Johnson-Neyman plot indicating the region of significance for the moderating effect of within-person anticipated effort on within-person intention and behaviour



To further decompose the interaction, a simple slopes analysis was computed and summarized in Table 4 (Bauer & Curran, 2005). The simple slopes analysis decomposes the interaction between within-person intention and within-person anticipated effort by estimating the effects of within-person intention on MVPA during the 120-min epoch following the survey at different levels of anticipated effort. Specifically, the slope of within-person intention predicting MVPA is estimated at mean within-person anticipated effort and ± 1 and ± 2 SD of

within-person anticipated effort. Plotting the simple slopes analysis allows for the visual comparison of how the moderating effects of within-person anticipated effort on the intention-behaviour relationship changes at different levels of anticipated effort. A significant p -value indicates that the within-person intention and MVPA relationship is moderated at the listed level of within-person anticipated effort.

Table 4

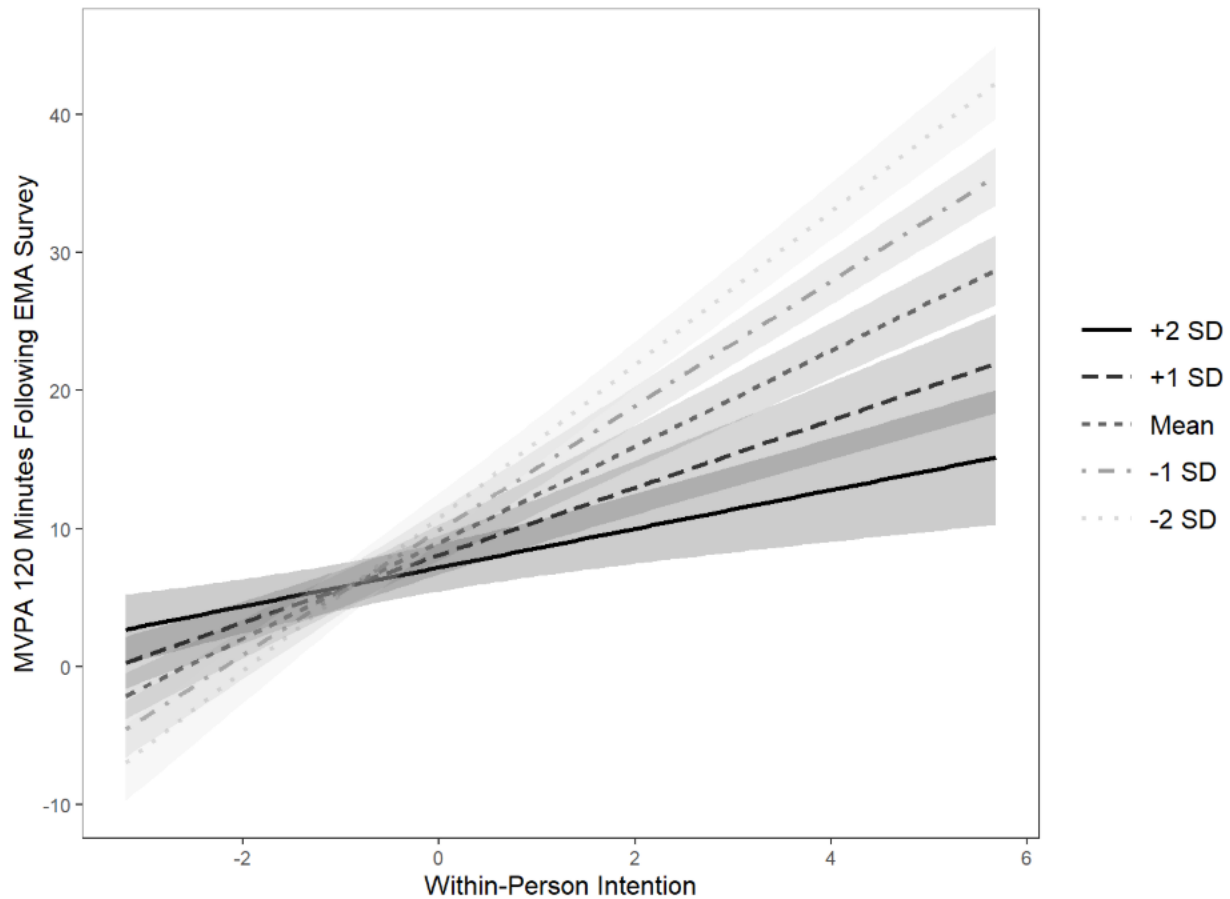
Results from simple slopes analysis of within-person anticipated effort on the within-person intention and MVPA 120-min epoch relationship.

Within-Person Anticipated Effort	Estimate	<i>SE</i>	<i>t</i>	<i>p</i>
-2 SD	5.51	0.24	22.63	<.001
-1 SD	4.44	0.17	25.62	<.001
Mean	3.37	0.18	18.79	<.001
+1 SD	2.30	0.26	8.98	<.001
+2 SD	1.23	0.36	2.41	<.001

Results from the simple slopes analysis is visualized in Figure 5. Results show that as participants report higher levels of anticipated effort relative to their own average, the strength of the association between within-person intention and MVPA (i.e., intention-behaviour relationship) weakens as the estimate decreases. When participants report lower levels of anticipated effort relative to their own average, the strength of the association increases.

Figure 5

*Predictive margin with 95% CIs for the within-person intention*within person anticipated effort interaction.*



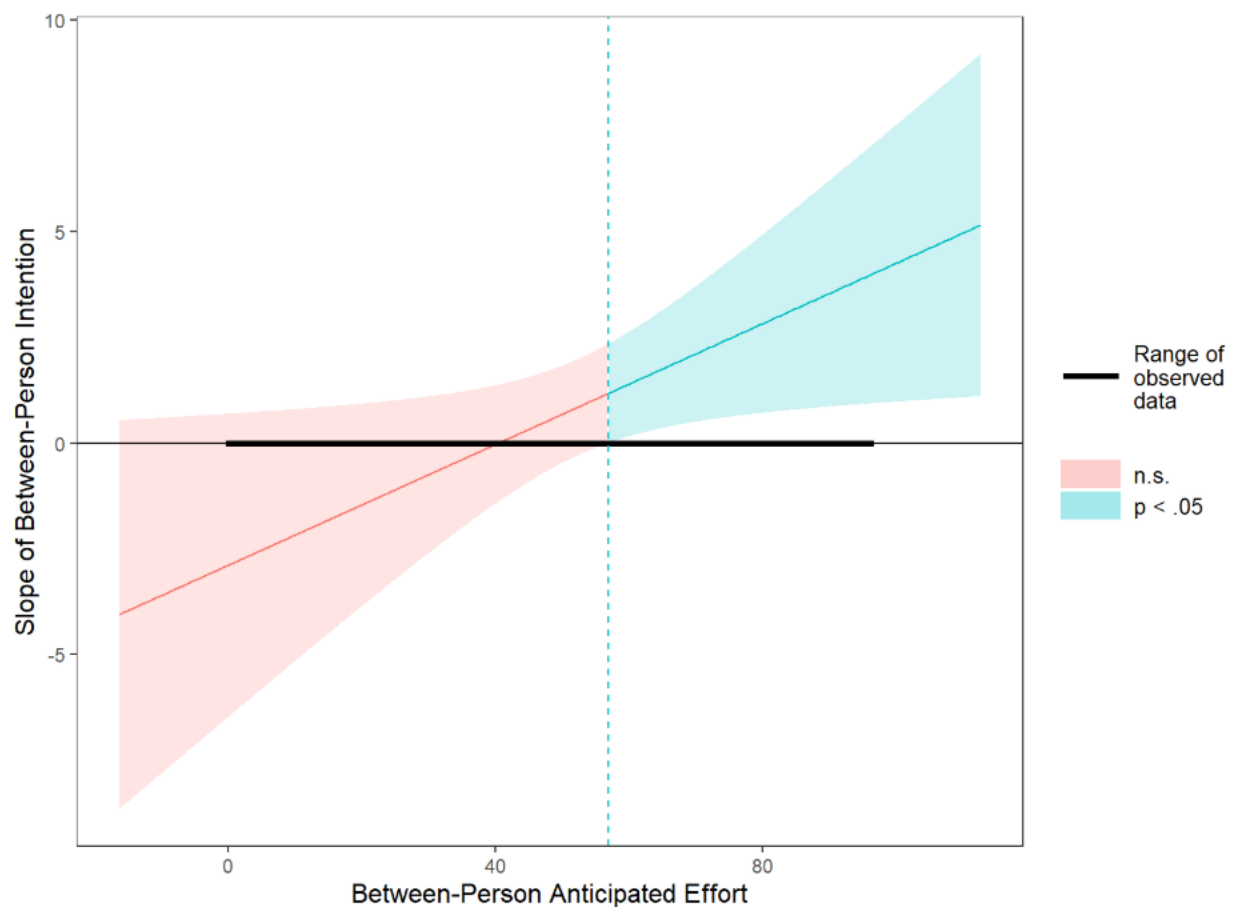
Note. Full range of within-person intention observations included within plot ($N = 3,004$ observations, $M = 0.00$, $SD = 1.75$, $min = -3.20$, $max = 5.68$).

The model also revealed a significant between-person intention X anticipated effort interaction ($b = 0.071$, $SE = 0.03$, $p = .03$). The Johnson-Neyman technique was conducted to determine the range of observations in which the between-person effects of anticipated effort were significant in moderating the relationship between intentions and MVPA in the 120-min epoch following the survey. Results from the between-person Johnson-Neyman plot is shown in Figure 6. The moderating effect of between-person anticipated effort was significant for all

between-person anticipated effort measures above 56.89, meaning the effect was significant across values near and above the mean across the full observed range of data ($n = 124$ participants, $M = 56.54$, $SD = 16.49$, $min = 0.00$, $max = 96.19$). In other words, the moderation effect of between-person anticipated effort on the intention-behaviour relationship is only present in participants who report an average anticipated effort between 56.89 and 96.19 ($n = 66$ participants).

Figure 6

A Johnson-Neyman plot indicating the region of significance for the moderating effect of between-person anticipated effort on between-person intention and behaviour



As previously done with within-person effects, a simple slopes analysis was computed and summarized in Table 5 and Figure 7. Consistent with the between-person Johnson-Neyman plot, the between-person interaction was significant at anticipated effort values above the mean with both the +1 *SD* and +2 *SD* simple slopes reaching statistical significance. The interaction shows that participants with higher mean levels of anticipated effort than others have a positive and significant relationship between intention (between-person) and MVPA in the 120-min epoch following the survey. This relationship between between-person intention and MVPA in the 120-min epoch following the survey is not observed for those at or below mean levels of between-person anticipated effort, suggesting that for participants who on average experience lower anticipated effort than others, intention does not predict MVPA in the 120-min epoch following each survey. However, results from the sensitivity analysis revealed that the between-person intention X anticipated effort interaction did not remain statistically significant when excluding all observations without complete wear time ($b = 0.066$, $SE = 0.036$, $p = 0.066$); these results are interpreted with caution.

Table 5

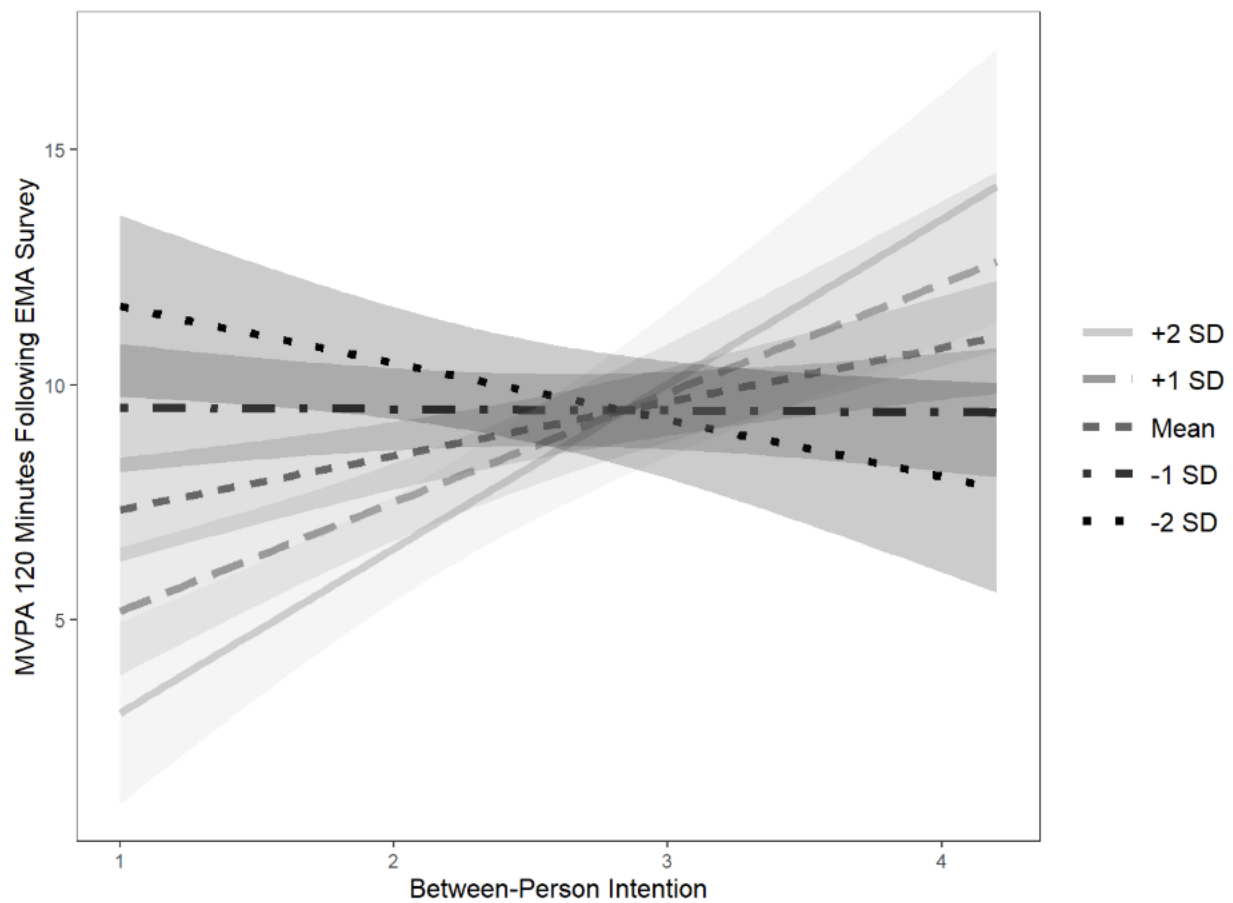
Results from simple slopes analysis of between-person anticipated effort on the between-person intention and MVPA 120-min epoch relationship.

Between-Person Anticipated Effort	Estimate	<i>SE</i>	<i>t</i>	<i>p</i>
-2 SD	-1.21	1.12	-1.08	.280
-1 SD	-0.03	0.71	-0.04	.970
Mean	1.15	0.60	1.93	.056

+1 SD	2.32	0.89	2.61	.010
+2 SD	3.50	1.35	2.59	.011

Figure 7

*Predictive margin with 95% CIs for the between-person intention*between-person anticipated effort to prepare to engage in physical activity interaction.*



Note. Full range of between-subject intention observations included within plot ($N = 3,472$ observations, $M = 2.46$, $SD = 0.75$, $min = 1$, $max = 4.2$).

Discussion

The present study aimed to examine (1) the effects of intention on MVPA within the 120-min epoch following survey prompts, (2) the effects of anticipated effort on MVPA 120-min epoch following survey prompts, and (3) the moderating effects of anticipated effort on the intention-to-behaviour relationship at both the between- and within-person levels. Results showed significant positive associations between intention and acute MVPA at the within-person level as well as negative associations between anticipated effort and MVPA at the within-person and between-person levels. Furthermore, the within-person interaction between intention and anticipated effort on MVPA was significant such that the association between within-person intention and MVPA in the 120-minute epoch following survey prompts was stronger under lower levels of anticipated effort consistent with study hypotheses. Additionally, the between-person interaction between intention and anticipated effort was significant indicating the association between intention and MVPA in the 120-minute epoch following survey prompts was stronger for people who reported higher mean levels of anticipated effort which is against study hypotheses. Age and self-reported weekly MVPA levels were not significant predictors of acute MVPA, but gender identity was a significant covariate such that men were more active than women during the study. Results also revealed an intention-to-behaviour gap of 41.5% within our study population.

Intention-behaviour Coupling

Consistent with prior research (Bray & Harris, 2025; Maher et al., 2017), the current study dichotomized intention and MVPA into binary variables to allow for the computation of intention-behaviour coupling for each observation. Labeling participants during each observation as having “intention” or “no intention” and as “active” or “not active” following the survey

allows for successful and unsuccessful attempts to be active to be quantified. In the present study, participants were classified as having an intention to engage in physical activity following the survey prompt in 7% of prompts. Based on identical classifications, Bray and Harris (2025) found that their population reported having an intention to be physically active in 34% of observations while Maher et al. (2017) labelled participants as having intention during 41% of all observations. The lower percentage of observations where participants reported an intention to engage in MVPA in the present study suggests that the current study population may have been less motivated to engage in physical activity when compared to other populations of a similar age. This may be in part due to differences in the study design, study population characteristics, and context. Notably, both Bray and Harris (2025) and Maher et al. (2017) worded their intention measure with “*I intend to be physically active for 10+ min sometime within the next few hours*” which represents a different period of measuring than the present study that asked “*I intend to be physically active for 10+ minutes within the next hour*”. The narrower time window for intentions to engage in PA in the present study may explain this discrepancy. Both Bray and Harris (2025) and Maher et al. (2017) observed a 180-min epoch following the survey compared to the present study which used a 120-min epoch. The longer epoch provides more opportunity for participants to be labelled as “active” when compared to the present study as behaviour was operationalized as engaging in 10 or more minutes of MVPA in the epoch of interest among all studies.

Differences between the ages of each study population may help explain differences in intentions. The present study targeted emerging adults between the ages of 18 and 29, with a mean age of 22.5 ($SD = 3.2$). The mean age of the sample recruited by Bray and Harris (2025) was 20.60 ($SD = 2.61$). Maher et al. (2017) recruited an older sample than both studies reporting

a mean age of 40.3 ($SD = 9.60$). It is also important to note that the current study population as well as the population recruited by Bray and Harris (2025) mostly consists of post-secondary students that can differ from community-dwelling adults recruited by Maher et al. (2017). These differences in participant age and proportion of students may contribute to differences in intention to engage in PA and PA behaviour as these populations can differ in intention surrounding PA. For example, Massie et al. (2021) found that for adults 40 and older, intentions to engage in PA were significantly impacted by factors such as restriction of activities (due to chronic health conditions), self-perceived health, and community belonging. In contrast, a mixed-methods study conducted by Poobalan et al. (2012) found that amongst a population from 18-25 years old, intention to engage in PA was informed by wanting to feel good and enjoyment rather than for long term health outcomes. Because emerging adults and adults aged 40 and older are influenced by different factors when forming PA intention, the two groups may show differing average momentary intention scores. The different variables informing one's average momentary intention may explain the difference in intention seen between past literature and the current study.

Additional differences between study populations includes their typical PA behaviour. Accelerometer assessed PA determined that the majority of the population (75.6%) in Maher et al. (2017) were not meeting PA guidelines (defined as 30+ minutes of MVPA/day) compared to the current study population self-reported a mean weekly PA of 363.67 ($SD = 326.11$) minutes per week. Differences in typical PA behaviour between the two studies may also explain the differences in reported levels of intention to engage in PA. Participants in the present study engaged in higher levels of PA suggesting they may report lower levels of intention to engage in PA if they have already met or surpassed their activity goals within the day. For example,

previous research found that a higher daily levels of PA were associated with lower motivation to engage in higher intensity PA based on a hypothetical decision-making paradigm (Harris et al., 2022). In contrast, the population observed by Maher et al. (2017) was less active than the population of the current study which may have affected their perceptions of PA and the associated planning requirements differently than participants in the present study. Thus, for a sample who more regularly engage in PA, it is plausible that they were more able to translate intentions to behaviour within the study period, resulting in lower intentions throughout the study period.

The lower proportion of observations with participants being labelled as having an “intention” compared to the previously mentioned studies may also be explained by the effects of seasonality on physical activity and physical activity decision making (Garriga et al., 2021). Data collection for the present study occurred from December through March within Southern Ontario where typical winter conditions could impact physical activity decision making. This should be considered given that Bray and Harris (2025) nor Maher et al. (2017) specify the season their data collection occurred in. While Bray and Harris (2025) studied a population from a similar geographical location within Southern Ontario, Maher et al. (2017) drew participants from Los Angeles, California which has a much more temperate environment compared to Southern Ontario.

The observed intention-to-behaviour gap of 41.5% also differs from the two previously mentioned studies where Bray and Harris (2025) observed an intention-behaviour gap of 30% while Maher et al. (2017) observed a gap of 84%. The intention-to-behaviour gap observed in the present study more closely aligns with results from a meta-analysis conducted by Feil et al. (2023) that observed an overall 47.6% intention-to-behaviour gap. However, direct comparisons

between results from the meta-analysis and the present study may not be appropriate as the meta-analysis investigates survey-based data rather than EMA data involving within-day measures and device assessed PA. The survey-based data from the meta-analysis involved recall of intention and behaviour over longer periods of time while EMA captures momentary intention and behaviour data. Findings from the present study extends upon the findings of the meta-analysis by describing the intention-behaviour gap on a within-day basis which includes momentary fluctuations not captured using survey-based methods.

Effects of Time on Anticipated Effort

Many studies involving EMA investigate how time-varying effects influence study variables of interest to better understand how they change within the day and within the week (Kekäläinen et al., 2024; Maher et al., 2016; Maher et al., 2019; Ruissen et al., 2022). Consistent with previous research examining the effects of time-varying factors on EMA variables, the present study investigated the effects of time of day, day of week, and day of study on PA intentions and anticipated effort. Results show a significant effect of time of day on PA intention where participants reported lower intentions later in the day and intentions decreased over the course of the study. These effects may be explained as reactivity bias (French & Sutton, 2010) from participating in the study. Prompting participants to think about their physical activity behaviour, environment, and intentions multiple times a day for a week over the course of the study may alter participants' typical thoughts surrounding PA and therefore PA intention. Furthermore, the Fitbit device, Fitbit app, and Pathverse app displaying MVPA data including steps, minutes of physical activity, and heart rate, may have increased participant's motivation, intention, and reflection surrounding physical activity (Orji et al., 2018), resulting in higher

intentions at the start of the study before returning closer to normal levels by the end of the study.

To the best of our knowledge this is the first study to examine time-varying predictors of anticipated effort. The effect of time of day and day of study on anticipated effort suggests a potential effect of measurement reactivity where participants change their perceptions around PA due to being measured (French & Sutton, 2010). By being enrolled in the study and repeatedly being asked about their intentions to engage in PA, participants may have increased their awareness and perceptions surrounding PA and therefore report higher anticipated effort to engage in PA later in the study period.

Within-person and Between-person effects of Anticipated Effort on Intention-behaviour Coupling

Results from the primary analysis demonstrate the significant within-person effects of intention and anticipated effort on within-day MVPA were superseded by a significant within-person interaction. Findings demonstrate a moderating effect of anticipated effort on the association between intention and behaviour, such that higher levels of within-person anticipated effort weaken the relationship between within-person intention and behaviour. That is, on occasions when participants reported momentary anticipated effort higher than their own average, the gap between intention and behaviour increased. These findings align with hypothesis 3 nested within the TEMPA (Cheval & Boisgontier, 2021) suggesting that increases in effort related processes would negatively impact PA decision making. These findings are also consistent with experimental findings from Harris and Bray (2021) showing that increases in perceptions of anticipated effort surrounding PA decreased PA motivation and decreased the likelihood people will decide to engage in PA compared to a sedentary alternative. Findings from

the present study extend this work by demonstrating similar effects occurring at multiple decision points within a week in people's naturalistic environment.

To probe the significant interaction, the Johnson-Neyman technique (Johnson & Fay, 1950) revealed that the moderating effect of anticipated effort on the intention-behaviour relationship was significant across nearly the entire range of observed within-person anticipated effort measures. To decompose the significant within-person interaction, a simple slopes analysis compared the within-person intention to behaviour relationship at five different levels of within-person anticipated effort, revealing that for every one-unit increase in within-subject intention, MVPA in the 120-min epoch following the prompt increased by an estimated 5.51 minutes when anticipated effort was 2 SD lower than a person's own average, compared to an estimated increase in 1.23 minutes when anticipated effort was 2 SD higher than a person's own average.

The primary analysis also revealed a significant interaction between intention and anticipated effort at the between-person level. The estimate was positive and significant, suggesting that participants who on average report higher anticipated effort have a stronger association between intention and MVPA than participants who on average reported lower anticipated effort. This result was inconsistent with study hypothesis 3 as it was hypothesized that participants who on average experienced lower anticipated effort would see a stronger intention-behaviour coupling. The moderating effect was only significant in the simple slopes analysis when participants reported between-person anticipated effort measures +1 SD and +2 SD above the mean, representing a total of 66 (53.2%) participants. Importantly, because this effect was not statistically significant in the sensitivity analysis, this effect should be interpreted with caution as the effect may not be as robust based on variables such as wear time. Results suggest that intention more strongly predicts subsequent PA for participants experiencing higher

average levels of anticipated effort than participants experiencing lower or average levels of anticipated effort. A similar pattern was observed for habit strength where van Bree et al. (2013) found that intention significantly predicted PA behaviour for individuals with low and medium habit strength but not for those with high habit strength, suggesting PA becomes less reliant on intention as habit strength increases. It is possible that for individuals reporting higher anticipated effort than others, intention plays a stronger role in predicting subsequent PA. For example, people reporting lower anticipated effort than others may generally engage in more habitual PA and some of the effort needed to prepare to engage in PA may be automatic and therefore go unnoticed (Lally & Gardner, 2013). Individuals who don't engage in PA out of habit or more regularly engage in PA may perceive more anticipated effort associated with engaging in PA and therefore must rely on high levels of intention to engage in PA. It is possible that between-person effort perceptions are attributed to baseline differences in perceptions around PA that are not currently well understood.

Theoretical Implications

The present study expands on previous cross-sectional studies investigating the effects of effortful-self-control on MVPA (Bourque et al., 2025) and experimental studies investigating the effects of anticipated effort on subsequent decisions to engage in that behavior (Harris & Bray, 2021). Results from the study build upon previous work by operationalizing the effort valuations and parsing apart anticipated effort to get ready for physical activity from the effort demands of engaging in physical activity itself, consistent with recommendations by Bourque and colleagues (2025). Within-person findings align with the aforementioned studies where increases in anticipated effort decreased subsequent PA engagement. However, the between-person findings differ from Bourque et al. (2025) and Harris and Bray (2021). The differences in the effects of

anticipated effort on MVPA likely come from study design in that the current study considers the dynamic nature of anticipated effort and disaggregates within-person and between-person effects.

The current study aimed to understand the role of anticipated effort to prepare to engage in PA independently and as a moderator of the intention-behaviour relationship within the context of the TEMPA (Cheval & Boisgontier, 2021). The TEMPA is a dual process theory which theorizes evolved automatic tendencies to avoid physical effort where people will automatically minimize effort when given the opportunity to do so, even when this conflicts with their pre-determined intentions. The study hypotheses were created to align with the TEMPA in that effort was expected to be integrated as a behavioural cost, subsequently leading to weaker translations of intention to behaviour. Within-person findings align with the theorized role of effort within the TEMPA in that increases in within-person anticipated effort leads to a weakening of the intention-behaviour relationship. However, between-person study findings contradict the theorized role of anticipated effort as participants reporting higher average anticipated effort had stronger intention-behaviour coupling compared to participants reporting lower average anticipated effort. One possible explanation for this result is due to the paradoxical nature of effort such that despite effort often being perceived as costly and therefore avoided, effort can also be valued in many situations and leading people to seek out effortful tasks (Inzlicht et al., 2018). Cheval et al. (2024) expand upon this concept with their development of the Physical Effort Scale (PES; Cheval et al., 2024) which accounts for individual differences in how physical effort is valued. As individuals may have different tendencies to approach or avoid effort, individuals may experience different effects of effort within the context of the TEMPA due to differing cost-valuations.

Individual tendencies to approach physical effort may help explain the between-person effect of anticipated effort on MVPA such that people with stronger approach tendencies towards physical effort may have less need for intention to drive behaviour even when anticipated effort is high. In contrast, individuals with stronger avoidance tendencies toward effort may require greater levels of intention than approach dominant individuals to be able to engage in physical activity, especially in the presence of high anticipated effort. As the moderating effect of between-person anticipated effort was not present for participants at mean levels or lower than average levels of between-person anticipated effort relative to other participants, difference in approach-avoidance tendencies may help explain why some people might perceive or experience lower anticipated effort than other people and why their intention might be a weaker predictor of PA behaviour. For example, individuals with a stronger approach tendency may assign lower cost to the same effortful behaviour than individuals with stronger avoidance tendency. Alternatively, individuals with stronger approach tendency may engage in higher amount of PA at the same level of assign anticipated effort than individuals with stronger avoidance tendency.

Anticipated effort may also reflect relevant constructs within other dual process theories such as the Multi-Process Action Control Model (MPAC; Rhodes, 2021). In their recommendations for EMA measurement, Rhodes and Kwan (2025) proposed that ongoing-perceived opportunity representing “*near real-time perceptions of accessibility within social and environmental contexts*” (Rhodes & Kwan, 2025, p. 4) as a theoretically relevant measure of EMA-based physical activity research within the MPAC. The significant within-subject effect of anticipated effort on MVPA observed in the study suggests that anticipated effort can function as a dynamic, state-based construct. This lends support to the idea that anticipated effort, like ongoing-perceived opportunity, can represent near real-time perception of accessibility within

social and environmental contexts which is a construct expected to be dynamic in nature and recommended for EMA research,

Practical Implications

Findings from this study position anticipated effort as a theoretically and practically relevant target for PA behavioural intervention. Expanding upon the TEMPA, Cheval et al. (2025) theorized that effort can shape PA decision making and PA behaviour because effort is integrated as a cost prior to, during, and after PA. Results from the present study provide support for effort as a behavioural cost impacting people's choices to engage or not engage in PA. Aligning with Cheval et al. (2025), anticipated effort may be a possible lever for interventions aimed to increase PA. Identifying methods to reduce anticipated effort can help maximize the cost-benefit ratio of engaging in PA thus increasing engagement. Plausible methods targeted towards reducing anticipated effort in the context of preparing to engage in physical activity may be derived from a qualitative approach to understand predictive variables and the strength of those variables on anticipated effort. Qualitative methods such as contextual, one-item, repeated, timely, open-ended (CORTO) method can be employed to gather open-ended in-the-moment qualitative data to capture the dynamic nature of effort within ecological contexts (Lukka et al., 2024). Variables identified in such a study could be used as an interventional lever within adaptive interventions such as Just-in-Time Adaptive Interventions (JITAIs; Nahum-Shani et al., 2017).

Similar to how EMA includes consideration for an individual's changing physical and psychological states (Shiffman et al., 2008), JITAIs attempt to capitalize on vulnerabilities and opportunities that may emerge rapidly (Nahum-Shani et al., 2017). JITAIs use an individual's state of vulnerability/opportunity and receptivity to provide interventions that are more

personalized in the hopes of increasing effectiveness by providing the correct type and amount of support at the right time. One's state of vulnerability is based on each individual's momentary tendency to engage with a maladaptive health behaviour and can be predicted by stable factors (e.g., socioeconomic status) but also dynamic factors (e.g., major life events, momentary life events, ecological state; Nahum-Shani et al., 2015). An individual's state of receptivity is based on the nature of support (e.g., how demanding the support is, type of content, and use of less cognitively demanding cues) and the recipient's ability and motivation to receive and enact this support which can be impacted by things like personality, emotions, and distractions (Nahum-Shani et al., 2015). Nahum-Shani et al. (2015) propose that when an individual is vulnerable to a maladaptive behaviour and in a receptive state to receive intervention, a JITAI can be employed to affect a proximal outcome to then impact a final distal outcome. To shorten the intention to behaviour gap, anticipated effort to prepare to engage in PA can be leveraged as a proximal outcome within a JITAI; however, what causes a change in anticipated effort needs to be empirically tested.

One possible pair of interventions to reduce momentary anticipated effort to prepare to engage in physical activity is action planning and coping planning. Action planning (Carey et al., 2019) prompts the detailed planning of the behaviour including implementation intentions while coping planning (Sniehotta et al., 2006) involves separate planning to overcome barriers to engaging in an intended behaviour in the case that the action plan fails. Previous research has examined the effects of action planning and coping planning on PA levels and have found that increases in action planning and coping planning were associated with increased self-reported MVPA (Sniehotta et al., 2006; Wee & Dillon, 2022). Action planning and coping planning may be directly applied within the context of anticipated effort to prepare to engage in physical

activity. Participants could action plan to decrease instances of high anticipated effort (e.g., packing clothing, scheduling to be close to exercise facilities, preparing food) and create coping strategies to pivot PA type when anticipated effort increases to the point where initial PA plans are too effortful to engage in.

Strengths and Limitations

This study involved several strengths. First, the use of EMA can be seen as a strength as EMA based research allows for granular data to be collected from participants from an ecologically valid point of view (Shiffman et al., 2008). In this case, participants responded to up to 28 surveys and device-assessed MVPA was captured following each survey providing real-time, within-day assessment of cognitions and PA behaviour in one's naturalistic environment. Previous research relying on self-reported PA behaviour is subject to social desirability bias (Adams, 2005) while including long recall periods provided self-reported PA measurements that are more subject to recall bias (Althubaiti, 2016). Using EMA reduces these biases using device-assessed PA and in-the-moment responses.

As an additional strength, the current study features high survey and wear-time compliance when compared to similar studies within the field among young and emerging adults (Bray & Harris, 2025; Dunton et al., 2014; Maher et al., 2019) and a meta-analysis including 677,536 participants demonstrating an average compliance of 79% (Wrzus & Neubauer, 2022). This may be in part due to the graded remuneration structure; however, previous research suggests that graded remuneration with bonuses should not impact compliance (Edney et al., 2023). Higher compliance could also possibly be due to higher levels of receptivity to the commercial wearable device compared to an accelerometer as previous research has shown that 45.2% of participants reported high burden in social settings due to embarrassment of research

grade accelerometer visibility (O'Brien et al., 2017). While the commercial wearables provided a cost-effective data collection method compared to using research grade devices, previous research has outlined concerns regarding the accuracy and validity of such devices (Fuller et al., 2020). While accuracy may be of concern when using Fitbit devices to collect data, all participants used the same model of watch to ensure that trends can still be captured and compared across individuals. Furthermore, previous validation studies have found that Fitbit devices have similar underestimations to energy expenditure and PA to research grade waist worn accelerometers (Imboden et al., 2017).

An additional study feature that may have supported high compliance includes offering participants the options to self-select between three study schedules (8am-8pm, 9am-9pm, and 10am-10pm) to account for participants' preferences and typical sleep-wake times. This allows participants to attempt to align the survey release schedule with their own waking day to minimize missed surveys and PA data.

Limitations of this study include biases still possibly present with the data. One example is the Hawthorn effect (McCambridge et al., 2014) where participants in the study could have changed their thoughts and behaviours surrounding PA given they knew they were being observed through the surveys and activity monitor. This interpretation may be supported by the significant effects of time of day and study day on intention and anticipated effort. It is also possible that the Fitbit device offering self-monitoring tools may have unintentionally caused measurement reactivity, causing participants to change their typical thoughts and behaviour (Maher et al., 2024).

While diverse in race and gender, the study population was primarily recruited from a student population and a population living within close proximity to a university campus in a

large city in Canada. This lends to the increased likelihood that the population recruited will be largely western, education, industrial, rich, and democratic (WEIRD; Muthukrishna et al., 2020). This can impact the generalizability of this data to non-WEIRD populations considering factors such as PA behaviour, access to resources, and digital literacy may differ. Furthermore, the study population may also be skewed by self-selection bias where participants who opt in to participate in the study may have had an increased willingness or interest due to the type of study, procedure length, recruitment length, and details regarding the recruitment poster (Alarie & Lupien, 2021). For example, participants who are more active and have greater digital literacy may be more likely to participate in a study involving PA behaviour and smartphone surveying.

While use of commercial wearables was listed as a study strength due to possible increases in adherence with similar accuracy to commercial grade wearables, the wrist-worn nature of the device could act as a limitation to the study. There is possible over-estimation or misclassification of activity due to wrist-worn accelerometers compared to waist-worn accelerometers (Shiroma et al., 2016). Furthermore, despite instructions to wear the accelerometer on their non-dominant wrist, participants could vary in individual placement of the device on the body leading to variance in measurement between people (Park et al., 2019).

While EMA research improves upon several weaknesses of past research methods to improve external validity, EMA still faces issues regarding quality of responses for participants who respond to surveys. There is a possible impact of ‘insufficient effort responding’ for the EMA surveys where participants intentionally or unintentionally provide careless responses leading to low-quality data (Huang et al., 2015). Currently, there are limited ways to detect careless responses within EMA as validation for these methods remain to be empirically tested (Vogelsmeier et al., 2026). The typical methods of flagging careless responses within surveys are

not feasible with EMA surveys without greatly impacting participant burden (e.g., attention check questions; Huang et al., 2015). Previous studies investigating response quality have found that 10-12% of participants will be careless responders (Meade & Craig, 2012).

The measurement properties of anticipated effort in the context of preparing to engage in physical activity in a real time context remains unexplored. Consequently, there lacks a validated measure to measure this form and timing of effort. While the item used in the present study was adapted from Bourque et al. (2025), psychometric properties of the item used were not assessed.

Future Directions

This study provides several future directions to expand upon initial findings to better understand the dynamic effects of anticipated effort to prepare to engage in PA on PA decision making. As an extension of the present study, future work should validate a measure of anticipated effort in the context of preparing to engage in physical activity. This may provide consistent language and understanding across studies to properly distinguish this form of anticipated effort from others.

Findings from the current study can be expanded by considering individual PA enjoyment levels or individual tendencies to approach or avoid physical effort. Including baseline characteristic measures like the Physical Effort Scale (PES; Cheval et al., 2024) or the Physical Activity Enjoyment Scale (PACES; Kendzierski & DeCarlo, 1991) to better understand how individual differences may explain differences in how anticipated effort can impact intention-behaviour coupling.

To further understand how people experience anticipated effort to prepare to engage in physical activity in changing real-world contexts, future research should include the CORTO

method to collect qualitative participant experiences as they occur in the real-world (Lukka et al., 2024). This qualitative approach can help define unique user-experience categories surrounding anticipated effort. Implementing the CORTO method could occur within an EMA study where participants are able to respond in a text box to an open-ended question regarding what is causing/informing their momentary anticipated effort. These categories should be included within a pilot JITAI style intervention to determine if anticipated effort can be targeted as a proximal outcome and PA behaviour as a distal outcome. Future research could also test action planning and coping planning as potential interventional levers to reduce anticipated effort to prepare to engage in physical activity.

Conclusion

The current study aims to understand anticipated effort to prepare to engage in PA on the intention-behaviour relationship in real-time using EMA. Anticipated effort to prepare to engage in PA sits within relevant theories such as the TEMPA (Cheval & Boisgontier, 2021) that frame effort as a potential barrier to PA behaviours even in the presence of an intention to engage in PA. Study findings show that as people experience higher levels of anticipated effort than their own average, the intention-behaviour gap widens. Findings also show that the intention-behaviour gap narrows for people who experience higher anticipated effort than others, perhaps due to a greater reliance on intention to engage in PA. Novel in-the-moment qualitative approaches can be used to further understand and validate anticipated effort to prepare to engage in PA before testing possible interventions. Overall, understanding dynamic factors impacting people's decisions to engage in PA in real-world environments is important to optimizing future interventions to support people in deciding to engage in healthy behaviours.

References

- Adams, S. A. (2005). The effect of social desirability and social approval on self-reports of physical activity. *American Journal of Epidemiology*, 161(4), 389–398.
<https://doi.org/10.1093/aje/kwi054>
- Aira, T., Vasankari, T., Heinonen, O. J., Korpelainen, R., Kotkajuuri, J., Parkkari, J., Savonen, K., Uusitalo, A., Valtonen, M., Villberg, J., Vähä-Ypyä, H., & Kokko, S. P. (2021). Physical activity from adolescence to young adulthood: Patterns of change, and their associations with activity domains and sedentary time. *International Journal of Behavioral Nutrition and Physical Activity*, 18(1). <https://doi.org/10.1186/s12966-021-01130-x>
- Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, 50(2), 179–211. [https://doi.org/10.1016/0749-5978\(91\)90020-T](https://doi.org/10.1016/0749-5978(91)90020-T)
- Alarie, S., & Lupien, S. J. (2021). Self-selection bias in human stress research: A systematic review. *Psychoneuroendocrinology*, 131, 105514.
<https://doi.org/10.1016/j.psyneuen.2021.105514>
- Althubaiti, A. (2016). Information bias in health research: Definition, pitfalls, and adjustment methods. *Journal of Multidisciplinary Healthcare*, 9(1), 211–217.
<https://doi.org/10.2147/JMDH.S104807>
- Anjali, A., & Sabharwal, M. (2018). Perceived barriers of young adults for participation in physical activity. *Current Research in Nutrition and Food Science Journal*, 6(2), 437–449. <https://doi.org/10.12944/crnfsj.6.2.18>

- Armitage, C. J., & Conner, M. (2001). Efficacy of the theory of planned behaviour: A meta-analytic review. *British Journal of Social Psychology*, 40(4), 471–499.
<https://doi.org/10.1348/014466601164939>
- Arnett, J. J. (2000). Emerging adulthood: A theory of development from the late teens through the twenties. *American Psychologist*, 55(5), 469–480. <https://doi.org/10.1037/0003-066X.55.5.469>
- Arnett, J. J., Žukauskienė, R., & Sugimura, K. (2014). The new life stage of emerging adulthood at ages 18–29 years: Implications for mental health. *The Lancet Psychiatry*, 1(7), 569–576. [https://doi.org/10.1016/s2215-0366\(14\)00080-7](https://doi.org/10.1016/s2215-0366(14)00080-7)
- Bauer, D. J., & Curran, P. J. (2005). Probing interactions in fixed and multilevel regression: Inferential and graphical techniques. *Multivariate Behavioral Research*, 40(3), 373–400. https://doi.org/10.1207/s15327906mbr4003_5
- Booth, F. W., Roberts, C. K., & Laye, M. J. (2012). Lack of exercise is a major cause of chronic diseases. *Comprehensive Physiology*, 2(2), 1143–1211.
<https://doi.org/10.1002/cphy.c110025>
- Bourque, J. R., Delli, A. G., Selby, E. A., Perdue, H. M., Poole, L. G., Sarwani, A. H., & Alderman, B. L. (2025). Effortful self-control as a potential target for physical activity maintenance. *Psychology of Sport and Exercise*, 80, Article 102926.
<https://doi.org/10.1016/j.psychsport.2025.102926>

- Bray, S. R., & Harris, S. (2025). Goal conflict and the physical activity intention-behavior relationship: Insights from a study of people's daily experiences. *Psychology of Sport and Exercise*, 78, Article 102805. <https://doi.org/10.1016/j.psychsport.2025.102805>
- Carey, R. N., Connell, L. E., Johnston, M., Rothman, A. J., de Bruin, M., Kelly, M. P., & Michie, S. (2019). Behavior change techniques and their mechanisms of action: A synthesis of links described in published intervention literature. *Annals of Behavioral Medicine*, 53(8), 693–707. <https://doi.org/10.1093/abm/kay078>
- Cheval, B., & Boisgontier, M. P. (2021). The theory of effort minimization in physical activity. *Exercise and Sport Sciences Reviews*, 49(3), 168–178. <https://doi.org/10.1249/jes.0000000000000252>
- Cheval, B., Maltagliati, S., Courvoisier, D. S., Marcora, S., & Boisgontier, M. P. (2024). Development and validation of the physical effort scale (PES). *Psychology of Sport and Exercise*, 72, Article 102607. <https://doi.org/10.1016/j.psychsport.2024.102607>
- Cheval, B., Maltagliati, S., Desplanques, F., & Wolff, W. (2025). Unpacking the dynamic role of physical effort in shaping behavior. *Trends in Cognitive Sciences* Advance online publication. <https://doi.org/10.1016/j.tics.2025.04.012>
- Clarke, J., Colley, R. C., Janssen, I., & Tremblay, M. S. (2019). Accelerometer-measured moderate-to-vigorous physical activity of Canadian adults, 2007 to 2017. *Health Reports*, 30(8), 3–10. <https://doi.org/10.25318/82-003-x201900800001-eng>

- Curran, P. J., & Bauer, D. J. (2011). The disaggregation of within-person and between-person effects in longitudinal models of change. *Annual Review of Psychology*, 62(1), 583–619. <https://doi.org/10.1146/annurev.psych.093008.100356>
- Delobelle, J., Lebuf, E., Compernelle, S., Vetrovsky, T., Van Cauwenberg, J., Cimler, R., Kuhnova, J., & Van Dyck, D. (2025). Sensor-triggered ecological momentary assessment in physical activity and sedentary behaviour research among Belgian community-dwelling elderly: Lessons learnt from intensive longitudinal studies. *BMJ Open*, 15(4), e096327. <https://doi.org/10.1136/bmjopen-2024-096327>
- Dunton, G. F. (2017). Ecological momentary assessment in physical activity research. *Exercise and Sport Sciences Reviews*, 45(1), 48–54. <https://doi.org/10.1249/jes.0000000000000092>
- Dunton, G. F., Huh, J., Leventhal, A. M., Riggs, N., Hedeker, D., Spruijt-Metz, D., & Pentz, M. A. (2014). Momentary assessment of affect, physical feeling states, and physical activity in children. *Health Psychology*, 33(3), 255–263. <https://doi.org/10.1037/a0032640>
- Edney, S., Goh, C. M., Chua, X. H., Low, A., Chia, J., Koek, D. S., Cheong, K., van Dam, R., Tan, C. S., & Müller-Riemenschneider, F. (2023). Evaluating the effects of rewards and schedule length on response rates to ecological momentary assessment surveys: Randomized controlled trials. *Journal of Medical Internet Research*, 25, e45764. <https://doi.org/10.2196/45764>
- Farah, B. Q., do Prado, W. L., Malik, N., Lofrano-Prado, M. C., de Melo, P. H., Botero, J. P., Cucato, G. G., de Almeida Correia, M., & Ritti-Dias, R. M. (2021). Barriers to physical

- activity during the COVID-19 pandemic in adults: A cross-sectional study. *Sport Sciences for Health*, 17(2), 441–447. <https://doi.org/10.1007/s11332-020-00724-5>
- Faries, M. D. (2016). Why we don't “just do it.” *American Journal of Lifestyle Medicine*, 10(5), 322–329. <https://doi.org/10.1177/1559827616638017>
- Feil, K., Fritsch, J., & Rhodes, R. E. (2023). The intention-behaviour gap in physical activity: A systematic review and meta-analysis of the action control framework. *British Journal of Sports Medicine*, 57(19), 1265–1271. <https://doi.org/10.1136/bjsports-2022-106640>
- Fredriksson, S. V., Alley, S. J., Rebar, A. L., Hayman, M., Vandelanotte, C., & Schoeppe, S. (2018). How are different levels of knowledge about physical activity associated with physical activity behaviour in Australian adults? *PLOS ONE*, 13(11), e0207003. <https://doi.org/10.1371/journal.pone.0207003>
- French, D. P., & Sutton, S. (2010). Reactivity of measurement in health psychology: How much of a problem is it? What can be done about it? *British Journal of Health Psychology*, 15(3), 453–468. <https://doi.org/10.1348/135910710x492341>
- Fuller, D., Colwell, E., Low, J., Orychock, K., Tobin, M. A., Simango, B., Buote, R., Van Heerden, D., Luan, H., Cullen, K., Slade, L., & Taylor, N. G. A. (2020). Reliability and validity of commercially available wearable devices for measuring steps, energy expenditure, and heart rate: Systematic review. *JMIR mHealth and uHealth*, 8(9), e18694. <https://doi.org/10.2196/18694>
- Garriga, A., Sempere-Rubio, N., Molina-Prados, M. J., & Faubel, R. (2021). Impact of seasonality on physical activity: A systematic review. *International Journal of*

Environmental Research and Public Health, 19(1), Article 2.

<https://doi.org/10.3390/ijerph19010002>

Godin, G., Amireault, S., Bélanger-Gravel, A., Vohl, M.-C., & Périus, L. (2009). Prediction of leisure-time physical activity among obese individuals. *Obesity*, 17(4), 706–712.

<https://doi.org/10.1038/oby.2008.599>

Hagger, M. S., & Hamilton, K. (2023). Longitudinal tests of the theory of planned behaviour: A meta-analysis. *European Review of Social Psychology*, 35(1), 1–57.

<https://doi.org/10.1080/10463283.2023.2225897>

Harris, S., & Bray, S. R. (2021). Mental fatigue, anticipated effort, and subjective valuations of exercising predict choice to exercise or not: A mixed-methods study. *Psychology of Sport and Exercise*, 54, Article 101924. <https://doi.org/10.1016/j.psychsport.2021.101924>

Harris, S., & Bray, S. R. (2023). Investigating real-time physical activity behavior using ecological momentary assessment: Effects of mental fatigue and benefit-cost valuations. *Psychology of Sport and Exercise*, 69, Article 102499.

<https://doi.org/10.1016/j.psychsport.2023.102499>

Harris, S., Stratford, P., & Bray, S. R. (2022). Is it really worth the effort? Examining the effects of mental fatigue on physical activity effort discounting. *Journal of Sport & Exercise Psychology*, 44(6), 1–11. <https://doi.org/10.1123/jsep.2021-0330>

Herazo-Beltrán, Y., Pinillos, Y., Vidarte, J., Crissien, E., Suarez, D., & García, R. (2017).

Predictors of perceived barriers to physical activity in the general adult population: A

- cross-sectional study. *Brazilian Journal of Physical Therapy*, 21(1), 44–50.
<https://doi.org/10.1016/j.bjpt.2016.04.003>
- Huang, J. L., Liu, M., & Bowling, N. A. (2015). Insufficient effort responding: Examining an insidious confound in survey data. *Journal of Applied Psychology*, 100(3), 828–845.
<https://doi.org/10.1037/a0038510>
- Idowu, O. A., Omoijahe, B., Fawole, H. O., Adeagbo, I., & Akinola, B. I. (2024). Physical activity information-seeking behaviour and barriers in a sample of university undergraduate emerging adults: A cross-sectional survey. *Bulletin of Faculty of Physical Therapy*, 29(1). <https://doi.org/10.1186/s43161-024-00187-6>
- Imboden, M. T., Nelson, M. B., Kaminsky, L. A., & Montoye, A. H. (2017). Comparison of four Fitbit and Jawbone activity monitors with a research-grade ActiGraph accelerometer for estimating physical activity and energy expenditure. *British Journal of Sports Medicine*, 52(13), 844–850. <https://doi.org/10.1136/bjsports-2016-096990>
- Inzlicht, M., Shenhav, A., & Olivola, C. Y. (2018). The effort paradox: Effort is both costly and valued. *Trends in Cognitive Sciences*, 22(4), 337–349.
<https://doi.org/10.1016/j.tics.2018.01.007>
- Johnson, P. O., & Fay, L. C. (1950). The Johnson-Neyman technique, its theory and application. *Psychometrika*, 15(4), 349–367. <https://doi.org/10.1007/BF02288864>
- Jones, A., Remmerswaal, D., Verveer, I., Robinson, E., Franken, I. H. A., Wen, C. K. F., & Field, M. (2018). Compliance with ecological momentary assessment protocols in

- substance users: A meta-analysis. *Addiction*, 114(4), 609–619.
<https://doi.org/10.1111/add.14503>
- Kekäläinen, T., Luchetti, M., Terracciano, A., Gamaldo, A. A., Sliwinski, M. J., & Sutin, A. R. (2024). Momentary associations between physical activity, affect, and purpose in life. *Annals of Behavioral Medicine*, 58(11), 752–762. <https://doi.org/10.1093/abm/kaae051>
- Kendzierski, D., & DeCarlo, K. J. (1991). Physical activity enjoyment scale. *Journal of Sport & Exercise Psychology*, 13(1). <https://doi.org/10.1037/t33669-000>
- Koenig, J., Farhat, L. C., & Bloch, M. H. (2024). Editorial: From adolescence into young adulthood—the importance of a longitudinal perspective across development in child and adolescent mental health. *Journal of Child Psychology and Psychiatry*, 66(1), 1–3.
<https://doi.org/10.1111/jcpp.14094>
- Koh, Y. S., Asharani, P. V., Devi, F., Roystonn, K., Wang, P., Vaingankar, J. A., Abdin, E., Sum, C. F., Lee, E. S., Müller-Riemenschneider, F., Chong, S. A., & Subramaniam, M. (2022). A cross-sectional study on the perceived barriers to physical activity and their associations with domain-specific physical activity and sedentary behaviour. *BMC Public Health*, 22(1). <https://doi.org/10.1186/s12889-022-13431-2>
- Kwan, M. Y., Cairney, J., Faulkner, G. E., & Pullenayegum, E. E. (2012). Physical activity and other health-risk behaviors during the transition into early adulthood. *American Journal of Preventive Medicine*, 42(1), 14–20. <https://doi.org/10.1016/j.amepre.2011.08.026>
- Lally, P., & Gardner, B. (2013). Promoting habit formation. *Health Psychology Review*, 7(Suppl. 1), S137–S158. <https://doi.org/10.1080/17437199.2011.603640>

- Liu, S., La, H., Willms, A., & Rhodes, R. E. (2022). A “no-code” app design platform for mobile health research: A development and usability study. *JMIR Formative Research*, 6(8).
<https://doi.org/10.2196/38737>
- Lukka, L., Karhulahti, V.-M., Bergman, V.-R., & Palva, J. M. (2024). Measuring digital intervention user experience with a novel ecological momentary assessment (EMA) method, CORTO. *Internet Interventions*, 35, Article 100706.
<https://doi.org/10.1016/j.invent.2023.100706>
- Löllgen, H., Böckenhoff, A., & Knapp, G. (2009). Physical activity and all-cause mortality: An updated meta-analysis with different intensity categories. *International Journal of Sports Medicine*, 30(3), 213–224. <https://doi.org/10.1055/s-0028-1128150>
- Maher, J. P., Arigo, D., Baga, K., Salvatore, G. M., Pasko, K., Hudgins, B. L., & König, L. M. (2024). Measurement reactivity in ecological momentary assessment studies of movement-related behaviors. *Journal for the Measurement of Physical Behaviour*, 7(1).
<https://doi.org/10.1123/jmpb.2023-0035>
- Maher, J. P., Dzubur, E., Huh, J., Intille, S., & Dunton, G. F. (2016). Within-day time-varying associations between behavioral cognitions and physical activity in adults. *Journal of Sport and Exercise Psychology*, 38(4), 423–434. <https://doi.org/10.1123/jsep.2016-0058>
- Maher, J. P., Dzubur, E., Nordgren, R., Huh, J., Chou, C.-P., Hedeker, D., & Dunton, G. F. (2019). Do fluctuations in positive affective and physical feeling states predict physical activity and sedentary time? *Psychology of Sport and Exercise*, 41, 153–161.
<https://doi.org/10.1016/j.psychsport.2018.01.011>

- Maher, J. P., Rhodes, R. E., Dzubur, E., Huh, J., Intille, S., & Dunton, G. F. (2017). Momentary assessment of physical activity intention-behavior coupling in adults. *Translational Behavioral Medicine*, 7(4), 709–718. <https://doi.org/10.1007/s13142-017-0472-6>
- Marquez, D. X., Aguiñaga, S., Vásquez, P. M., Conroy, D. E., Erickson, K. I., Hillman, C., Stillman, C. M., Ballard, R. M., Sheppard, B. B., Petruzzello, S. J., King, A. C., & Powell, K. E. (2020). A systematic review of physical activity and quality of life and well-being. *Translational Behavioral Medicine*, 10(5), 1098–1109. <https://doi.org/10.1093/tbm/ibz198>
- Massie, A. S., Johnston, H., Sibley, D., & Meisner, B. A. (2021). Factors associated with the intention to begin physical activity among inactive middle-aged and older adults. *Health Education & Behavior*, 49(1), 109019812110308. <https://doi.org/10.1177/10901981211030867>
- McCambridge, J., Witton, J., & Elbourne, D. R. (2014). Systematic review of the Hawthorne effect: New concepts are needed to study research participation effects. *Journal of Clinical Epidemiology*, 67(3), 267–277. <https://doi.org/10.1016/j.jclinepi.2013.08.015>
- Meade, A. W., & Craig, S. B. (2012). Identifying careless responses in survey data. *Psychological Methods*, 17(3), 437–455. <https://doi.org/10.1037/a0028085>
- Muthukrishna, M., Bell, A. V., Henrich, J., Curtin, C. M., Gedranovich, A., McInerney, J., & Thue, B. (2020). Beyond western, educated, industrial, rich, and democratic (WEIRD) psychology: Measuring and mapping scales of cultural and psychological distance. *Psychological Science*, 31(6), 678–701. <https://doi.org/10.1177/0956797620916782>

- Nahum-Shani, I., Hekler, E. B., & Spruijt-Metz, D. (2015). Building health behavior models to guide the development of just-in-time adaptive interventions: A pragmatic framework. *Health Psychology, 34*(Suppl.), 1209–1219. <https://doi.org/10.1037/hea0000306>
- Nahum-Shani, I., Smith, S. N., Spring, B. J., Collins, L. M., Witkiewitz, K., Tewari, A., & Murphy, S. A. (2017). Just-in-time adaptive interventions (JITAIs) in mobile health: Key components and design principles for ongoing health behavior support. *Annals of Behavioral Medicine, 52*(6), 446–462. <https://doi.org/10.1007/s12160-016-9830-8>
- O'Brien, W. J., Shultz, S. P., Firestone, R. T., George, L., Breier, B. H., & Kruger, R. (2017). Exploring the challenges in obtaining physical activity data from women using hip-worn accelerometers. *European Journal of Sport Science, 17*(7), 922–930. <https://doi.org/10.1080/17461391.2017.1323952>
- Orji, R., Lomotey, R., Oyibo, K., Orji, F., Blustein, J., & Shahid, S. (2018). Tracking feels oppressive and ‘punishy’: Exploring the costs and benefits of self-monitoring for health and wellness. *Digital Health, 4*. <https://doi.org/10.1177/2055207618797554>
- Park, S., Toth, L. P., Hibbing, P. R., Springer, C. M., Kaplan, A. S., Feyerabend, M. D., Crouter, S. E., & Bassett, D. R. (2019). Dominant vs. non-dominant wrist placement of activity monitors: Impact on steps per day. *Journal for the Measurement of Physical Behaviour, 2*(2), 118–123. <https://doi.org/10.1123/jmpb.2018-0060>
- Poobalan, A. S., Aucott, L. S., Clarke, A., & Smith, W. C. S. (2012). Physical activity attitudes, intentions and behaviour among 18–25 year olds: A mixed method study. *BMC Public Health, 12*(1). <https://doi.org/10.1186/1471-2458-12-640>

- Raglin, J. S. (1990). Exercise and mental health. *Sports Medicine*, 9(6), 323–329.
<https://doi.org/10.2165/00007256-199009060-00001> [Note: journal issue (9(6)) suggests original publication year is 1990, not 2012 — verify]
- Rhodes, R. E. (2021). Multi-process action control in physical activity: A primer. *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.797484>
- Rhodes, R. E., Cox, A., & Sayar, R. (2021). What predicts the physical activity intention-behavior gap? A systematic review. *Annals of Behavioral Medicine*, 56(1), 1–20.
<https://doi.org/10.1093/abm/kaab044>
- Rhodes, R. E., & de Bruijn, G.-J. (2013). How big is the physical activity intention-behaviour gap? A meta-analysis using the action control framework. *British Journal of Health Psychology*, 18(2), 296–309. <https://doi.org/10.1111/bjhp.12032>
- Rhodes, R. E., & Kwan, M. Y. W. (2025). Dynamic representations of theory testing in physical activity using ecological momentary assessment: An example guide utilizing multi-process action control. *Frontiers in Psychology*, 16.
<https://doi.org/10.3389/fpsyg.2025.1547090>
- Rhodes, R. E., McEwan, D., & Rebar, A. L. (2019). Theories of physical activity behaviour change: A history and synthesis of approaches. *Psychology of Sport and Exercise*, 42, 100–109. <https://doi.org/10.1016/j.psychsport.2018.11.010>
- Roberts, K., Yao, X., Carson, V., Chaput, J.-P., & Janssen, I. (2017). Meeting the Canadian 24-Hour Movement Guidelines for Children and Youth. *Health Reports*, 28(10), 3–7.

- Ross, R., Chaput, J.-P., Giangregorio, L. M., Janssen, I., Saunders, T. J., Kho, M. E., Poitras, V. J., Tomasone, J. R., El-Kotob, R., McLaughlin, E. C., Duggan, M., Carrier, J., Carson, V., Chastin, S. F., Latimer-Cheung, A. E., Chulak-Bozzer, T., Faulkner, G., Flood, S. M., Gazendam, M. K., ... Tremblay, M. S. (2020). Canadian 24-hour movement guidelines for adults aged 18–64 years and adults aged 65 years or older: An integration of physical activity, sedentary behaviour, and sleep. *Applied Physiology, Nutrition, and Metabolism*, 45(10, Suppl. 2), S57–S102. <https://doi.org/10.1139/apnm-2020-0467>
- Ruissen, G. R., Beauchamp, M. R., Puterman, E., Zumbo, B. D., Rhodes, R. E., Hives, B. A., Brinkley, S. M., Vega, J., Low, C. A., & Wright, A. G. C. (2022). Continuous-time modeling of the bidirectional relationship between incidental affect and physical activity. *Annals of Behavioral Medicine*, 56(12), 1284–1299. <https://doi.org/10.1093/abm/kaac024>
- Salmon, J., Owen, N., Crawford, D., Bauman, A., & Sallis, J. F. (2003). Physical activity and sedentary behavior: A population-based study of barriers, enjoyment, and preference. *Health Psychology*, 22(2), 178–188. <https://doi.org/10.1037/0278-6133.22.2.178>
- Sani, S. H. Z., Fathirezaie, Z., Brand, S., Pühse, U., Holsboer-Trachsler, E., Gerber, M., & Talepasand, S. (2016). Physical activity and self-esteem: Testing direct and indirect relationships associated with psychological and physical mechanisms. *Neuropsychiatric Disease and Treatment*, 12, 2617–2625. <https://doi.org/10.2147/ndt.s116811>
- Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology*, 4(1), 1–32. <https://doi.org/10.1146/annurev.clinpsy.3.022806.091415>

- Shiroma, E. J., Schepps, M. A., Harezlak, J., Chen, K. Y., Matthews, C. E., Koster, A., Caserotti, P., Glynn, N. W., & Harris, T. B. (2016). Daily physical activity patterns from hip- and wrist-worn accelerometers. *Physiological Measurement*, 37(10), 1852–1861.
<https://doi.org/10.1088/0967-3334/37/10/1852>
- Singh, B. (2023). Effectiveness of physical activity interventions for improving depression, anxiety and distress: An overview of systematic reviews. *British Journal of Sports Medicine*, 57(18), 1203–1209. <https://doi.org/10.1136/bjsports-2022-106195>
- Sniehotta, F. F., Scholz, U., & Schwarzer, R. (2006). Action plans and coping plans for physical exercise: A longitudinal intervention study in cardiac rehabilitation. *British Journal of Health Psychology*, 11(1), 23–37. <https://doi.org/10.1348/135910705x43804>
- Thomas, A. M., Beaudry, K. M., Gammage, K. L., Klentrou, P., & Josse, A. R. (2019). Physical activity, sport participation, and perceived barriers to engagement in first-year Canadian university students. *Journal of Physical Activity and Health*, 16(6), 437–446.
<https://doi.org/10.1123/jpah.2018-0198>
- Tonkin, S., Gass, J., Wray, J., Maguin, E., Mahoney, M., Colder, C., Tiffany, S., & Hawk, L. W. (2023). Evaluating declines in compliance with ecological momentary assessment in longitudinal health behavior research: Analyses from a clinical trial. *Journal of Medical Internet Research*, 25, e43826. <https://doi.org/10.2196/43826>
- van Bree, R. J. H., van Stralen, M. M., Bolman, C., Mudde, A. N., de Vries, H., & Lechner, L. (2013). Habit as moderator of the intention–physical activity relationship in older adults: A longitudinal study. *Psychology & Health*, 28(5), 514–532.
<https://doi.org/10.1080/08870446.2012.749476>

- Vogelsmeier, L. V. D. E., Siepe, B. S., Ulitzsch, E., Eisele, G., Geeraerts, J., Klocek, A., Proppert, R. K. K., Rieble, C. L., Tutunji, R., Dejonckheere, E., Kuppens, P., & Fried, E. I. (2026). Identifying careless responding in ecological momentary assessment: Inconsistent signals from different detection methods in the WARN-D data. *Psychological Methods*. Advance online publication. <https://doi.org/10.1037/met0000845>
- Weatherson, K. A., Joopally, H., Wunderlich, K., Kwan, M. Y. W., Tomasone, J. R., & Faulkner, G. (2021). Post-secondary students' adherence to the Canadian 24-hour movement guidelines for adults: Results from the first deployment of the Canadian Campus Wellbeing Survey (CCWS). *Health Promotion and Chronic Disease Prevention in Canada*, 41(6), 173–181. <https://doi.org/10.24095/hpcdp.41.6.01>
- Wee, Z. Q. C., & Dillon, D. (2022). Increasing physical exercise through action and coping planning. *International Journal of Environmental Research and Public Health*, 19(7), Article 3883. <https://doi.org/10.3390/ijerph19073883>
- Wewers, M. E., & Lowe, N. K. (1990). A critical review of visual analogue scales in the measurement of clinical phenomena. *Research in Nursing & Health*, 13(4), 227–236. <https://doi.org/10.1002/nur.4770130405>
- Williams, D., & Rhodes, R. E. (2016). The confounded self-efficacy construct: Review, conceptual analysis, and recommendations for future research. *Health Psychology Review*, 10(2), 113–128. <https://doi.org/10.1080/17437199.2014.941998>
- Wrzus, C., & Neubauer, A. B. (2022). Ecological momentary assessment: A meta-analysis on designs, samples, and compliance across research fields. *Assessment*, 30(3), 372–411. <https://doi.org/10.1177/10731911211067538>

Appendix A: Baseline Demographic Measures

Age: _____ years

Are you currently enrolled in a post-secondary program?

- ☐ Yes
 - ☐ *If yes:* What is your current year/level of study:
 - ☐ Undergraduate - Year 1
 - ☐ Undergraduate - Year 2
 - ☐ Undergraduate - Year 3
 - ☐ Undergraduate - Year 4+
 - ☐ Graduate – Master’s program
 - ☐ Graduate – Doctoral/Professional program
 - ☐ Other (please specify): _____
- ☐ No

What is your gender identity (select all that apply):

- ☐ Woman (cisgender and transgender)
- ☐ Man (cisgender and transgender)
- ☐ Non-binary person
- ☐ Another identity (please specify): _____
- ☐ Prefer not to say

What race categories best describe you? Select all that apply:

- ☐ Black
- ☐ East Asian
- ☐ Latino
- ☐ Middle Eastern
- ☐ South Asian
- ☐ Southeast Asian
- ☐ White
- ☐ Another race category (please specify): _____
- ☐ Prefer not to say

Appendix B: International Physical Activity Questionnaire

Regular Physical Activity Definition

Please take an extra minute to read this section. It is very important that you clearly understand our definition of what constitutes regular physical activity before you proceed with the survey. Please refer back to these definitions for all physical activity-related questions.

- Engaging in physical activity on a regular basis can be defined as 150 minutes of at least moderate-intensity activity per week.
- What is moderate-intensity physical activity? This includes activities like brisk walking, tennis, easy bicycling, or dancing; such activities may work up a light perspiration but is not exhausting. Several short bouts (but not less than 10 minutes) can be accumulated.
- Note: Typical weight training (free weight, weight machines) and callisthenic-type activities (such as push-ups, sit-ups) should be considered as moderate-intensity activity. Count only the minutes that you are actually active. For example, during a 1.5 hour workout, you may only be lifting for 30 minutes.
- What is vigorous-intensity physical activity? This includes activities like running, aerobics, fast bicycling, or basketball. Such activities cause significant sweating and large increases in breathing and heart rate

International Physical Activity Questionnaire

How active are you usually? Please consider your usual activity level during a typical 7 day period in the past 6 months and answer the following about moderate and vigorous activity participation.

MODERATE Physical Activity Definition

Moderate physical activity or exercise includes activities such as brisk walking, light swimming, dancing, biking, gardening, and yardwork. You should be able to carry on a conversation when doing moderate activities. Please consider a TYPICAL week for you and answer the following questions about moderate activities.

1. How many days per week are you moderately physically active or do you exercise moderately? _____ days per week

2. Approximately how many minutes are you moderately physically active or do you exercise moderately each day? _____ minutes per day

VIGOROUS Physical Activity Definition:

Vigorous physical activity or exercise includes hard activities such as jogging, aerobics, swimming, and fast biking. You may have a hard time carrying on a conversation when doing vigorous activities. Please consider a TYPICAL week for you and answer the following questions about vigorous activities.

-
1. How many days per week are you vigorously physically active or do you exercise vigorously? _____ **days per week**
 2. Approximately how many minutes are you vigorously physically active or do you exercise vigorously each day? _____ **minutes per day**
-

Appendix C: Study Reference Sheet
The Psychology Research on Exercise and Health Lab

Study Reference Sheet

Thank you for your interest in participating in the study! This package will include information and instructions that may be helpful as you complete this study. If this package does not solve your problem or answer your question, please email us at khspych@uwaterloo.ca and we will reply to you as soon as possible.

FitBit Maintenance and Troubleshooting

Device care and maintenance

Devices are cleaned by researchers before and after each data-collection period. Regular cleaning is recommended throughout the study to avoid skin irritation. To clean the device, please wipe down the device with a dampened paper towel or cloth with a disinfectant or water and mild detergent. Please do not spray the device directly with any cleaning solution.

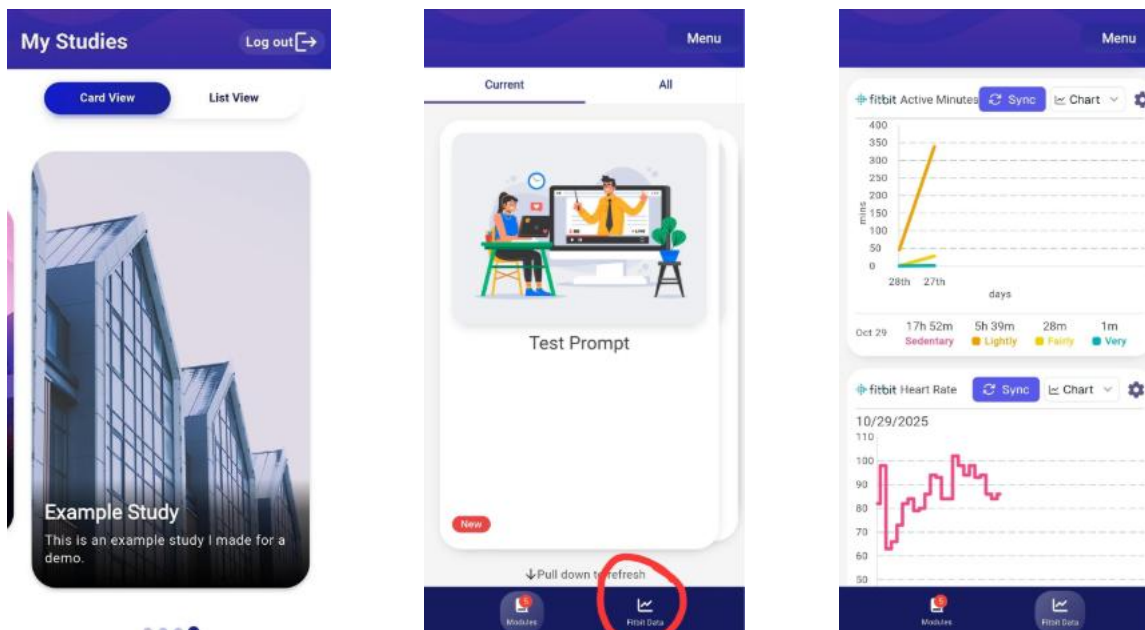
Please do not shower with the device on and avoid scratching, bumping, or dropping the device. The FitBit device is water resistant up to 50m so it is possible to swim with the device on. Before swimming, swipe down from the clock screen, tap the “Swim” exercise tile, and then press the side button to start the exercise to initiate the water lock. It is recommended to keep the device dry whenever possible and to manually dry it immediately upon getting it wet.

When storing the device (overnight or prior to returning the device), please store it in a safe, cool, and dry location. Avoid storing the device near extreme temperatures or where it may be lost or stolen.

How to sync the FitBit device to Pathverse

Here are the instructions to sync your FitBit data with Pathverse.

Step 1: Open the Pathverse app and tap on the study you are enrolled in	Step 2: Click on the “FitBit Data” tab at the bottom left of the page	Step 3: Click on ALL of the “Sync” buttons
---	---	--



Pathverse App Troubleshooting

Account and passwords

All Pathverse accounts are created by the research team. Please do not share this login information with anyone else. Your account details have been emailed to you at the start of the study. In the case that you are logged out and have forgotten your password, please refer to our email including the login information. If you are still having issues logging in, please contact us immediately.

Notification settings

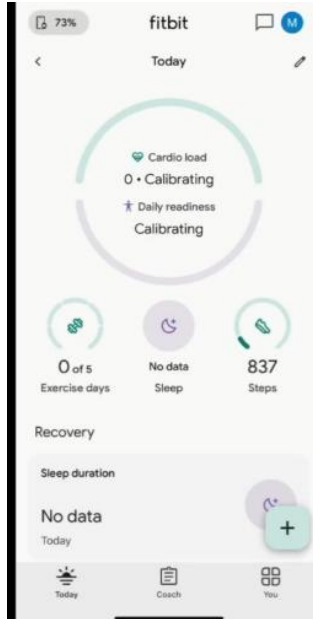
Enabling notifications will be important for this study. There are many ways in which notifications can be impeded. Please ensure the following:

- A) Notifications are turned on in your phone settings
- B) If you use “Do not disturb” mode, consider allowing Pathverse to bypass and still provide notifications
- C) The Pathverse app is not put into “Deep Sleep” by your phone

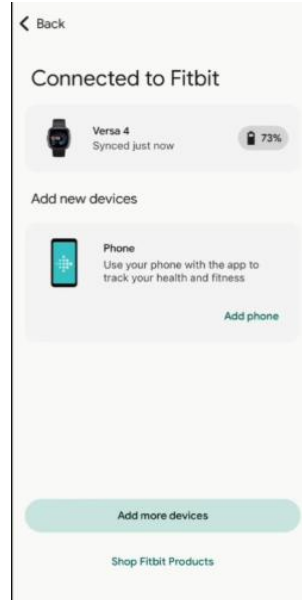
The FitBit device may also display your phone's notifications. We recommend adjusting your FitBit notification settings to only allow Pathverse notifications. You can change your FitBit settings by following the steps on the next page.

Enabling Pathverse notifications on the FitBit for Apple

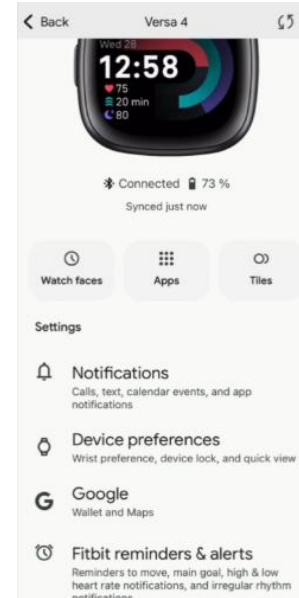
Step 1: Open the FitBit app and click on the device battery icon in the top left



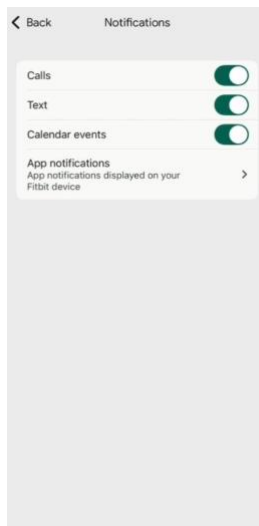
Step 2: Click on the “Versa 4”



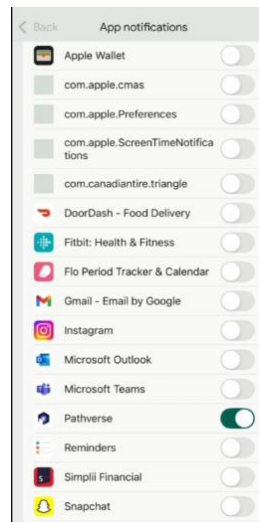
Step 3: Click on “Notifications”



Step 4: Click on “App notifications”

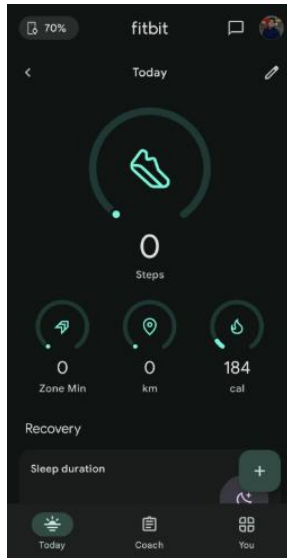


Step 5: Disable notifications from all apps and ensure Pathverse is turned on

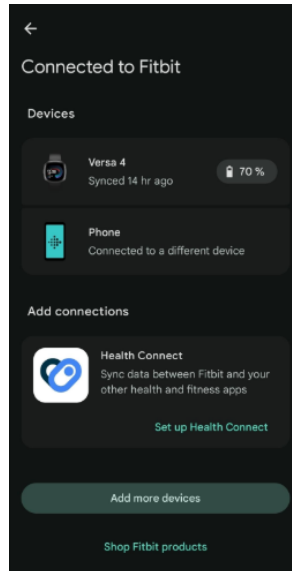


Enabling Pathverse notifications on the FitBit for Android

Step 1: Open the FitBit app and click on the device battery icon in the top left



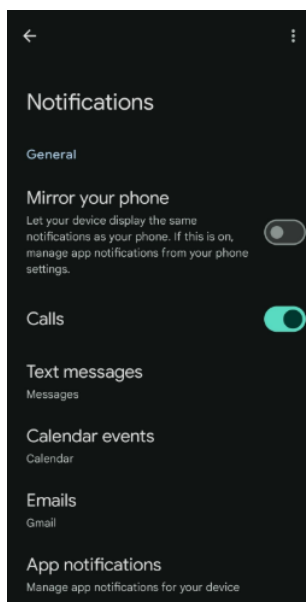
Step 2: Click on the “Versa 4”



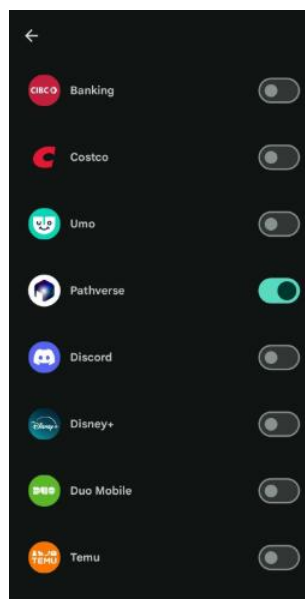
Step 3: Click on “Notifications”



Step 4: Turn off “Mirror your phone” and then click on “App notifications”



Step 5: Disable notifications from all apps and ensure Pathverse is turned on



Description of survey questions

If you are unsure what a question is asking, please refer to this resource for more detailed explanations. Physical activity in the questions below includes any movement of the body including (but not limited to-) walking, running, incidental exercise, and planned exercise. When answering these questions, please be honest as there is no right or wrong answer.

“How many hours of sleep did you get in total last night?”

- Please include how many hours you think you slept the previous night, rounded to the nearest half hour. Give your best guess based on roughly when you went to sleep and when you woke up.

“Since responding to the last survey yesterday, did you engage in any moderate-to-vigorous intensity physical activity yesterday (e.g., brisk walking, cycling, running, aerobics)?”

- This question is only available at the first prompt of the day. The question is asking you to report any physical activity you engaged in after answering the last prompt of the previous day (i.e., after the last prompt of the previous day to midnight).

“Before the first survey for today, did you engage in any moderate-to-vigorous intensity physical activity (e.g., brisk walking, cycling, running, aerobics)?”

- This question is only available at the first prompt of the day. The question is asking you to report any physical activity you engaged in before answering the current prompt (i.e., from midnight to receiving the first prompt of the day).

“Since the last survey, did you engage in any moderate-to-vigorous intensity physical activity (e.g., brisk walking, cycling, running, aerobics)?”

- This question is asked in the 2nd, 3rd, and 4th prompt of the day. The question is asking you to report any physical activity you engaged in since the last prompt. Please consider the time between notifications even if you were unable to respond to the previous prompt.

“What were you doing right before you opened this prompt?”

- This question is asking what activity you were engaged in prior to opening the prompt. Please select what feels most accurate. In the case that none of the options feel accurate, please select “other”. You will have the option to elaborate in the next question.

“Please describe the type of physical activity or exercise you were participating in (i.e., walking, running, sport, yoga, etc...) Please leave type N/A if not applicable : _____”

- This question allows you to expand on the previous question if needed. Please include a simple definition of the type of exercise or activity you were engaging in if you selected ‘physical activity or exercise’ or ‘other’.

“Please use the sliding scale to indicate what you feel represents your perception of your current state of mental fatigue.”

- This question measures your current levels of mental fatigue. For the scale, look at the words on either end of the line and move the sliding scale to the point on the line that represents what you are feeling at that moment in time. In the case that your answer is on the very left side of the scale, you will need to slide away then back to the left side to input your answer.

“At this moment I feel:”

- There are 6 versions of this question. For each version, look at the words on either end of the line and move the sliding scale to the point on the line that represents what you are feeling at that moment in time. In the case that your answer is on the very left side of the scale, you will need to slide away then back to the left side to input your answer.

“I intend to be physically active for 10+ minutes within the next hour.”

- This question is asking about your intention to engage in physical activity for 10+ minutes. For the scale, look at the words on either end of the line and move the sliding scale to the point on the line that represents what you are feeling at that moment in time. In the case that your answer is on the very left side of the scale, you will need to slide away then back to the left side to input your answer.

“Within the next hour, how much effort do you feel it will take to get ready to engage in physical activity.”

- Consider how much time you have, where you are, who you’re with, and what you’re doing and the specific steps necessary to get ready to engage in the amount of physical activity you intend to do. Based on this information, move the sliding scale to the point on the line that represents how much effort you think it will take to get ready to engage in physical activity. This question is still applicable even if you do not intend to engage in physical activity. In the case that your answer is on the very left side of the scale, you will need to slide away then back to the left side to input your answer.

“Where are you right now?”

- Based on your current location, please select the option that best describes where you are. If none are applicable, please select ‘Other’.

“How safe do you feel right now?”

- Based on your current location, please select the option that best describes where you are. If none are applicable, please select ‘Other’.

“How many trees and plants are there in the area where you are right now?”/“How much traffic is on the closest street to where you are right now?”/“How much litter or garbage is on the ground where you are right now?”

- For each of these questions, select the option that best reflects your current outdoor environment. If you are currently indoors, please select ‘Not applicable – currently indoors’.

“Are you currently alone?”

- Based on the people in your immediate environment, please select the option that best describes who you are with.

“How well do you know this person/these people? Please input any number if alone”

- Consider the people you are currently with and if you know these people well. Move the slider based on how close you feel to these individuals. In the case that your answer is on the very left side of the scale, you will need to slide away then back to the left side to input your answer.

“How important was this interaction to you? Please input any number if alone”

- Consider who you are with, where you are, and what you are doing. Based on your interaction with the people you are with and how much you are enjoying the interaction, move the slider based on how you feel. In the case that your answer is on the very left side of the scale, you will need to slide away then back to the left side to input your answer.

Appendix D: Sensitivity Analysis Results

Results from the sensitivity analysis for the multi-level mixed effects model predicting moderate-to-vigorous intensity physical activity in the 120-min epoch following the survey using EMA data

	Estimate	SE	p
Intercept	20.250	5.840	<.001
Within-person intentions	3.584	0.214	<.001
Within-person anticipated effort	-0.037	0.014	0.006
Within-person intentions*anticipated effort	-0.041	0.006	<.001
Between-person intentions	-2.701	1.969	0.173
Between-person anticipated effort	-0.186	0.084	0.028
Between-person intentions*anticipated effort	0.066	0.036	0.066
Age	-0.160	0.140	0.256
Gender Identity	-3.921	0.904	<.001
Self-report Weekly MVPA	0.002	0.001	0.168

Note. Gender Identity, Man = 0, Woman = 1, Non-Binary = 2, Another Identity = 3.