MENTAL FATIGUE, PLANNING, AND PERSUASIVE MESSAGE EXPOSURE:

A UNQIUE PERSPECTIVE IN THE CONTEXT OF PHYSICAL ACTIVITY

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ABSTRACT

Existing research shapes our understanding of the effects of mental fatigue on physical activity (PA) behaviour, the importance of planning for PA to enhance PA participation, and the value of including persuasive messaging techniques within PA behaviour change interventions. However, extant literature does not directly provide understanding regarding the effects of a PA planning intervention on experiences of mental fatigue, the potential negative influence of mental fatigue on choice to plan for PA and PA plan quality, nor the potential effects of persuasive message exposure on choice to plan for PA when mentally fatigued.

Study 1 explored if planning for PA heightened feelings of mental fatigue, and how individual psychological characteristics relate to experiences of mental fatigue. Study 2 examined the effects of a mentally fatiguing task on choice to plan for PA and the quality of a PA plan, as well as explored potential psychological correlates of mental fatigue. Study 3 examined if exposure to persuasive messages would influence not only choice to plan for PA, but also influence psychosocial predictors of the Health Action Process Approach (HAPA) model following a mentally fatiguing task. Changes in HAPA variables were examined as predictors of choice to plan for PA.

Across these three studies, results suggest that: a) although likely not more mentally fatiguing than other daily tasks, planning for PA may still contribute to heightened feels of mental fatigue, b) experiences of heightened mental fatigue may or may not influence choice to plan for PA and PA plan quality, but trait self-control and trait grit are important psychological factors in the relationship between mental fatigue and choice to plan for PA, and c) exposure to persuasive messaging can increase the likelihood of choosing to plan for PA at a relatively high level, at least in the short term. Future researchers should attempt to better understand the

relationship between mental fatigue, PA planning, and persuasive messaging by conducting studies that are mixed-method and naturalistic, with longer follow up periods to better analyze plan follow through.

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CHAPTER 1 – Literature Review

1.1 Physical Activity, Motivation, and the Intention Behaviour-Gap

It is widely accepted that participation in physical activity (PA) has tremendous physiological, psychological, and social benefits accumulating to an enhanced overall quality of life (Marquez et al., 2020; Martin-Rodriguez et al., 2024). That said, studies examining global rates of PA suggest that approximately 30% of adults meet the PA recommendations of the World Health Organization (i.e., an average of 150 minutes of moderate intensity PA per week; Guthold et al., 2018; WHO, 2020). Such statistics indicate a need for improved motivation to participate in PA. Motivation is a central tenet of human psychology and a heavily researched construct, both within and outside of PA literature. Broadly, motivation can be defined as driving forces or desires that direct behaviour toward goal-directed action or inaction (Dweck, 2017). Research has shown that the greater one's motivation to participate in PA, the more likely they are to adopt and maintain PA behaviour (see Englert & Taylor, 2021 for a review). It is understood that motivational processes form an individual's intentions to carry out a given behaviour, therefore rendering motivation a key antecedent to PA intentions, and subsequent PA participation (Gollwitzer, 1990; Schwarzer, 2008). Although the definition of intention is somewhat ambiguous, it is widely accepted as one of the strongest predictors of PA (Gollwitzer, 1990; Schwarzer, 2008). Despite the established relationship between PA intentions and PA participation, numerous studies have demonstrated that PA intentions often do not translate into PA behaviour; a phenomenon known as the 'intention-behaviour gap' (Rhodes & Rebar, 2017; Rhodes et al., 2020). Behaviour change models, such as the health action process approach (HAPA; Schwarzer, 2008), suggest that the likelihood of translating PA motivation, into PA

intentions, and ultimately into PA behaviour, is largely dependent upon one's ability to self-regulate and exert effort.

1.2 Self-Regulation and Effort

Self-regulation has been heavily studied since the 1970s and is one of the strongest predictors of goal persistence and achievement (Carver & Sheier, 1998; Duckowrth & Sleigman, 2017). Self-regulation can be defined as the ability to utilize volitional processes (i.e., consciousness) to align one's thoughts, emotions, and behaviours with a desired end state or goal (Baumeister et al., 1998; Carver & Sheier, 2001; Hofmann et al., 2012). The greater one's self-regulatory ability (either innately or learned), the more likely they are to achieve their goals (De Ridder et al., 2017). Alternatively, the poorer one's self-regulatory ability, the less likely they are to achieve their goals and the more likely they are to participate in maladaptive behaviours (Tangney et al., 2004). As such, the ability to self-regulate is an extremely valuable process of volition, but does require effort.

Effort (both mental and physical) is another highly influential contributor to goal achievement and behaviour change. While motivation orients individuals toward a specific goal, effort is the "subjective intensification of mental and/or physical engagement in the service of meeting some goal" (Eisenberger., 1992). The law of least work states that when presented with more than one option, individuals will typically avoid tasks that require more effort and choose to participate in tasks that require less effort (i.e., people are 'lazy organisms' that want to exert as little effort as possible; Hull, 1943; McGuire, 1969). Recent research has continued to reinforce this dogma of effort and has further suggested that although the exertion of effort can be valuable, experiences of effort exertion are often unpleasant and aversive (Dreisbach & Fischer, 2015; Inzlicht et al., 2018; Kurzban, 2016). One's ability to self-regulate and their

perception of effort are therefore subjective experiences that influence the relationship between PA intentions and PA participation (Shenhav et al., 2017).

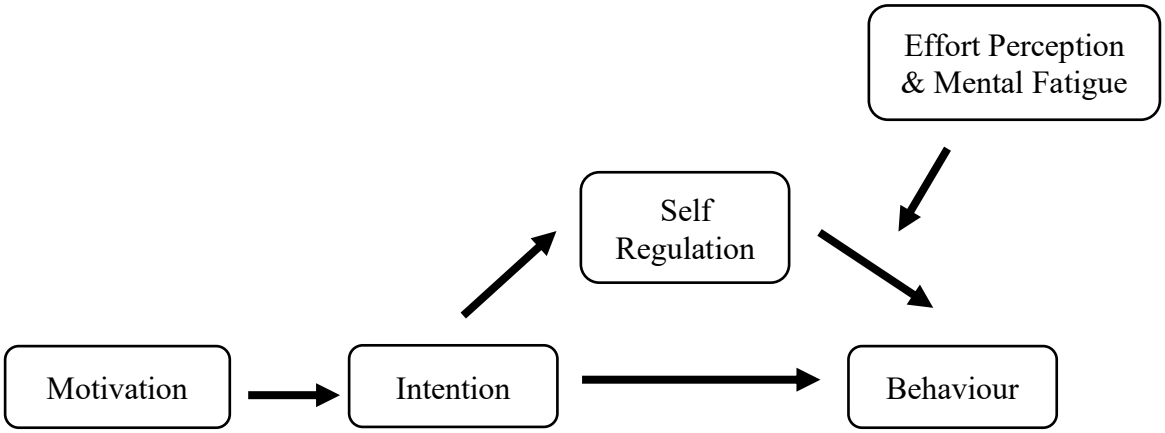
1.3 Psychobiological Model and Mental Fatigue

The psychobiological model (Marcora, 2010) is an effort-based decision-making theory that attempts to further explore how subjective experiences of motivation and effort can influence the relationship between PA intentions and PA participation. Specifically, the psychobiological model is rooted in motivational intensity theory (Brehm & Self, 1989) and parallels original conceptualizations of effort such as the law of least work and the lazy organism model (Hull, 1943; McGuire, 1969). Originally created to enhance the understanding of self-regulation during PA endurance tasks (e.g., long-distance running), the psychobiological model suggests the following four factors play a role in one's willingness to choose to exert and maintain effort during PA: a) perception of effort, b) motivation to participate in the PA, c) knowledge about the PA task and effort required, and d) previous subjective experiences of effort exertion during PA (Marcora, 2010; Pageaux, 2014). This model further suggests that individuals do not disengage or reduce effort during PA solely because of physical exhaustion, but also because of conscious decisions regarding motivation (i.e., the maximum amount of effort that one is willing to exert), and perception of effort (i.e., conscious acuities of the duration and intensity of required effort; Marcora, 2010). More simply, the psychobiological model predicts that experiences of mental fatigue occur when the amount of perceived effort required to successfully complete a PA task exceeds either one's degree of motivation or their perceived ability to sustain a level of effort needed to be successful at that task (Marcora, 2010; Marcora & Staiano, 2010; Pageaux, 2014). From this perspective, the experience of mental fatigue is a critical factor in PA participation such that under circumstances of mental fatigue individuals

self-regulate by shifting their motivation from more to less effort (Marcora, 2010). Mental fatigue is, therefore, an index of one's perceived effort and can be defined as the subjective psychophysiological state of tiredness (or lack of energy) in response to completing an effortful task that requires cognition (Boksem & Tops, 2008). A substantial amount of previous research regarding the impact of mental fatigue on PA has been rooted in the psychobiological model and regularly parallels its predictions (see Figure 1; Brown et al., 2020; Giboin & Wolff, 2019; Graham & Brown, 2021; Holgado et al., 2020; 2021; Pageaux & Lepers, 2016)

Figure 1.

The Conceptual Relationship between Motivation, Intention, Self-Regulation, Effort/Mental Fatigue, and Behaviour



1.4 Mental Fatigue and Physical Activity

Comprehensive reviews and meta-analyses have been conducted to examine the carryover effects of cognitive exertion, and therefore experiences of mental fatigue, specifically in relation to PA participation (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021). Consistent with the application of the psychobiological model (Marcora, 2010), three meta-analyses comprised of 136 studies suggest a small-to-medium negative effect of mental

fatigue on various forms of PA participation (i.e., isometric and dynamic resistance, motor performance, and aerobic performance; Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021). That is, the greater one's experience of mental fatigue, the more likely they are to disengage from or reduce their PA participation (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Pageaux & Lepers, 2016). In line with these meta-analytic results and the psychobiological model (Marcora, 2010), previous research has also suggested that mental fatigue is a 'cardinal

exercise stopper' for fixed demand PA tasks (e.g., repeated dead-lift) and a 'cardinal effort regulator' for variable demand PA tasks (e.g., long distance running; Graham & Brown, 2021; Staiano et al., 2018). Collectively, the application of the psychobiological model (Marcora, 2010) combined with existing literature suggest that mental fatigue can be an unpleasant and aversive experience which makes one inclined to modify both the quantity and quality of effort exerted during PA, therefore potentially minimizing PA rates and quality of PA participation. To date however, there is limited research exploring the potential impact of mental fatigue on antecedents of PA participation such as self-regulatory efforts, including planning.

1.5 Planning and the HAPA Model

Although there is value in understanding how experiences of mental fatigue influence PA participation itself, it is equally important to explore how mental fatigue may influence antecedents of PA participation, particularly planning for PA. In tackling globally low rates of PA participation (i.e., ~30% of adults meeting PA recommendations; Guthold et al., 2018; WHO, 2020), self-regulatory strategies that positively influence key antecedents of PA participation are critical to support positive behaviour change and therefore PA participation (Schwarzer, 2008). A critical antecedent of PA participation is planning, as it is often touted as a

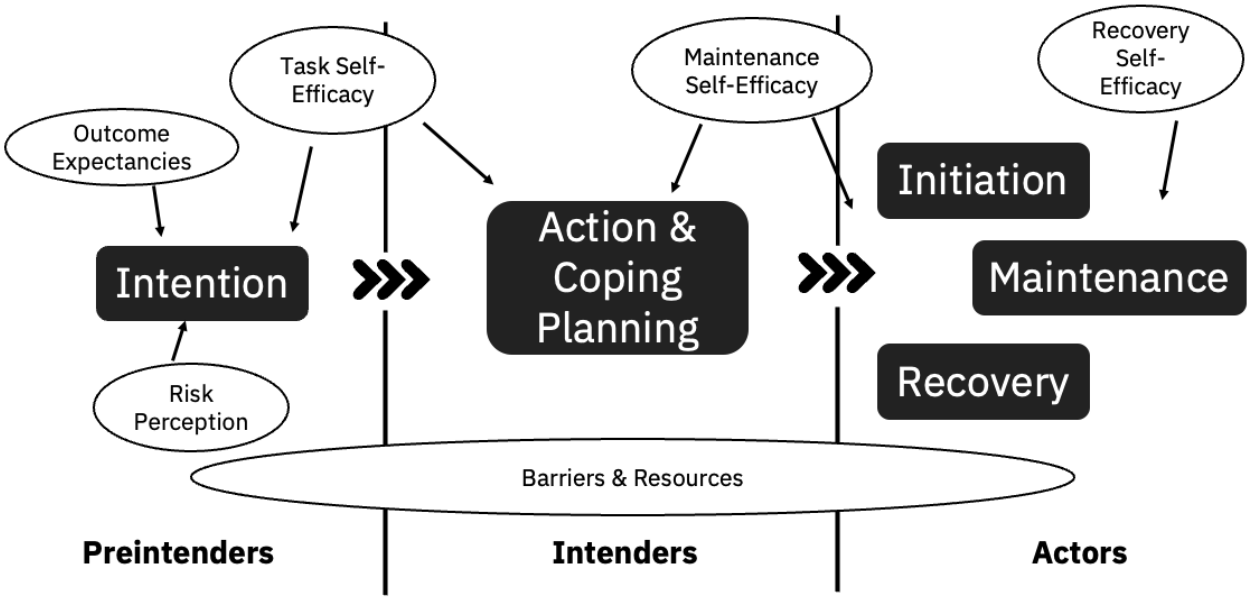
panacea for enhancing PA participation (Englert & Taylor, 2021; Moyers & Hagger, 2021). The HAPA model (Schwarzer, 2008) explicitly suggests that self-regulation via planning significantly predicts the translation of PA intentions into PA participation. More specifically, the HAPA advises that the adoption, initiation, and maintenance of health behaviours [including PA] must be explicitly conceived as a process that consists of at least a motivational phase and a volitional phase (Schwarzer, 2008). In the context of PA, the motivational phase is centered on intention formation, which is understood to be directly influenced by risk perception (i.e., perceived likelihood of being affected by engaging or not engaging PA planning), outcome expectancies (i.e., perceived outcomes attainable by engaging in PA planning), and task self-efficacy (i.e., confidence to engage in PA planning; Schwarzer, 2008). The volitional phase is sub-divided into: a) action and coping planning, and b) behaviour initiation, maintenance, and recovery, all of which are influenced by maintenance self-efficacy (i.e., confidence to continue to PA plan even in the face of barriers) and recovery self-efficacy (i.e., confidence to resume PA planning after a lapse), as well as general barriers and facilitators (i.e., physical accessibility, financials, available time; Schwarzer, 2008).

According to the HAPA model (Schwarzer, 2008) and previous research (Moyers & Hagger, 2021), planning is a particularly promising strategy to support PA behaviour change, and can be defined as "a cognitive activity that creates a narrative about the future, in which a series of actions follow a meaningful sequence, usually in the form of reaching some goal" (p. 127; Sjastad & Baumeister, 2018). Planning can be divided into two major categories: a) action planning: the process of identifying when, where, and how a specific behaviour will be performed, and b) coping planning: the process of identifying potential barriers that may interfere with an action plan, and subsequently identifying 'if-then' strategies to manage these

barriers (Pfeffer & Strobach, 2020). In the context of the HAPA model and previous PA research, action and coping planning can mediate the intention-behaviour gap, therefore catalyzing the process of translating PA intentions into PA participation (see Figure 2; Belanger-Gravel et al., 2013; Courtney et al., 2021; Moyers & Hagger, 2021; Gourlan et al., 2019; Hamilton & Schwarzer, 2018; Pfeffer et al., 2020; Pfeffer & Strobach 2019; 2020; Schwarzer, 2008; Schwarzer et al., 2011).

Figure 2.

The Health Action Process Approach (Schwarzer, 2008)



Although planning is often positioned as the gold-standard self-regulation strategy for addressing the PA intention-behaviour gap (Englert & Taylor., 2021; Moyers & Hagger, 2021), it is a complex behaviour unto itself and therefore requires effort (Bassett-Gunter & Chang, 2016; Hutchinson & Bassett-Gunter, 2016; Larocca, 2023; Michalovic et al., 2018; Tanna et al., 2017). This is evident as previous research suggests that it can be challenging to get individuals to choose to plan for PA (i.e., ~50% of samples often choose not to plan for PA when given the chance; Englert & Taylor, 2021; Guthold et al., 2018; Michalovic et al., 2018; Mistry et al.,

2015; Moyers & Hagger, 2021; Sweet et al., 2014). As such, planning for PA may be a valuable self-regulation strategy, but only if individuals are likely to actually choose to plan for PA. Extrapolating from the psychobiological model (Marcora, 2010) and the aforementioned research exploring the effects of mental fatigue on PA behaviour (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; Holgado et al., 2021; Pageaux & Lepers, 2016), it is possible that the choice to plan for PA, the quality of a PA plan, and the follow-through of a PA plan may be significantly and negatively influenced by heightened experiences of mental fatigue. Specifically, choice to plan for PA can be considered the cognitive equivalent of a fixed-demand PA task, whereas PA plan quality and follow-through can be considered cognitive equivalents of a variable-demand PA task, therefore potentially rendering mental fatigue as a negative correlate of PA planning. That said, little is known about the relationship between mental fatigue and planning for PA.

1.6 Planning for PA and Mental Fatigue

In 2018, Sjastad & Baumeister conducted a four-part study to explore the effects of ego-depletion (i.e., a parallel concept to mental fatigue) on planning outside of the PA context. Interestingly, they found that shoppers leaving the store (presumably mentally fatigued from shopping) were less willing to make a long-term plan for the next four weeks compared to shoppers who were just arriving at that same store (presumably less mentally fatigued than those leaving the store). In the same research project, they also found that participants in a laboratory setting who were more mentally fatigued were less willing to make plans for the next four weeks and were half as likely to choose a planning task compared to less mentally fatigued participants. Although this research was not focused on planning for PA, the results are in line with the tenets of the psychobiological model (Marcora, 2010) and suggest that compared to less mentally

fatigued individuals, those with heightened experiences of mental fatigue are less likely to choose to create a plan (i.e., a negative relationship between mental fatigue and choice to plan; Sjastad & Baumeister, 2018). Overall, this research suggests there may be value in considering the role of mental fatigue in understanding planning for PA as well.

The first known study to explore the relationship between mental fatigue and planning in the context of PA compared changes in both actual PA effort exertion and planned effort exertion for future PA participation (Martin-Ginis & Bray, 2009). Specifically, researchers compared participants in an intervention group who completed a mentally fatiguing task with participants in a control group who completed a mundane reading task (i.e., a task that does not typically increase the experience of mental fatigue; Martin-Ginis & Bray, 2009). Consistent with the application of the psychobiological model (Marcora, 2010), compared to the control group, participants in the mental fatigue intervention group not only exhibited a larger decrease in effort exertion during two bouts of PA, but also reported a larger decrease in planned PA intensity for future bouts of PA (Martin-Ginis & Bray, 2009). In a more recent study, choice to participate in a PA task versus a sedentary task did not differ when comparing participants who did and did not complete a mentally fatiguing task (Harris & Bray, 2019). However, experiences of increased mental fatigue were associated with a decrease in perceived value of PA participation, which may ultimately decrease the likelihood to plan for future PA (Harris & Bray, 2019). A third study found similar results with no difference in choice to participate in a PA task versus a sedentary task when comparing two groups with significantly different levels of mental fatigue (Harris & Bray, 2021). Most recently, it was observed that as experiences of mental fatigue rise, participants are less likely to choose to engage in more vigorous PA and are more likely to choose to engage in lighter future PA if provided with the option (Harris et al., 2024). Although

not directly examining the effects of mental fatigue on *planning for PA* as a behaviour itself, the results of these previous studies do align with the psychobiological model (Marcora, 2010) and previous PA research (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; Holgado et al., 2021; Pageaux & Lepers, 2016). Such alignment provides context on the potential negative effects of mental fatigue on planning for PA, and vice versa. It is therefore possible that experiences of mental fatigue may significantly reduce the choice to plan for PA and PA plan quality, and that planning for PA itself may produce heightened experiences of mental fatigue. That is, motivational strategies may be necessary to prompt PA planning, particularly among individuals under conditions of increased mental fatigue.

1.7 Messaging

One strategy of consideration for motivating planning for PA under conditions of mental fatigue is messaging. Messaging is a commonly used behaviour change technique that influences meaningful determinants of behaviour and is a well-known contributor to the additive effects of multicomponent PA interventions (Bergeron et al, 2019; Covey, 2014; Latimer et al 2007; Rhodes et al., 2021; Williamson et al, 2020). A message is specific content to be communicated to an audience, whereas messaging is "the overall process of designing, creating, and delivering the message" (p. 3; Williamson et al., 2020). The most common form of PA messaging directed at the general public is threshold messaging, typically referred to as PA guidelines. These messages are information-centered and outline the frequency, intensity, duration, and type of PA needed to achieve specific outcomes (Segar at el., 2020). Despite their widespread use, threshold messages are largely ineffective (Bergeron et al., 2019; Clarke et al., 2020; Guthold et al., 2018; WHO, 2020). That said, when *persuasive* messages are included as part of multicomponent health interventions targeting behaviours such as PA, relatively high rates of the desired

behaviour change are observed (Budzynski-Seymour et al., 2020; Milton et al., 2020). Persuasion is, "a symbolic process in which communicators try to convince other people to change their attitudes or behaviors regarding an issue through the transmission of a message in an atmosphere of free choice" (p. 15; Perloff, 2003). Assuming that engaging in complicated behaviours like PA and planning for PA requires a relatively high degree of decisional complexity, individuals are best persuaded by a message when implicit appeals to psychological determinants of behaviours are the primary focus (Budzynski-Seymour et al., 2020; Hanoch et al., 2017; Mulderrig, 2017). For example, within the context of the HAPA model, persuasive messages may appeal to and significantly influence psychological determinants of PA (e.g., risk perceptions, outcome expectancies, task/maintenance/recovery self-efficacy; Schwarzer, 2008) and therefore potentially increase the likelihood of behaviour change.

Matching messages to characteristics of the recipient audience has become recognized as a highly effective method to enhance the success of persuasive health behaviour messages (e.g., PA messages; Budzynski-Seymour et al., 2020; Faught et al., 2020; Joyal-Desmarais, 2020; Nobles et al., 2020; Segar et al., 2020; Teeny et al., 2020; Williamson et al., 2020). PA interventions can maximize the effectiveness of a message by deliberately matching characteristics of the intended audience (e.g., demographical, psychological, functional, or contextual) with features of the message (e.g., content, source of the message, and setting of the message delivery; Lasswell, 1948; McGuire, 1969; Teeny et al., 2020; Williamson et al., 2020). There are four types of message matching, categorized as: functional matching (i.e., matching the message to motivational variables), message framing (i.e., creating gain- or loss-framed messages depending upon the content of the message and population), message tailoring (i.e., matching messages to individual characteristics), and context matching (i.e., matching messages

to contextual variables; Joyal-Desmarais, 2020). Several reviews have been published in the last decade supporting the general effectiveness of exposure to persuasive messaging on motivating individuals to participate in various health behaviours (Budzynski-Seymour et al., 2019; Joyal-Desmarais, 2020; Lustria et al., 2009; Teeny et al., 2020).

1.8 Messaging and Planning for Physical Activity

Previous research outside of (Bergeron et al, 2019; Covey, 2014; Joyal-Desmarais et al., 2019; Joyal-Desmarais et al., 2020; Latimer et al 2007; Teeny et al., 2021; Williamson et al., 2020) and within the PA planning context (Bassett-Gunter et al., 2014; Michalovic et al., 2018; Mistry et al., 2015) has also shown that persuasive messaging can be an effective method for priming motivation to create a plan. Recent reviews concerning multicomponent health interventions shine light on the potential for persuasive message exposure to influence motivation and intention, therefore contributing to desired behaviour change across a spectrum of health behaviours, including planning for PA and participation in PA itself (Bergeron et al, 2019; Budzynski-Seymour et al., 2020; Milton et al., 2020; Rhodes et al., 2021; Williamson et al, 2020). Only three known studies have directly examined how exposure to persuasive messages influences planning for PA. Exposure to persuasive messages has been found to result in greater quantity and quality of PA plans created (Mistry et al., 2015; Sweet et al., 2014) and greater PA plan enactment (Mistry et al., 2015). Furthermore, emotional risk perception may moderate the impact of message exposure on PA planning (i.e., the greater one's risk perception, the more likely they are to plan for PA when exposed to gain-framed messages; Michalovic et al., 2018). Interestingly, the HAPA model (Schwarzer, 2008) describes risk perception as one of five modifiable psychosocial predictors of motivation, intention and behaviour; the other predictors being outcome expectancies as well as task, maintenance, and recovery self-efficacy. It is

therefore possible that persuasive message exposure may not only influence risk perception, but also each of the other HAPA model variables. Moreover, the HAPA model (Schwarzer, 2008) suggests that these five psychosocial predictors are proximal determinants of action and coping planning (Schwarzer, 2008). Exposure to persuasive messaging that influences these HAPA predictors may lead to changes in motivation and intention, which may ultimately prompt behaviour change. In the context of this dissertation, the target behaviour being examined and explored is planning for PA. There is no known research that has explored the effects of persuasive messages on the behaviour of planning for PA within the context of HAPA and under conditions of mental fatigue. The motivational influence of persuasive messaging may be particularly beneficial under conditions of mental fatigue whereby individuals may experience a heightened sense of effort and less motivation for performing a task such as planning for PA. Indeed, consistent with the application of the psychobiological model (Marcora, 2010), experiences of mental fatigue arise when perceptions of effort significantly outweigh motivation to participate in the task (e.g., planning for PA). Accordingly, it is possible that exposure to persuasive messages may lower perceptions of effort or increase feelings of motivation, therefore promoting the exertion of effort during planning for PA when experiencing heightened feelings of mental fatigue (i.e., following a mentally fatiguing task; Herlambang et al., 2019; Herlambang et al., 2021). There is limited research to understand the effects of persuasive messages on PA planning, and little is known about the role of mental fatigue in this relationship. The current dissertation sets out to deepen our understanding of the relationship between mental fatigue, planning for PA, and persuasive messaging in order to better support the optimization of future research and real-world multicomponent PA interventions.

1.9 Purpose of the Dissertation

Guided by the psychobiological (Marcora, 2010) and HAPA (Schwarzer, 2008) models, this dissertation brings a unique perspective to the examination of the relationship between mental fatigue, planning, and persuasive message exposure in the context of PA. Existing research shapes our understanding of: a) the effects of mental fatigue on PA behaviour (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; Holgado et al., 2021; Pageaux & Lepers, 2016), b) the importance of planning for PA to enhance PA participation (Belanger-Gravel et al., 2013; Courtney et al., 2021; Moyers & Hagger, 2021; Gourlan et al., 2019; Hamilton & Schwarzer, 2018; Pfeffer et al., 2020; Pfeffer & Strobach 2019; 2020; Schwarzer, 2008; Schwarzer et al., 2011), and c) the value of including persuasive messaging techniques within PA behaviour change interventions (Bassett-Gunter et al., 2014; Bergeron et al, 2019; Covey, 2014; Joyal-Desmarais et al., 2019; Joyal-Desmarais et al., 2020; Latimer et al 2007; Michalovic et al., 2018; Mistry et al., 2015; Teeny et al., 2021; Williamson et al., 2020). However, existing literature does leave questions regarding the effects of PA planning on experiences of mental fatigue, as well as the potential negative influence of mental fatigue on choice to plan for PA and PA plan quality. Additionally, questions remain about the potential effects of persuasive message exposure on choice to plan for PA when experiencing heightened feelings of mental fatigue. This dissertation attempted to fill these gaps via three phases of research examining: a) Study 1: the effects of a PA planning intervention on experiences of mental fatigue, b) Study 2: the effects of mental fatigue on choice to plan for PA and PA plan quality, and c) Study 3: the effects of persuasive message exposure on choice to plan for PA following a mentally fatiguing task. This research aimed to contribute to the PA planning literature while pragmatically contributing to an

improved understanding around strategies to bridge the PA intention-behaviour gap, motivate planning for PA, and enhance the viability of multicomponent PA interventions.

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Chapter 2: Study 1- The Relationship Between Planning for Physical Activity and Experiences of Mental Fatigue: An Exploratory Study

2.1 Abstract

Previous research indicates that planning is a valuable self-regulation strategy. That said, planning is a complex behaviour and therefore requires effort. This exertion of effort may lead to experiences of mental fatigue and may contribute to the avoidance of planning, poor quality planning, and a lack of plan follow through. The primary purpose of this study was to explore the effects of planning for physical activity (PA) on mental fatigue. Participants first completed a baseline measure of mental fatigue and were then randomized to either the control group (i.e., no planning; watched video), the action planning group, or the action plus coping planning group. All participants then reassessed their mental fatigue. A total of 252 undergraduate university students successfully completed the online study. A two (time) x three (condition) repeated measures ANOVA was conducted. There was a significant main effect for time (F (1, 247) = 30.3, $p < 0.001$; partial $\eta^2 = .11$) with participants in all conditions reporting increased mental fatigue at follow up, but no significant time x group effect (F (2, 247) = .44, $p = 0.64$; partial $\eta^2 = .004$). Results suggest that planning for PA evokes levels of mental fatigue that are similar to engaging in other daily tasks. Future research should directly compare levels of mental fatigue following planning for PA versus various daily tasks, and further explore how experiences of mental fatigue relate to one's willingness to plan for PA, plan quality, and plan follow through.

2.2 Introduction

Intentions to engage in physical activity (PA) often do not translate into PA behaviour, a phenomenon commonly referred to as the 'intention-behaviour gap' (Rhodes & Rebar, 2017; Rhodes et al., 2020). Planning is one self-regulation strategy that can support the process of

translating PA intentions into PA behaviour (see Englert & Taylor, 2021 for a review), and can be defined as a "cognitive activity that creates a narrative about the future, in which a series of actions follow a meaningful sequence, usually in the form of reaching some goal" (p. 127; Sjastad & Baumeister, 2018). Commonly, planning is divided into two major categories: a) action planning: the process of identifying when, where, and how a specific behaviour (e.g., PA) will be performed, and b) coping planning: the process of identifying potential barriers that may interfere with an action plan, and subsequently identifying 'if-then' strategies to manage these barriers (Pfeffer & Strobach, 2020). Previous research has repeatedly and extensively indicated that action and coping planning are valuable self-regulation strategies that can catalyze the process of translating intentions into behaviour (Belanger-Gravel et al., 2013; Courtney et al., 2021; Englert & Taylor., 2021; Gourlan et al., 2019; Hamilton & Schwarzer, 2018; Pfeffer et al., 2020; Pfeffer & Strobach, 2019; Pfeffer & Strobach, 2020; Schwarzer, 2008; Schwarzer et al., 2011). Although planning is often positioned as the gold-standard self-regulation strategy for addressing the PA intention-behaviour gap (Englert & Taylor., 2021), it is a complex behaviour unto itself and therefore requires motivation, intention, and effort (Bassett-Gunter & Chang, 2016; Hutchinson & Bassett-Gunter, 2016; Larocca, 2023; Michalovic et al., 2018; Tanna et al., 2017).

There is limited research to understand the intricacies of planning for PA within the context of effort. However, planning for PA may be an effortful task that could lead some individuals to avoid planning or engage in poor quality planning, unless adequate support is provided. For example, just over 50% of adults who received motivational messages about PA went on and chose to create a PA plan, and among those who did, plan quality varied (Michalovic et al., 2018). Additionally, despite high levels of motivation to support PA among

children with disabilities, less than 20% of parents who did not receive additional support chose to create a plan for their children's PA (Tanna et al., 2017). Indeed, it appears that there are barriers to planning as a strategy to facilitate PA behaviour (Englert & Taylor., 2021). It may be important to consider planning for PA within the context of effort to further understand the viability and implementation of planning interventions as a strategy to enhance PA participation.

There is limited research to inform our understanding of planning for PA within the context of factors related to effort. Nonetheless, some existing research suggests that there is value in considerations around the effort involved with PA planning. For example, it has been observed that individuals plan to exert significantly less effort during future PA bouts when they are experiencing a state of ego-depletion (i.e., a state that is said to occur when one's capacity and willingness to engage in an effortful task is significantly reduced due to effort exertion; Baumeister et al., 1998; Martin-Ginis & Bray, 2009). Outside of the PA literature, a series of studies have examined to what degree the exertion of mental effort may cause a state of ego-depletion and significantly impact the likelihood of engaging in planning. Although this research was not focused on planning for PA per se, the results suggest that compared to a control group, ego-depleted individuals are less likely to choose to create a plan (Sjastad & Baumeister, 2018). This research was supported within the PA context via results from two studies indicating that compared to a control group, mentally fatigued individuals are significantly less likely to choose to participate in PA, therefore suggesting that the exertion of mental effort and experiences of mental fatigue may significantly and negatively affect PA planning behaviour (Harris & Bray, 2019; 2021).

Although the existing research suggests that individuals are less likely to engage in planning when experiencing a state of mental fatigue, it remains unknown if participating in

planning itself may require enough effort to *cause* a state of mental fatigue. Specifically, mental fatigue can be understood as an index of one's perceived effort, and defined as the subjective psychophysiological state of tiredness (or lack of energy) in response to completing an effortful task that requires cognition (e.g., planning for PA; Boksem & Tops, 2008). Previous research outside of (Sjastad & Baumeister, 2018) and within (Harris & Bray, 2019; 2021) the PA context has shown that experiences of mental fatigue may negatively influence one's choice to plan in general and one's choice to participate in PA specifically. That said, extant literature has not examined experiences of mental fatigue following a PA planning activity. This is important to consider because if planning for PA is found to be mentally fatiguing, then this could at least in part explain why many people are unwilling to engage in planning for PA in the first place. Further, this could also in part explain why some individuals do not follow through on their plans and therefore do not engage in PA post planning (Englert & Taylor., 2021).

In addition to exploring the effects of planning for PA on mental fatigue, it is valuable to understand how mental fatigue is associated with various psychological characteristics. A commonly deployed framework in the PA and effort literature, the psychobiological model (Marcora, 2010), along with several other cognitive models of self-regulation and effort reinforce that differences in psychological characteristics (innate or learned) lead some individuals to be more inclined than others to exert effort even when mentally fatigued (Anderson et al., 2004; Aston-Jones & Cohen, 2005; Inzlicht et al., 2018; Keller, 1987; Kool & Botvinick, 2014; Kurzban et al., 2013; Muller & Apps, 2019; Paas et al., 2005; Sjastad & Baumeister, 2018; Taatgen, 2013; Westbrook et al., 2013). The importance of considering the effects of psychological characteristics on one's willingness to exert effort while planning has been highlighted in previous research. For example, people with a higher degree of trait self-control

were found to be significantly more likely to engage in planning than those with lower levels of trait self-control (Sjastad & Baumeister, 2018). As such, trait self-control as well as other psychological characteristics (e.g., motivation, perception of effort, need for cognition, self-regulation, grit, and meaningfulness of effort) known to influence one's willingness to exert effort may also be associated with experiences of mental fatigue following a PA planning task (Borg, 1998; Campbell et al., 2022; Carey et al., 2004; Duckworth & Quinn, 2009; Lins de Holanda Coelho et al., 2020; Stults-Kolehmainen et al., 2020). There is no known research examining the association between individual psychological characteristics and experiences of mental fatigue while planning for PA. In response to the recent call for future research to explore individual level psychological characteristics in relation to experiences of mental fatigue, (Graham & Brown, 2021), the present study not only explored the effects of planning for PA on mental fatigue, but also how various psychological characteristics relate to experiences of mental fatigue.

As such, the primary purpose of this study was to explore if planning for PA increases experiences of mental fatigue. It was hypothesized that participants who engaged in a PA planning task would report significantly greater increases in mental fatigue than those in a non-planning control group. It was also hypothesized that individuals who created an action plan *and* coping plan would report significantly greater increases in mental fatigue than those who created only an action plan. The secondary purpose of this research was to explore how individual psychological characteristics were related to experiences of mental fatigue. Given the exploratory nature of the secondary purpose of this study, there were no a priori hypotheses.

2.3 Methods

2.3.1 Participants

A G*Power calculation with the power set to .80 was conducted and determined that a minimum of 158 participants was required to detect a medium effect (f = 0.25) at p = .05 (Serdar et al., 2020). Participants were recruited online through two university undergraduate participant pools. All data were collected online using Survey Monkey. Inclusion criteria included: a) being an undergraduate student, b) having access to a computer and internet, and c) having the ability to participate in English. A total of 252 participants were included in the final analyses. Study protocol and analyses were approved by the Office of Research Ethics of York University, Toronto, Canada (certificate #: e2022-306).

2.3.2 Procedure

Undergraduate students who chose to participate provided informed consent (Appendix A) and were directed to the baseline questionnaire assessing demographic variables and baseline mental fatigue. Participants were then randomized to either one of two intervention conditions (i.e., action planning group, action plus coping planning group) or a control condition (i.e., watching a video). Following the intervention and control tasks (approximately 10 to 15 minutes in length), mental fatigue was reassessed and participants completed questionnaires assessing manipulation and robustness checks as well as various psychological characteristics. Finally, participants were debriefed and received credit toward their undergraduate course.

2.3.3 Materials

Action and Coping Planning Tasks. The online action planning task was informed by an existing planning framework (Rhodes et al., 2010), which describes a six-step PA action planning system concerning PA type, location of activity, date and time, equipment needed, motivation, and incentive. Specifically, participants were provided with a seven-day calendar on Google Docs that included the six-step PA action planning system, in which participants were

provided with a one-day example and were instructed to directly fill in the rest of the calendar in accordance with the instructions, example, and the Canadian Physical Activity Guidelines for Adults (i.e., at least 150-minutes of moderate to vigorous PA per week). Participants randomized to the action and coping planning condition completed the action planning task and then subsequently completed an online coping planning task informed by the same framework. For coping planning, participants were asked to identify potential barriers they may experience when attempting to participate in PA (Rhodes et al., 2010) and were provided with examples of physical, psychological, physiological, social, financial, and priority barriers to PA, as well as a completed example of an "if-then" coping planning statement. Participants were then provided with three fillable sections where they completed their own "if-then" coping planning statements.

Control Task. The control task required participants to watch a 13-minute cooking video on YouTube titled *Cookin' Somethin' with Matty Matheson – The Greatest Meatball Sub.* This video was chosen for the control condition in response to limitations highlighted in previous research (Fortes et al., 2020; Graham & Brown, 2021; Mangin et al., 2021; Milyavskaya et al., 2019) suggesting that future studies should: a) move away from traditional control tasks such as documentaries, b) utilize control tasks that are longer than the traditional three-to-five-minute tasks; pilot testing demonstrated that the typical time to complete the planning interventions was 10 to 15 minutes, therefore making the 13 minute control task similar in length, and c) utilize control tasks that attempt to avoid inducing a state of boredom as such a state can be easily perceived as a mental fatigue.

2.3.4 Measures

Mental Fatigue. Participants self-reported their experiences of mental fatigue using a visual analogue scale (LaChappelle & Finlayson, 1998; Lee et al., 1991). Participants were asked

to report how mentally fatigued they felt *at that exact moment* and chose an option on a visual scale ranging from 0 (completely alert and engaged) to 10 (extremely mentally fatigued).

Psychological Characteristics. Participants completed self-report measures of the following variables: a) motivation for PA was measured using the 10-item CRAVE Scale for PA, ranging from 1 (not at all) to 10 (more than ever; Cronbach $\alpha > .85$; Stults-Kolehmainen et al., 2020), b) perception of effort following the intervention and control task was measured using the Borg Rating of Perceived Exertion, ranging from 6 (no exertion at all) to 20 (maximal exertion; Borg, 1998), c) trait need for cognition was measured using the 6-item Need for Cognition Scale, ranging from 1 (extremely uncharacteristic) to 5 (extremely characteristic; Cronbach $\alpha > .86$; Lins de Holanda Coelho et al., 2020), d) trait self-regulation was measured using the 31-item Self-Regulation Questionnaire, ranging from 1 (strongly disagree) to 5 (strongly agree; Cronbach $\alpha > .84$; Carey et al., 2004; Neal & Carey, 2005), e) trait self-control was measured using the 13-item Brief Self-Control Scale, ranging from 1 (very much like me) to 5 (not at like me at all; Cronbach $\alpha > .82$; Manapat et al., 2021; Tangney et al., 2004), f) trait grit was measured using the 8-item Short Grit Scale, ranging from 1 (very much like me) to 5 (not at like me at all; Cronbach $\alpha = .60$ to .79; Duckworth & Quinn, 2009), and g) trait meaningfulness of effort was measured using the 18-item Meaningfulness of Effort Scale, ranging from 1 (strongly disagree) to 5 (strongly agree; Cronbach $\alpha = .91$; Campbell et al., 2022). A measure of boredom was also included as the subjective experience of boredom is understood to parallel that of mental fatigue and can confound the mental fatigue results (Mangin et al., 2021; Milyavskaya et al., 2019). Boredom was measured using a visual analogue scale, ranging from 0 (completely alert and engaged) to 10 (extremely bored; LaChappelle & Finlayson, 1998).

Manipulation & Robustness. Plan quality and task recall were assessed as manipulation and robustness checks. The scoring of the quality of each participant's plan was based on previous research (Mistry et al., 2015). Specifically, action plan quality was scored on a range from 0-6, whereas the action plus coping planning quality was scored from 0-9 (i.e., 6 for the action planning aspect and 3 for the coping planning aspect). One researcher reviewed each participant's plan. A single point was awarded for each aspect (i.e., PA type, location of activity, date and time, equipment needed, motivation, and incentive) if present within the action planning component. For participants who also created a coping plan, additional points were awarded for completing an if-then statement, with a total of three if-then statements to be completed. Higher scores represented higher quality plans. Plan quality was considered as a manipulation and robustness check; participants (N = 17) with very low-quality plans (i.e., < 3 for action planning and < 4 for action plus coping planning) were removed from the dataset due to concerns that they may not have exerted sufficient effort to increase experiences of mental fatigue. Ultimately, these participants did not adequately complete the planning task. Task recall was assessed via a multiple-choice question asking participants to indicate what task they just completed. Participants who were not able to correctly recall the planning task (N = 43) were removed from the analyses as they may not have paid enough attention nor allocated sufficient effort to increase experiences of mental fatigue.

Demographics. Participants self-reported their sex, age, year of undergraduate study, university major, and ethnicity. PA participation was measured through self-report of the average minutes of moderate to vigorous aerobic PA completed per week over the past month. Previous experience with planning was measured using a 9-item scale derived from previous planning research (Cronbach $\alpha > .80$; Pfeffer & Strobach, 2019; Sniehotta et al., 2005), asking participants

about the current action and coping planning behaviours, with items ranging from 1 (completely disagree) to 4 (completely agree). Full details regarding Study 1 materials and measures can be found in Appendix B.

2.4 Results

2.4.1 Data Cleaning and Assumption Testing

Data were analyzed using using SPSS version 28 (IBM Corporation, Armonk, NY, USA), were cleaned, and inspected for violations of statistical assumptions. Little's MCAR test was utilized to determine if data were missing completely at random (Little, 1988). There were minimal data found to be missing (n = 6), all of which were indicated to be missing completely at random. Pairwise deletion was employed in the analyses.

2.4.2 Descriptive Results

A final sample of 252 participants were included in the analyses (i.e., N = 76 control group, N = 102 action planning group, N = 74 action plus coping planning group). The majority of participants regularly engaged in PA (i.e., participated in at least 150 minutes of PA per week; *n* = 131, 52%), were female (*n* = 179, 71%), aged 18 to 23 (*n* = 238, 94.4%), second year university students, (*n* = 143, 56.7%), kinesiology majors (*n* = 144, 57.1%), and people of colour (*n* = 128, 50.7%). The average minutes per week of moderate to vigorous PA were 144.1 (*SD* = 138.9), while the average previous experience with planning for PA score was 2.6 out of 4 (*SD* = 0.7). See Table 1 for a complete description of participant characteristics.

Table 1.

Descriptive Statistics of the Sample (N = 252)

Variable	Overall (*n* = 252)				Control (*n* = 76)		Action Planning (*n* = 102)		Action + Coping Planning (*n* = 74)	
	n	**%**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Baseline PA (avg mins per week)			144.1	138.9	157.3	153.5	140.3	130.3	135.5	135.6
Baseline Planning			2.6	0.7	2.62	0.73	2.65	0.53	2.58	0.71
Change in Mental Fatigue			0.51	1.47	0.46	1.25	0.45	1.37	0.64	1.78
Quality of PA Plan			-	-	-	-	5.6	0.76	8.34	0.90
Boredom			4.5	2.34	4.74	2.13	4.39	2.4	4.39	2.5
Perception of Effort			7.02	3.36	6.25	3.48	7.40	3.06	7.28	3.56
Motivation to Participate in PA			5.9	1.3	5.72	1.33	6.07	1.33	5.92	1.30
Need for Cognition			3.1	0.6	3.08	0.66	3.08	0.62	3.01	0.62
Trait Self-Regulation			3.4	0.4	3.34	0.41	3.41	0.43	3.50	0.41
Trait Self-Control			3.2	0.6	3.12	0.67	3.16	0.62	3.32	0.58
Trait Grit			3.1	0.7	3.02	0.67	3.12	0.68	3.20	0.60
Meaningfulness of Effort			3.5	0.5	3.38	0.40	3.52	0.50	3.48	0.50
Sex										
Male	73	29.0								
Female	179	71.0								
Age										
18 to 23	238	94.4								
24 and above	14	5.6								
Year in University										
First Year	85	33.7								
Second Year	143	56.7								
Third Year or Above	24	9.5								
Major in University										
Kinesiology	144	57.1								
Psychology	40	15.9								
Other	68	27.0								
People of Colour										
Yes	128	50.7								
No	113	44.8								
Do not wish to report	11	4.5								

2.4.3 Changes in Mental Fatigue

A two (time; baseline vs post-intervention) x three (condition; action plan vs action plus coping plan vs control) repeated measures ANOVA was calculated with mental fatigue as the dependent variable (see Table 2). There was a significant main effect for time (F (1, 247) = 30.3, $p < 0.001$; partial $\eta^2 = .11$), but no significant time x group effect (F (2, 247) = .44, $p = 0.64$; partial $\eta^2 = .004$). As such, experiences of mental fatigue did not significantly differ over time between groups, but did significantly increase across all groups from pre- to post-intervention. Post hoc analyses were not completed due to a lack of significant time x group interaction effect. See Figure 1 for a visual representation of experiences of mental fatigue over time and between groups.

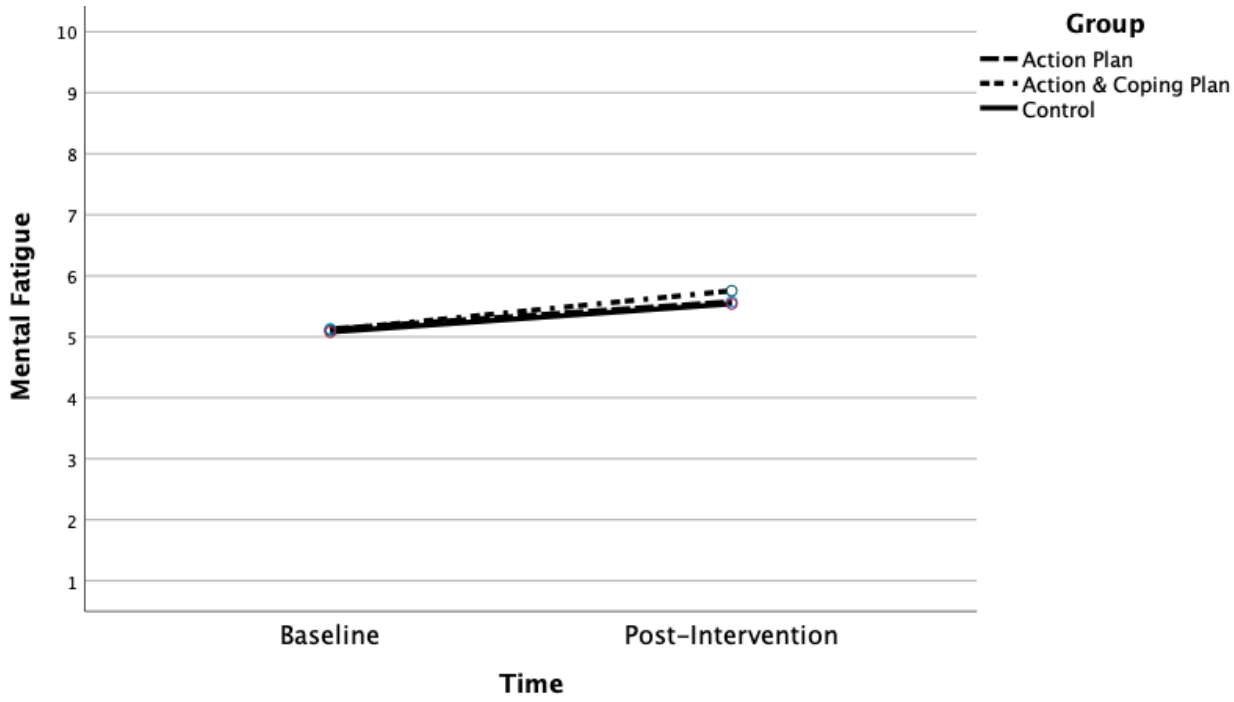
Table 2.

Repeated Measures ANOVA of Mental Fatigue by Time and Group

Group	**Baseline** ***M(SD)***	**Post-Intervention** ***M(SD)***	**Time**	**Group**	**Time* Group**
Control	5.08 (2.15)	5.54 (2.26)	F (1, 247) = 30.3, $p < 0.001$; partial $\eta^2 = .11$	F (1, 247) = .06, $p = 0.94$; partial $\eta^2 = .00$	F (2, 247) = .44, $p = 0.64$; partial $\eta^2 = .004$
Action Planning	5.13 (2.43)	5.57 (2.36)			
Action + Coping Planning	5.11 (2.33)	5.75 (2.52)			

Figure 1.

Changes in Mental Fatigue from Baseline to Post-Intervention



2.4.4 Association between Mental Fatigue and Psychological Characteristics

Previous experience with planning for PA was found to be significantly and negatively correlated with pre-intervention mental fatigue (r = -.16, p < .05). Trait grit was significantly and negatively correlated with both pre- (r = -.13, p < .05) and post-intervention mental fatigue (r = -.13, p < .05), while trait self-control was significantly and negatively correlated with post-intervention mental fatigue (r = -.16, p < .05). See Table 3 for more correlations.

Table 3.

Correlation Matrix

	Base PA	Base Plan	AP + CP Quality	AP Quality	Base MF	Post MF	Bored	Effort	Motiv	Cog	Self-Reg	Self-Control	Grit	Meaning Effort
Base PA	1													
Base Plan	.53**	1												
AP + CP Quality	-.17	.01	1											
AP Quality	.02	-.10	c.	1										
Base MF	-.07	-.16*	-.06	-.13	1									
Post MF	-.06	-.09	.00	-.10	.81**	1								
Bored	-.06	-.14*	-.07	-.28**	.43**	.31**	1							
Effort	.11	.17**	.03	.12	.05	.12	.11	1						
Motiv	.22**	.29**	-.05	.05	.06	.12	.03	.38**	1					
Cog	.00	.10	-.07	-.16	.00	.00	-.11	-.02	.14*	1				
Self-Reg	.16*	.26**	.07	.10	.02	.06	-.07	.15*	.27**	.28**	1			
Self-Control	.06	.22**	.05	.16	-.12	-.16*	-.23**	-.07	-.01	.24**	.28**	1		
Grit	.01	.26**	.21	.10	-.13*	-.13*	-.17**	-.02	.02	.26**	.27**	.74**	1	
Meaning Effort	.16*	.34**	.04	.07	-.07	-.03	-.11	.22**	.30**	.22**	.53**	.15*	.21**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
c. Cannot be computed because at least one of the variables is constant.
Note. Base PA = baseline physical activity, Base Plan = baseline planning experience, AP+ CP Quality = action plus coping plan quality, AP Quality = action plan quality, Base MF = baseline mental fatigue, Post MF = post-intervention mental fatigue, Bored = current level of boredom, Effort = perception of effort, Motiv = motivation for PA, Cog = need for cognition, Self-Reg = trait self-regulation, Self-Control = trait self-control, Grit = trait grit, Meaning Effort = meaningfulness of effort

2.5 Discussion

2.5.1 Planning for Physical Activity and Mental Fatigue

Expanding on previous research within and beyond the PA context (Harris & Bray, 2019; 2021; Sjastad & Baumeister, 2018), the purpose of this study was to explore: a) if planning for PA increases experiences of mental fatigue, and b) the association between experiences of mental fatigue and various psychological characteristics.

Significant increases in mental fatigue were observed for participants in all conditions including the planning conditions and the control condition. Although planning for PA may not be *more* mentally fatiguing than engaging in another task (i.e., watching a video), participants did experience a medium-to-large increase in mental fatigue following planning. This finding suggests that planning for PA has potential to create a psychophysiological state of tiredness or lack of energy (Boksen & Tops, 2008), which may ultimately negatively influence people's willingness to plan for PA, plan quality, and the likelihood of plan follow-through (i.e., widen the intention-behaviour gap for PA participation; Englert & Taylor., 2021 Rhodes & Rebar, 2017; Rhodes et al., 2020). Unfortunately, our failure to employ a truly non-mentally fatiguing control task makes it difficult to unpack the results of the study. However, it is important not to overlook the possible mentally fatiguing effects of planning that could have implications for future research and real-world PA interventions. For example, implementation of strategies to mitigate experiences of mental fatigue or support one's ability to exert effort while experiencing mental fatigue may help to optimize peoples' ability to plan for PA. Future research is necessary to better understand the effects of planning on mental fatigue.

Although the cooking-show control task ultimately failed to provide a non-mentally fatiguing task, it was employed in response to previous research and a recent meta-analysis suggesting that researchers should move away from control tasks that rely on traditional documentaries and induce a state of boredom, while concurrently utilizing tasks longer than three-to-five minutes (Fortes et al., 2020; Graham & Brown, 2021; Mangin et al., 2021; Milyavskaya et al., 2019). Despite our best efforts, the control task did impact mental fatigue. More research is needed to fully understand how to effectively deploy a control task when exploring the effects of various behaviour (e.g., planning for PA) on mental fatigue (Graham &

Brown, 2021). Future research should either continue to explore alternatives in order to find a control task that does not heighten experiences of mental fatigue (and boredom) by any degree, or should expect that any control task participants complete will induce at least some level of mental fatigue (or boredom) and design studies to determine the relative mental fatigue evoked by intervention tasks (e.g., planning) compared to control tasks. Furthermore, future research can directly compare levels of mental fatigue caused by planning for PA versus other daily tasks (e.g., answering emails, house-hold chores, caring for children) and continue to explore how mental fatigue relates to individuals' willingness to plan for PA, plan quality, and plan follow through. Researchers should can also ensure the ecological validity of results through the exploration of this relationship within a natural environment, as the experimental paradigm and laboratory setting itself may have been mentally fatiguing.

2.5.2 Mental Fatigue and Psychological Characteristics

The secondary purpose of this research was based on the understanding that exerting effort to complete a task such as planning for PA, especially while experiencing mental fatigue, is difficult and aversive, yet adaptive (Dreisbach & Fischer, 2015; Inzlicht et al., 2018; Kurzban, 2016; Shenhav et al., 2017). Indeed, differences in psychological characteristics may significantly influence individuals' experiences of mental fatigue (Englert & Taylor., 2021; Graham & Brown, 2021; Inzlicht et al., 2018). As such, the secondary purpose of this research was to explore how individual psychological characteristics may be related to experiences of mental fatigue.

Baseline levels of mental fatigue were significantly and negatively correlated with previous experience with planning for PA. It is possible that participants with previous experience with planning for PA identified with the words 'physical activity' and 'planning' in

the title of the study. Consistent with the psychobiological model, it is possible that in anticipation of engaging in a task related to PA and planning, participants who had previous experience planning for PA may have experienced a reduction of perceived effort and enhanced motivation to successfully complete the study, therefore minimizing experiences of mental fatigue (Marcora, 2010). And vice versa, it is possible that participants with little to no previous experience with planning for PA may have seen title of the study and may have experienced a rise in perceived effort and a reduction in motivation, therefore enhancing their experiences of mental fatigue (Marcora, 2010). Future research should further explore the mechanisms underlying the possible psychological shifts predicted by the psychobiological model that could lead to reduced perception of effort as well as enhanced motivation, and ultimately lower levels of mental fatigue. Furthermore, trait self-control was significantly and negatively correlated with baseline mental fatigue, while trait grit was significantly and negatively correlated with both baseline and post-planning mental fatigue. These findings suggest that individuals with higher levels of trait self-control and trait grit may experience lower levels of mental fatigue. Both of these psychological characteristics are malleable and can be improved upon to allow for persistence toward a desired goal (Duckworth & Quinn, 2009; Sjastad & Baumeister, 2018; Tangney et al., 2004). The importance of considering the effects of trait self-control, and other psychological characteristics such as 'interest for PA' (Milyavskaya et al., 2021), on willingness to plan has been previously highlighted outside of the PA context with results indicating that individuals with higher levels of trait self-control are significantly more likely to engage in planning than those with lower levels of trait self-control (Sjastad & Baumeister, 2018). Future research should explore how to foster positive psychological characteristics or support those with poorer levels of self-control and grit within the PA planning context. In addition, future research

should consider moderation analyses to examine when individuals are more likely to choose to plan, create higher quality plans, and follow through on their PA plans. An improved understanding of how individual psychological characteristics mediate and/or moderate the relationship between mental fatigue and planning for PA would be valuable.

2.5.3 Limitations and Future Directions

Although the current study aimed to provide novel insights on how planning for PA may affect experiences of mental fatigue, and how individual psychological characteristics may be related to experiences of mental fatigue, there were several limitations to consider. Beyond the aforementioned commentary that the control task elicited experiences of mental fatigue that were similar in magnitude to the planning tasks, even larger increases in mental fatigue may have been observed among participants in the intervention tasks if those planning tasks were more difficult and therefore required more effort. The planning tasks were modelled after previous research attempting to support real-world PA planning and participation for families, and not to elicit experiences of mental fatigue (Rhodes et al., 2010). It is possible the planning tasks provided were too simple or too structured, and as such did not require the degree of effort needed to generate significantly greater experiences of mental fatigue, compared to the control task. This may have been particularly true for the participants who had experience in planning for PA prior to the study. Future research should therefore consider the use of more complex planning tasks to determine at what point of difficulty planning for PA becomes significantly more mentally fatiguing than a typical control task. It is also possible that the sample characteristics contributed to the lack of larger observed increases in mental fatigue in the intervention groups, compared to the control group. Specifically, the current research recruited through two undergraduate participant pools comprised of Psychology and Kinesiology students. It is possible that previous

exposure to research by the Psychology student participants may have contributed to an awareness around the study design and as a result they may have adjusted their answers in accordance to what they believed was 'correct' instead of what they more accurately 'felt'. It is also possible that Kinesiology student participants may have been already participating in planning for PA and PA itself, evident by the relatively high (yet variable) average minutes of reported PA per week within this sample, which is consistent with higher-than-average PA rates observed among Kinesiology students (Many et al., 2016). Future research should therefore attempt to explore the relationship between planning for PA and mental fatigue within samples of individuals who are not formally exposed to psychological measures and study designs, as well as have less interest in or experience with PA (Milyavskaya et al., 2021).

Future research in this area may benefit from the guidance of the health action process approach (HAPA; Schwarzer, 2008). The HAPA model suggests that planning, specifically action and coping planning, are essential tools to support the translation of intentions into behaviour, most importantly among 'PA intenders' (i.e., individuals who currently do not participate in adequate levels of PA but intend to do so). As such, future researchers should comprise their samples of PA intenders only to explore how such results would compare among that specific group of participants (Schwarzer, 2008). Lastly, this study solely examined the effect of planning for PA on mental fatigue and not the effect of mental fatigue on planning for PA. Future researchers can expand our current understanding by examining how experiences of mental fatigue may influence one's willingness to plan for PA, plan quality, and plan follow-through (Harris & Bray, 2019; 2021).

2.6 Conclusion

This study directly examined the effects of planning for PA on mental fatigue. There was a significant main effect for time suggesting that when individuals complete daily tasks including planning for PA, they will likely experience increased levels of mental fatigue. The effect of these changes in mental fatigue on willingness to plan for PA, plan quality, and plan follow-through remains unknown. Trait self-control, and grit characteristics were significantly associated with experiences of mental fatigue, and therefore may significantly influence willingness to choose to plan for PA. Future research should: a) continue to explore optimization of a control task in this context, b) deploy the HAPA model to more precisely explore the relationship between planning for PA and mental fatigue among PA intenders, and c) empirically examine how experiences of mental fatigue may influence willingness to plan for PA, plan quality, and plan follow-through.

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Chapter 3: Study 2 – The Effects of a Mentally Fatiguing Task on Physical Activity Plan Choice and Plan Quality

3.1 Abstract

It is understood that mental fatigue appears to serve as an adaptive experience that makes one inclined to modify both the *quantity* and *quality* of effort exerted during physical activity (PA). There is also value in understanding how experiences of mental fatigue influence antecedents of PA, particularly planning. The purpose of this study was to examine the effects of a mentally fatiguing task on the *choice* to plan for PA and the *quality* of PA planning. Mental fatigue was assessed before and after a mentally fatiguing task (experimental group) and control task (control group). Participants (N = 94) were then invited to create a PA plan. Chi-square analyses demonstrated no significant difference in choice to plan for PA between the control (54.2%) and intervention groups (54.3%; $\chi^2 = .000$, df = 1, $p = .99$, V = .002), with t-test results indicating no significant differences in PA plan quality between groups ($t(49) = -1.08$, $p = .29$, $d = .30$). Baseline mental fatigue was significantly correlated with trait self-control ($r = -.26$, $p = .05$) and trait grit ($r = -.23$, $p = .05$). Choice to plan for PA and PA planning quality may not be affected by increased feelings of mental fatigue. However, relatively low levels of choice to plan for PA suggest that strategies to motivate and support choice to plan for PA should be explored in future research.

3.2 Introduction

The psychobiological model is an effort-based decision-making theory (Marcora, 2010). This model works to understand factors beyond physiological exhaustion to explain why one chooses to disengage from or reduce their effort during physical activity (PA; Graham & Brown, 2021; Marcora, 2010; Pageaux, 2014). Originally created to enhance the understanding of self-

regulation during physical endurance tasks (e.g., long-distance running), the psychobiological model suggests that the following factors play a critical role in determining one's willingness to exert and maintain physical effort during PA: a) current perception of effort, b) motivation to participate in the PA, c) knowledge about the PA task and effort required, and d) previous subjective experience of effort exertion during PA (Marcora, 2010; Pageaux, 2014). More simply, the psychobiological model predicts that experiences of mental fatigue occur when the amount of perceived effort required to successfully complete a PA task exceeds either one's degree of motivation or their perceived ability to sustain a level of effort needed to be successful at that task (Marcora, 2010; Marcora & Staiano, 2010; Pageaux, 2014). From this perspective, mental fatigue is an index of one's perceived effort and can be defined as the subjective psychophysiological state of tiredness (or lack of energy) in response to completing an effortful task requiring cognition (Boksem & Tops, 2008). Since mental fatigue can be understood as the *subjective* experience of one's *perceived* effort, it is also thought that some individuals are more inclined than others to not only experience mental fatigue, but also exert effort when mentally fatigued (Inzlicht et al., 2018; Milyavskaya et al., 2021). As predicted by the psychobiological model (Marcora, 2010), previous research has extensively suggested that experiences of heightened mental fatigue can significantly and negatively influence many aspects of PA (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Pageaux & Lepers, 2016; 2018).

A recent comprehensive review and meta-analysis examined the carryover effects of cognitive exertion, and therefore experiences of mental fatigue, specifically in relation to PA (Brown et al., 2020). This review highlights the robust negative effects of mental fatigue on PA participation (Brown et al., 2020). Indeed, as predicted by the psychobiological model (Marcora, 2010), three meta-analyses comprised of 136 studies suggest a small-to-medium negative effect

of mental fatigue on various forms of PA (i.e., isometric and dynamic resistance, motor performance, and aerobic performance; Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021). As such, existing literature suggests that the greater one's experience of mental fatigue, the more likely they are to disengage from or reduce their PA participation (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Pageaux & Lepers, 2016). In line with these meta-analytic results and the psychobiological model (Marcora, 2010), previous research has also suggested that mental fatigue is a 'cardinal exercise stopper' for fixed demand PA tasks (e.g., repeated dead-lift) and a 'cardinal effort regulator' for variable demand PA tasks (e.g., long distance running; Graham & Brown, 2021; Staiano et al., 2018). Collectively, the extant literature and the psychobiological model (Marcora, 2010) suggest that mental fatigue appears to serve as an adaptive experience that makes one inclined to modify both the *quantity* and *quality* of effort exerted during PA. To date however, there is limited research exploring the potential impact of mental fatigue on important antecedents of PA participation (e.g., planning), and the potential individual psychological characteristics that may influence the experience of mental fatigue in the context of PA antecedents like planning.

Although there is value in understanding how experiences of mental fatigue influence PA participation itself, it is equally important to explore how mental fatigue may influence antecedents of PA participation, particularly planning for PA. In tackling globally low rates of PA (i.e., <30% of adults meet PA recommendations; Guthold et al., 2018), self-regulatory strategies such as planning are critical to support positive behaviour change and therefore PA participation (Schwarzer, 2008). Planning is a particularly promising strategy to support PA behaviour change (Moyers & Hagger, 2021), and can be defined as, "a cognitive activity that creates a narrative about the future, in which a series of actions follow a meaningful sequence,

usually in the form of reaching some goal" (p. 127; Sjastad & Baumeister, 2018). The health action process approach (HAPA) is a behaviour change model suggesting that planning, specifically action and coping planning, are important methods of self-regulation that significantly support one's ability to initiate, maintain, and recover their PA participation (Schwarzer, 2008). The HAPA model and extant literature often tout planning as a panacea in addressing the PA intention-behaviour gap through the translation of PA intentions into PA participation (Courtney et al., 2021; Moyers & Hagger, 2021; Pfeffer & Strobach 2020; Schwarzer, 2008). However, planning for PA is a complex behaviour unto itself and therefore requires motivation, effort and self-regulation. Extrapolating from the psychobiological model (Marcora, 2010) and the aforementioned research regarding the effects of mental fatigue on PA participation itself (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Pageaux & Lepers, 2016), it is possible that both the *choice to plan for PA* and the *quality of a PA plan* may be significantly and negatively influenced by experiences of mental fatigue. Specifically, under circumstances of heightened mental fatigue, the choice to plan for PA may be negatively influenced by one's heightened perception of effort required to complete the PA plan relative to the motivation to participate in that PA plan. Similarly, even if one chooses to plan for PA while experiencing heightened feelings of mentally fatigue, the quality of that PA plan may be negatively influenced by one's heightened perception of effort required to successfully complete and follow-through on that plan relative to their motivation to participate in the PA itself. That said, there is only one known study examining how planning for PA may be mentally fatiguing (Santino et al., Under Review), and minimal research examining the potential negative influence of mental fatigue on choice to plan for PA and plan quality.

Outside of the PA context, researchers have conducted a four-part study to explore the effects of ego-depletion (i.e., a parallel concept to mental fatigue) on planning more generally (Sjastad & Baumeister, 2018). Interestingly, shoppers leaving a store (presumably mentally fatigued from shopping) were less willing to make a long-term plan for the next four weeks compared to shoppers who were just arriving at that same store (presumably not mentally fatigued from shopping). They also found that participants in a laboratory setting who were mentally fatigued were less willing to make plans for the next four weeks and were half as likely to choose a planning task compared to the non-mentally fatigued participants (Sjastad & Baumeister, 2018). Although this research was not focused on planning for PA per se, results are in line with the psychobiological model (Marcora, 2010) and suggest that compared to less mentally fatigued individuals, those with heightened experiences of mental fatigue are less likely to choose to create a plan (Sjastad & Baumeister, 2018).

That said, the first known study to examine the relationship between mental fatigue and planning in the context of PA compared changes in both actual effort exertion and planned effort exertion for PA participation (Martin-Ginis & Bray, 2009). Specifically, researchers compared participants in an intervention group who completed a mentally fatiguing task with participants in a control group who completed a mundane reading task (i.e., a task that typically does not induce a state of mental fatigue; Martin-Ginis & Bray, 2009). In line with the psychobiological model (Marcora, 2010), participants in the mental fatigue intervention group not only exhibited a larger decrease in effort exertion during two bouts of PA, but also reported a larger decrease in planned PA intensity for future bouts of PA compared to the control group (Martin-Ginis & Bray, 2009). In a more recent study, choice to participate in a PA task versus a sedentary task did not differ when comparing participants who did and did not complete a mentally fatiguing task

(Harris & Bray, 2019). However, experiences of increased mental fatigue were associated with a decrease in perceived value of PA participation, which may ultimately decrease the likelihood to plan for future PA (Harris & Bray, 2019). A third study in the PA literature found similar results with no difference in choice to immediately participate in a PA task versus a non-PA task when comparing two groups with significantly different levels of mental fatigue (Harris & Bray, 2021). Most recently, it was observed that as experiences of mental fatigue rise, participants are less likely to choose to engage in more vigorous PA and are more likely to choose to engage in lighter PA if provided with the option (Harris et al., 2024). These results align with the psychobiological model (Marcora, 2010) and provide context on the potential negative effects of mental fatigue on PA and one's plan to participate in PA. However, there are important gaps that the current research will address. First, existing research suggests that experiences of mental fatigue can negatively influence choice to participate in PA and future plans to participate in PA (Martin-Ginis & Bray, 2009; Harris & Bray, 2019; 2021; Harris et al., 2024), as well as negatively influence the quality of PA participation (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Staiano et al., 2018). However, previous research has not directly examined the potential negative effect of a mentally fatiguing task on *choice to actually plan for PA* and the *quality of that PA plan*. Second, although models such as the HAPA (Schwarzer, 2008), and psychobiological model (Marcora, 2010), as well as extant literature (Englert & Taylor., 2021; Inzlicht et al., 2018; Milyavskaya et al., 2021) acknowledge that effort allocation is at least in part affected by individual psychological characteristics (Englert & Taylor., 2021; Inzlicht et al., 2018), there is no known direct examination of the correlation between various individual psychological characteristics and one's experience of mental fatigue in the context of planning for PA.

As such, there is value in furthering the understanding of the potential effects of mental fatigue on PA planning in order to better optimize existing and new planning tools to support PA behaviour change. Guided by the psychobiological model (Marcora, 2010), the primary purpose of this study was to examine the effects of a mentally fatiguing task on choice to plan for PA. It was hypothesized that compared to a control group who did not participate in a mentally fatiguing task, participants who completed a mentally fatiguing task would be significantly less likely to choose to plan for PA. The secondary purpose was to examine the effects of a mentally fatiguing task on the quality of PA planning. It was hypothesized that among participants who chose to plan for PA, those who participated in a mentally fatiguing task would create significantly lower quality plans than a control group who did not participate in a mentally fatiguing task. The tertiary purpose of this study was to explore potential psychological correlates of mental fatigue. Given the exploratory nature of the tertiary purpose, there were no a priori hypotheses.

3.3 Methods

3.3.1 Participants

A G*Power calculation with the power set to .80 was conducted and determined that a minimum of 128 participants was required to detect a medium effect at $p = .05$ (Serdar et al., 2021). Participants were recruited online through two university undergraduate participant pools and data were collected using Qualtrics. Inclusion criteria included: a) being an undergraduate student, b) having access to a computer and internet, and c) having the ability to participate in English. A total of 94 participants were included in the final analyses. Study protocol and analyses were approved by the Office of Research Ethics of York University, Toronto, Canada (certificate #: e2022-306).

3.3.2 Procedure

Once arriving to the on-campus laboratory, participants provided informed consent (Appendix C) and then were randomized to either the experimental group (i.e., mentally fatiguing task) or a control group (i.e., no mentally fatiguing task assigned). Once randomized, participants completed a baseline questionnaire assessing demographic variables and baseline levels of mental fatigue. Participants then completed the 20-minute mentally fatiguing task or one of the control tasks for 20-minutes (i.e., be on their phone, play Pac man, or watch a nature documentary). Next, mental fatigue was reassessed and all participants were asked if they would like to create a PA plan for the following week or complete a different task that would require approximately the same amount of time and effort as the PA planning task. Those who chose not to plan for their PA, did not in fact have to complete a different task, and were simply redirected to the final survey consisting of manipulation and robustness checks, as well as a battery of psychological characteristics. Those who chose to plan were provided with materials to complete their PA plan, and then completed the aforementioned final survey. Finally, all participants were debriefed and received participation credit toward their undergraduate course.

3.3.3 Materials

Mentally Fatiguing Task. The AX-Continuous Performance Task (Cohen et al., 1999) was deployed to generate a state of mental fatigue among participants in the experimental group. The task was delivered on a computer screen, in which participants responded to stimulus (in the form of X, A, B, and +) by pressing specific keyboard buttons when a target stimulus appears. This task required participants to maintain their effort and continuously process the stimulus for 20-minutes.

Control Task. Participants in the control group were told to complete one of the following three tasks for 20-minutes: a) use their phone as they wish, b) play Pac-man, or c) watch a nature documentary. The 20-minute timeline and three options provided were chosen in response to limitations highlighted in previous research suggesting that studies should: a) provide options for what control task participants want to complete, b) utilize control tasks that are longer than the traditional three-to-five-minute tasks, and c) utilize control tasks that attempt to avoid inducing a state of boredom which can be easily perceived as mental fatigue (Fortes et al., 2020; Graham & Brown, 2021; Mangin et al., 2021; Milyavskaya et al., 2019).

PA Planning Task. The planning task was informed by an existing framework (Rhodes et al., 2010), which describes a six-step PA action planning system concerning PA type, location of activity, date and time, equipment needed, motivation, and incentive. Participants were provided with a seven-day calendar on Google Docs that included the six-step PA action planning system, in which participants were provided with a one-day example and were instructed to directly fill in the rest of the calendar in accordance with the instructions, example, and the Canadian Physical Activity Guidelines for Adults (i.e., at least 150-minutes of moderate to vigorous PA per week). Participants also engaged in coping planning whereby they were asked to identify potential barriers they may experience when attempting to participate in PA (Rhodes et al., 2010) and were provided with examples of physical, psychological, physiological, social, financial, and priority barriers to PA, as well as a completed example of an "if-then" coping planning statement. Participants were then provided with three fillable sections where they completed their own "if-then" coping planning statements.

3.3.4 Measures

Mental Fatigue. Participants self-reported their experiences of mental fatigue using a visual analogue scale, ranging from 0 (completely alert and engaged) to 10 (extremely mentally fatigued; LaChappelle & Finlayson, 1998; Lee et al., 1991). Participants' degree of perceived exertion and boredom post-intervention were measured as additional considerations to further understand the experience of mental fatigue among participants. Perception of effort following the intervention and control tasks was measured using the Borg Rating of Perceived Exertion, ranging from 6 (no exertion at all) to 20 (maximal exertion; Borg, 1998); perception of effort is a proxy for mental fatigue and provides further insight into the experiences of the participants (Sjastad & Baumeister, 2018). Boredom was measured using a visual analogue scale, ranging from 0 (completely alert and engaged) to 10 (extremely bored; LaChappelle & Finlayson, 1998). A measure of boredom was included because the subjective experience of boredom is understood to parallel that of mental fatigue and can assist in bettering understanding the effectiveness of mentally fatiguing task (Mangin et al., 2021; Milyavskaya et al., 2019).

Choice to Plan for PA. The choice to plan was measured based on participants' response to the question, "what activity would you like to do next? Multiple choice options included: a) plan your PA for the next week, or b) do another activity that will require the same amount of time and effort as the above planning activity. The deception of an alternative task was utilized in order to mitigate the temptation to choose no activity over any activity (i.e., with a choice to plan or do-nothing model, it is possible that participants would have chosen nothing in order to end the study and receive their course credit).

PA Plan Quality. The quality of each participant's plan was scored based on previous research (Mistry et al., 2015). Specifically, the PA plans were scored on a range from 0-9 (i.e., 6

points for the action planning aspect and 3 points for the coping planning aspect). One researcher reviewed each participant's plan. A single point was awarded for each of the six action aspects present in the plan (i.e., one point for: PA type, location of activity, date and time, equipment needed, motivation, and incentive). A single point was also awarded for each of the three coping aspects (i.e., if-then statements). Higher scores represented higher quality plans.

Psychological Characteristics. Participants completed self-report measures of the following variables:

a) motivation for PA was measured using the 10-item CRAVE Scale for PA, ranging from 1 (not at all) to 10 (more than ever; Cronach α >.85; Stults-Kolehmainen et al., 2020), b) trait need for cognition was measured using the 6-item Need for Cognition Scale, ranging from 1 (extremely uncharacteristic) to 5 (extremely characteristic; Cronbach α > .86; Lins de Holanda Coelho et al., 2020), c) trait self-regulation was measured using the 31-item Self-Regulation Questionnaire, ranging from 1 (strongly disagree) to 5 (strongly agree; Cronbach α > .84; Carey et al., 2004; Neal & Carey, 2005), d) trait self-control was measured using the 13-item Brief Self-Control Scale, ranging from 1 (very much like me) to 5 (not at like me at all; Cronbach α > .82; Manapat et al., 2021; Tangney et al., 2004), e) trait grit was measured using the 8-item Short Grit Scale, ranging from 1 (very much like me) to 5 (not at like me at all; Cronbach α = .83; Duckworth & Quinn, 2009), and f) trait meaningfulness of effort was measured using the 18-item Meaningfulness of Effort Scale, ranging from 1 (strongly disagree) to 5 (strongly agree; Cronbach α = .91; Campbell et al., 2022).

Demographics. Participants self-reported their sex, age, year of undergraduate study, university major, and ethnicity. PA participation was measured through self-report of the average minutes of moderate to vigorous aerobic PA completed per week over the past month. Previous

experience with PA planning was measured using a 9-item scale derived from previous planning research (Cronbach $\alpha > .80$; Pfeffer & Strobach, 2019; Sniehotta et al., 2005), asking participants about their previous PA planning behaviour over the past month, with items ranging from 1 (completely disagree) to 4 (completely agree). Full details regarding Study 2 materials and measures can be found in Appendix D.

3.4 Results

3.4.1 Data Cleaning and Assumption Testing

Data were cleaned, inspected for violations of statistical assumptions, and analyzed using using SPSS version 28 (IBM Corporation, Armonk, NY, USA). One participant was removed for being an extreme outlier beyond three standard deviations above or below the mean in every variable (Field, 2009). Forty-three participants chose not to plan for PA and therefore did not have a plan quality score; there were no other missing data points.

3.4.2 Descriptive Results

A final sample of 94 participants were included in the analyses (i.e., N = 48 control group, N = 46 experimental group). The majority of participants were female (*n* = 65, 69.1%), aged 18 to 23 (*n* = 80, 85.1%), second year university students, (*n* = 61, 64.9%), kinesiology majors (*n* = 62, 66.0%), and people of colour (*n* = 55, 58.5%). The average minutes per week of moderate to vigorous aerobic PA was 164.2 (*SD* = 160), while the average previous experience with planning for PA score was 2.7 out of 4 (*SD* = 0.6). See Table 1 for a complete description of participant characteristics.

Table 1.

Descriptive statistics of the sample.

Variable	Overall (*n* = 94)				Control (*n* = 48)		Experimental (*n* = 46)	
	n	%	Mean	SD	Mean	SD	Mean	SD
Quality of PA Plan					7.85	1.08	8.12	0.67
Baseline PA (avg mins per week)			164.2	160.0	158.5	133.9	170.1	184.7
Baseline Planning			2.71	0.57	2.76	0.58	2.65	0.56
Change in Mental Fatigue			0.14	1.71	-0.44	1.6	0.74	1.63
Boredom			4.29	2.18	4.21	2.10	4.37	2.27
Perception of Effort			7.59	1.35	7.42	1.33	7.76	1.35
Motivation to Participate in PA			6.38	0.85	6.51	0.99	6.23	0.66
Need for Cognition			3.02	0.52	3.10	0.49	2.94	0.54
Trait Self-Regulation			3.29	0.25	3.30	0.25	3.37	0.36
Trait Self-Control			3.22	0.59	3.21	0.55	3.22	0.64
Trait Grit			3.15	0.61	3.13	0.54	3.18	0.68
Meaningfulness of Effort			3.39	0.35	3.39	0.31	3.38	0.39
Sex								
Male	29	30.9						
Female	65	69.1						
Age								
17 & under	7	7.4						
18 to 23	80	85.1						
24 & above	7	7.4						
Year in University								
First Year	27	28.7						
Second Year	61	64.9						
Third Year or Above	6	6.5						
Major in University								
Kinesiology	62	66.0						
Psychology	11	11.7						
Other	21	22.3						
People of Colour								
Yes	55	58.5						
No	139	41.5						

3.4.3 Differences in Mental Fatigue between Groups over Time

A two (time; baseline vs post-experiment) x two (group; experimental vs control) repeated measures ANOVA was calculated with mental fatigue as the dependent variable (see

Table 2). There was no significant main effect for time (F (1, 92) = 0.82, p = .37, partial η^2 = .01), but there was a significant group (F (1, 92) = 10.72, p = .001, partial η^2 = .10) and time x group effect (F (1, 92) = 12.43, p < .001, partial η^2 = .12; see Figure 1). The manipulation was successful as demonstrated by group differences in changes in mental fatigue over time; compared to participants in the control group, participants who completed the mentally fatiguing task had a significant increase in mental fatigue. Similarly, an independent t-test was calculated to compare differences in perceived exertion post-intervention and found that participants in the control group reported significantly lower levels of mental exertion (M = 3.60; SD = 2.03) compared to participants in the experimental group (M = 5.50; SD = 2.85), t(92) = -3.73 p < .001.

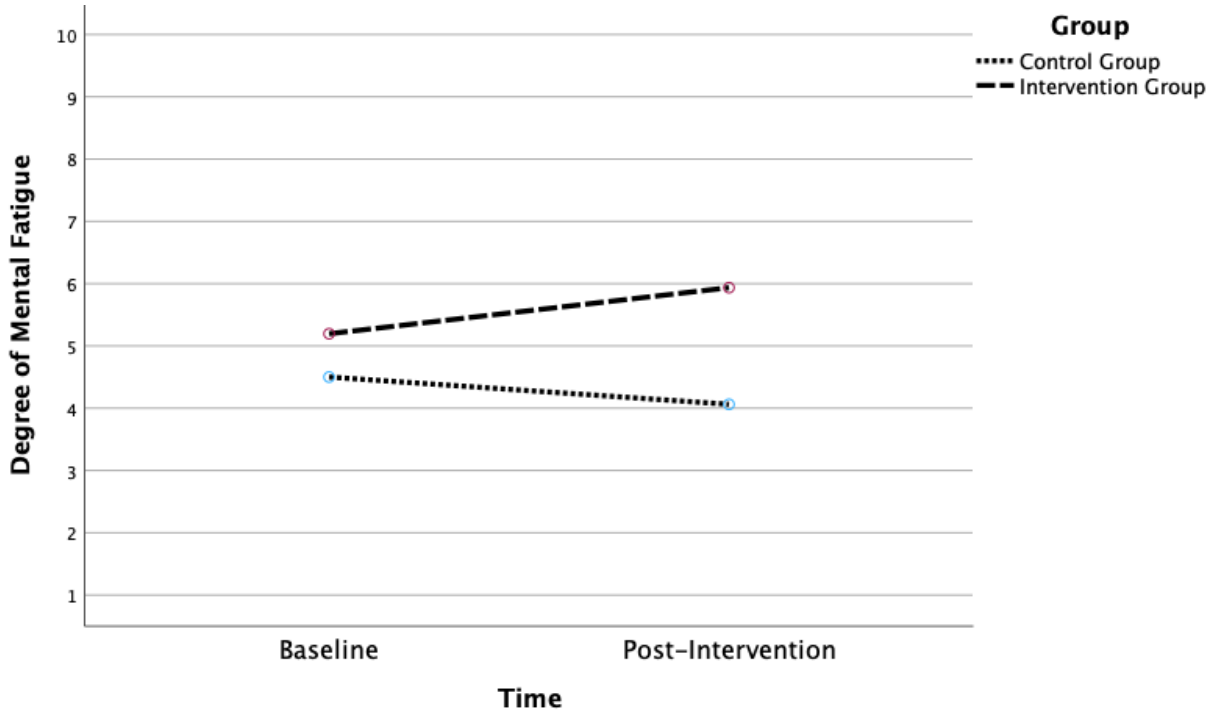
Table 2.

Results of Repeated Measures ANOVA of Mental Fatigue by Time and Group

Group	**Baseline** ***M(SD)***	**Follow Up** ***M(SD)***	**Time**	**Group**	**Time* Group**
Control	4.50 (1.92)	4.06 (1.80)	F (1, 92) = .82, p = 0.37; partial η^2 = .01	F (1, 92) = 10.72, p = 0.001; partial η^2 = .10	F (1, 92) = 12.43, p < 0.001; partial η^2 = .12
Experimental	5.20 (2.29)	5.93 (2.23)			

Figure 1.

Repeated Measures ANOVA of Changes in Mental Fatigue from Baseline to Post-Intervention Between Groups



3.4.4 Group and Choice to Plan for Physical Activity

A chi-square test of independence was performed to evaluate the relationship between group and choice to plan for PA. Results were not significant ($\chi^2 = .000$, df = 1, $p = .99$, V = .002), indicating that participants in the control group and the experimental group were equally likely to choose to create a PA plan (see Table 3). Indeed, despite group differences in levels of mental fatigue, there was an almost identical number of individuals who chose to plan in the experimental group ($n = 25$, 54.3%) as the control group ($n = 26$, 54.2%).

Table 3.

Details for Choice of Planning for Physical Activity

Group	Choice to Plan			
	Yes	**%**	**No**	**%**
Control	26	54.2	22	45.8
Experimental	25	54.3	21	45.7
Total	51	54.3	43	45.7

3.4.5 Group and Physical Activity Plan Quality

An independent t-test was calculated to examine the differences in the quality of PA plans between the control and experimental groups. There were no significant differences in PA plan quality between groups $t(49) = -1.08$, $p = .29$, $d = .30$ (see Table 4); on average, participants across both groups created high-quality plans with minimal variation in scores within and between groups (control: M = 7.85 SD = 1.08; experimental: M = 8.12, SD = 0.67).

Table 4.

Results of Independent T-Test in Difference in Physical Activity Plan Quality Between Groups

	Control *M(SD)*	**Intervention *M(SD)***	**t**	**df**	**p**	**Mean Difference**	**SE Difference**
Plan Quality	7.85 (1.08)	8.12(0.67)	-1.08	49	.29	-.27	.25

3.4.6 Correlation between Mental Fatigue and Psychological Characteristics

Both post-intervention ($r = .28$, $p = .01$) and change in mental fatigue ($r = .24$, $p = .05$) were significantly and positively correlated with perceived exertion, while pre-intervention ($r = .24$, $p = .05$), post-intervention ($r = .44$, $p = .01$), and change levels ($r = .28$, $p = .01$) of mental fatigue were all found to be significantly and positively correlated with boredom. Pre-

intervention mental fatigue was also significantly and negatively correlated with both trait self-control (r = -.26, p = .05), and trait grit (r = -.23, p = .05).

Table 5.

Correlation Matrix

	Base PA	Base Plan	Pre-MF	Post MF	Change MF	Plan Quality	Boredom	Effort	Motivation	Cognition	Self-Reg	Self-Control	Grit	Meaning Effort
Base PA	1													
Base Plan	.42**	1												
Pre-MF	.01	.04	1											
Post MF	.07	.02	.69**	1										
Change MF	.07	-.02	-.35**	.44**	1									
Plan Quality	-.06	-.09	-.12	-.27	-.16	1								
Boredom	.16	.01	.24*	.44**	.28**	-.19	1							
Effort	-.12	-.04	.11	.28**	.24*	.10	.11	1						
Motivation	.29**	.26*	.050	-.07	-.15	.03	-.07	-.13	1					
Cognition	.37**	.30**	-.05	-.10	-.07	.22	.02	-.09	.09	1				
Self-Reg	.06	.10	.080	.08	.01	-.21	.05	.11	.24*	.08	1			
Self-Control	.17	.25*	-.26*	-.12	.16	.11	-.20	.03	-.18	.06	-.38**	1		
Grit	.18	.24*	-.23*	-.17	.07	.18	-.07	-.09	-.05	.07	-.46**	.71**	1	
Meaning Effort	-.11	.06	.02	.12	.13	.05	.12	.06	.07	.19	.47**	-.29**	-.32**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Note. Base PA = baseline physical activity, Base Plan = baseline planning experience, Pre MF = baseline mental fatigue, Post MF = post-intervention mental fatigue, Change MF = change in mental fatigue from baseline to post-intervention, Plan Quality = quality of a PA plan, Boredom = current level of boredom, Effort = perception of effort, Motivation = motivation for PA, Cognition = need for cognition, Self-Reg = trait self-regulation, Self-control = trait self-control, Grit = trait grit, Meaning Effort = meaningfulness of effort

3.5 Discussion

The current study expands on previous research examining: a) mental fatigue and PA performance (Brown et al., 2020; Graham & Brown, 2021; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Staiano et al., 2018), b) the effects of mental fatigue on choice to participate in PA (Harris & Bray, 2019; 2021; Harris et al., 2022; Harris et al., 2024; Martin-Ginis & Bray,

2009), and c) the effects of mental fatigue on planning outside of the PA context (Sjastad & Baumeister, 2018).

3.5.1 Mental Fatigue and Choice to Plan for Physical Activity

The primary purpose of this study was to explore the effects of a mentally fatiguing task on *choice to plan for PA*. Although mental fatigue was successfully manipulated within the experimental condition, there were no group differences in choice to plan for PA. That is, participants who did not or did not complete a mentally fatiguing task were equally likely (or unlikely) to choose to create a PA plan. As such, results from the current study suggest that a mentally fatiguing experience does not affect choice to create a PA plan. The overall relatively low rates of PA planning suggest that in general individuals are not likely to choose to plan for PA, which has been observed in previous research (Harris & Bray, 2019; 2021; Harris et al., 2022; Harris et al., 2024; Martin-Ginis & Bray, 2009). Indeed, experimentally enhancing the probability of choice to plan has been historically difficult (Moyers & Hagger, 2021), further supporting the idea that planning for PA is a complex behaviour unto itself. The potential pragmatic difficulty for planning-based PA interventions, may in fact be motivating individuals to actually *choose* to plan for PA. Although the HAPA model (Schwarzer, 2008) and extant literature (Courtney et al., 2021; Gourlan et al., 2019; Hamilton & Schwarzer, 2018; Moyers & Hagger, 2021; Pfeffer et al., 2020; Pfeffer & Strobach 2019; 2020) highlight that planning is a critical self-regulation strategy that catalyzes the translation of PA intentions into PA participation, motivating individuals to choose to create a PA plan may be a challenge regardless of mental fatigue. According to the application of the HAPA model, choice to engage in action and coping planning for PA may be influenced by multiple factors, including intentions, risk perceptions, outcome expectancies, task-self-efficacy, maintenance self-efficacy, recovery self-

efficacy, and general barriers/resources (Schwarzer, 2008). Future research may benefit from exploring how the relationship between mental fatigue and planning for PA interact with the aforementioned psychosocial predictors outlined within the HAPA model. Future research should also attempt to better understand how to motivate individuals to choose to create PA plans through targeting the psychosocial predictors of the HAPA model more broadly (e.g., interventions to enhance risk perception, outcome expectancies, and self-efficacy; Schwarzer, 2008). One strategy to enhance HAPA variables could be exposure to persuasive messaging, which is a valuable motivational strategy previously examined in the context of PA planning interventions (Bassett-Gunter et al., 2014; Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014).

3.5.2 Mental Fatigue and Physical Activity Plan Quality

The secondary purpose of this study was to explore the effects of a mentally fatiguing task on the *quality of a PA plan*. There were no differences found in PA plan quality between individuals who did or did not complete a mentally fatiguing task. Among participants who chose to plan, quality was high with minimal variation in scores within and between these groups. Such results suggest that once individuals choose to plan for PA and are provided with enough structure and instructions, they are likely to complete a PA plan at a relatively high quality. Again, these results highlight that the pragmatic hurdle in using planning as a self-regulation strategy is likely in motivating individuals to choose to create a plan for PA.

The generalizability of the results should be interpreted with caution given that the participants had relatively high levels of PA participation (i.e., >150 minutes of PA per week on average) and high levels of experience with PA planning. Consistent with the psychobiological model (Marcora, 2010), high levels of knowledge about participating in and planning for PA may have

affected perceptions of effort and motivation for PA, and possibly nullified any potential influence of mental fatigue on *choice to plan for PA* and *plan quality*. According to the principles of the psychobiological model (Marcora, 2010), it was expected that differences in experiences of mental fatigue between groups would result in greater perceptions of effort in relation to motivation for PA in the intervention group compared to the control group. However, perception of effort and motivation for PA were similar between groups (i.e., both groups reported in the range of 'very light' effort and 'moderate' PA motivation). Although beyond the scope of the current research, it would be interesting to examine the relationship between mental fatigue, perception of effort, and motivation for PA among a sample of individuals with more diverse PA and PA planning experiences. Future research should also explore the effects of mental fatigue on PA planning specifically among inactive individuals with limited PA participation and PA planning experience. Among these individuals, it is possible that experiences of mental fatigue may affect choice to plan for PA and plan quality.

3.5.3 Mental Fatigue and Psychological Correlates

The final purpose of the current study was to explore psychological correlates of mental fatigue. Although the decision to include each of the individual psychological characteristics was grounded in theory (Baumeister et al., 1998; Inzlicht et al., 2014; Marcora, 2010; Schwarzer, 2008) and previous literature (Inzlicht et al., 2018; Sjastad & Baumeister, 2018), only trait self-control and trait-grit were found to significantly correlate with mental fatigue. Specifically, trait self-control and trait-grit were significantly and negatively related to mental fatigue such that higher levels of trait self-control and trait-grit were observed among individuals who reported lower levels of baseline mental fatigue. Considering self-control and grit as plastic psychological characteristics that can be improved upon (Duckworth & Quinn, 2009; Sjastad & Baumeister,

2018; Tangney et al., 2004), future PA intervention research should explore how the modification of self-control and grit may interact with mental fatigue in the context of PA.

3.5.4 Limitations and Future Directions

Although the current study provides a unique direct examination of the effects of a mentally fatiguing task on choice to plan for PA and plan quality, it is not without limitations. The study was underpowered with 94 participants included in the final analyses, which reduces the chances of detecting a true effect and reduces the probability that significant results reflect a true event (i.e., type 1 and 2 error; Button et al., 2013; Christley, 2010). That said, both of the groups were comprised of over 30 participants, therefore mirroring the common rule of thumb for a minimum viable sample size described by central limit theorem (Nolan & Heinzen, 2011; Zhang et al., 2023). Furthermore, a measure of state boredom was included as manipulation and robustness check as boredom is known to parallel the experience of mental fatigue (Mangin et al., 2021; Milyavskaya et al., 2019). This perspective implies that it is possible for participants to confuse mental fatigue with boredom and vice versa, making boredom a potential confounding variable to mental fatigue. Within the sample, boredom was significantly and positively correlated with pre-intervention, post-intervention, and change in mental fatigue; indicating that it is possible that when participants were attempting to report levels of mental fatigue, they may have instead been reporting on their current state of boredom. It may be valuable for future research to explore similarities and differences of experiences of mental fatigue and boredom, such that analyses could account for the potential confounding effect of boredom on mental fatigue. Furthermore, the manipulation of mental fatigue among one group and not another is a challenge for researchers in this field as it is virtually impossible to have a control group with absolutely zero mental fatigue. The goal for future research should therefore not be to have zero

mental fatigue among participants in the control group and maximal mental fatigue among participants in the intervention group, but rather better understand how the degree of one's experience of mental fatigue (i.e., thresholds of mental fatigue) may influence choice to plan for PA and plan quality.

3.6 Conclusion

The current study directly examined the effects of a mental fatigue task on the critical antecedent of PA participation that is *planning for PA*. Choice to plan for PA and plan quality did not differ between those who did or did not complete a mental fatigue task. Having higher levels of trait self-control and trait-grit were significantly and negatively correlated with experiences of mental fatigue, suggesting that these psychological characteristics may be important to consider in future research regarding mental fatigue and PA. The primary difficulty for planning-based PA interventions is likely not the ability to support the creation of high-quality PA plans, but instead, the ability to motivate people to *choose to plan for PA*. Future researchers may benefit from incorporating principles of the HAPA model and further exploring strategies to motivate planning for PA, such as persuasive message exposure.

3.7 References

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Chapter 4: Study 3 – How Planning and Persuasive Messaging Interventions Relate to Experiences of Mental Fatigue in the Context of Physical Activity

4.1 Abstract

Although planning is often considered the gold-standard self-regulation strategy to support physical activity (PA), motivating PA planning can be difficult. Mental fatigue may further discourage PA planning as such experiences generally lead to an aversion to effort. Persuasive messaging may enhance motivation for PA planning, yet its impact in the context of mental fatigue remains unknown. Guided by the health action process approach (HAPA), this study aimed to determine whether following a mentally fatiguing task persuasive messages would: a) influence the choice to engage in PA planning, and b) affect psychosocial predictors of the HAPA model. This study also examined if changes in HAPA psychosocial predictors would predict PA planning under conditions of mental fatigue. Participants (N = 110) reported baseline mental fatigue and HAPA variables, completed a mentally fatiguing task, and then reassessed their mental fatigue. Participants were assigned to receive persuasive messages (intervention) or not (control) before deciding whether to create a PA plan. HAPA variables were then reassessed. Participants who received persuasive messages (i.e., intervention groups) were significantly more likely to create a PA plan compared to participants in the control condition ($\chi 2 = 29.57$, df = 2, $p < .001$, V = .52). Regarding changes in HAPA variables, a main effect for time ($F(5, 101) = 4.63$, $p < .001$, Wilk's $\Lambda = .81$, partial $\eta 2 = .19$) was superseded by a significant time × group interaction ($F(10, 204) = 1.95$, $p = .04$, Wilk's $\Lambda = 1.99$, partial $\eta 2 = .09$), suggesting that some psychosocial predictors of PA planning from the HAPA model changed over time among participants in the intervention groups. After controlling for baseline scores, HAPA variables explained 23.7 (Cox & Snell R^2) - 31.9% (Nagelkerke R2) of the variance in choice to create a

PA plan ($\chi 2 = 29.27$, df = 5, $p < .001$). Persuasive messaging may be a useful strategy for promoting PA planning under conditions of mental fatigue. Future research should be conducted to attempt to better understand the relationship between mental fatigue, PA planning, and persuasive messaging by designing and conducting studies that are mixed-method and naturalistic with longer follow up periods to better analyze plan follow through and PA behaviour change.

4.2 Introduction

Physical activity (PA) is a challenging behaviour for many individuals. Numerous research studies have explored behaviour change strategies to foster motivation for PA and support individuals in translating PA intentions into PA behaviour (Englert & Taylor, 2021). Recent reviews suggest planning is a particularly promising strategy to support PA behaviour change (Moyers & Hagger, 2021). Planning can be broadly defined as "a cognitive activity that creates a narrative about the future, in which a series of actions follow a meaningful sequence, usually in the form of reaching some goal" (p. 127; Sjastad & Baumeister, 2018). Specifically, action planning can be understood as the process of identifying when, where, and how a specific behaviour (e.g., PA) will be performed, whereas coping planning is the process of identifying potential barriers that may interfere with an action plan and subsequently identifying 'if-then' strategies to manage these barriers (Pfeffer & Strobach, 2020). Although planning is often positioned as the gold-standard self-regulation strategy for translating PA intentions into PA behaviour (Englert & Taylor., 2021; Moyers & Hagger, 2021; Schwarzer, 2008), it is a complex behaviour unto itself and therefore requires motivation and effort (Bassett-Gunter & Chang, 2016; Hutchinson & Bassett-Gunter, 2016; Larocca, 2023; Michalovic et al., 2018; Tanna et al., 2017).

Although a great deal of research has been conducted to explore the use of planning as a behaviour change strategy to support PA (see Moyers & Hagger, 2021 for a review), planning-based PA interventions often assume individuals are sufficiently motivated to plan and therefore willing to engage in PA planning when given the choice to do so. In contrast, previous research has suggested it can be challenging to get individuals to choose to plan for PA such that ~50% of samples often choose not to plan for PA when given the chance (Englert & Taylor, 2021; Guthold et al., 2018; Michalovic et al., 2018; Mistry et al., 2015; Moyers & Hagger, 2021; Santino et al., Under Review; Sweet et al., 2014). One factor that may exacerbate challenges around the willingness to choose to plan for PA is mental fatigue, which can be broadly defined as the subjective psychophysiological state of tiredness (or lack of energy) in response to completing an effortful task that requires cognition (Boksem & Tops, 2008). Self-regulatory models such as the psychobiological model (Marcora, 2010) predict that experiences of mental fatigue occur when the amount of perceived effort required to successfully complete a task exceeds one's degree of motivation or their perceived ability to sustain a level of effort needed to be successful at that task (Marcora, 2010; Marcora & Staiano, 2010). Within the context of PA behaviour change, planning itself may be mentally fatiguing for some individuals (Santino et al., Under Review) and some may require enhanced motivation for planning when facing heightened feelings of mental fatigue that can result from many daily activities.

The detrimental effects of mental fatigue on PA *behaviour* are well established with evidence showing individuals are more likely to quit PA or reduce PA effort exertion when experiences of mental fatigue rise (Brown & Bray, 2019; Brown et al., 2020; Giboin & Wolff, 2019; Graham & Brown, 2021; Holgado et al., 2020; Holgado et al., 2021; Staiano et al., 2018). However, there is limited research concerning the effects of mental fatigue on *planning for PA*.

Outside of the PA context, it has been observed that increased mental fatigue is associated with reduced likelihood of *choosing to plan* (Sjastad & Baumeister, 2018). Further, in the face of experiences parallel to mental fatigue, those who do choose to plan are less likely to make long-term plans (Sjastad & Baumeister, 2018). Although there is limited research within the PA context, there is sufficient evidence to suggest there is value in further considering the role of mental fatigue in understanding PA planning. For example, it has been observed that individuals with heightened mental fatigue report significantly lower planned intensity for future bouts of PA compared to those experiencing less mental fatigue (Martin-Ginis & Bray, 2009). Individuals experiencing greater mental fatigue also express lower perceived value of PA participation, which may ultimately decrease the likelihood to engage in future PA (Harris & Bray, 2019; 2021). Although insightful, these studies have not directly examined the relationship between mental fatigue and *PA planning* as a behaviour itself.

Only one known study has directly examined the effects of mental fatigue on PA planning specifically (Santino et al., Under Review). Rates of PA planning did not differ between participants who completed a mentally fatiguing task and participants in a control group. This study could be interpreted to suggest mental fatigue has no relationship with PA planning, but it is important to consider that participants in the control condition who did not complete a mentally fatiguing task per se (i.e., an ax-continuous performance task in this case), did also report moderate levels of mental fatigue from baseline to post intervention (Santino et al., Under Review). Both the intervention and control groups reported experiencing mental fatigue, with rate of choice to plan for PA being approximately equal between groups (i.e., ~50% of participants in both groups chose to plan for PA). Further research is therefore needed to better understand the relationship between mental fatigue and planning for PA, and to explore

strategies for enhancing motivation to choose to engage in PA planning under conditions of mental fatigue.

Persuasive messaging may be one strategy to enhance motivation for PA planning, as it has been shown to be an effective strategy for enhancing behaviour enactment both outside of and within the PA context (Bassett-Gunter et al., 2014; Bergeron et al, 2019; Budzynski-Seymour et al., 2020; Covey, 2014; Hatchell et al., 2013; Joyal-Desmarais et al., 2020; Latimer et al 2007; Michalovic et al., 2018; Milton et al., 2020; Mistry et al., 2015; Teeny et al., 2021; Williamson et al., 2019). However, most of the persuasive messaging literature does not consider how mental fatigue may play a role in motivation for behaviour change. As noted earlier, experiences of mental fatigue may negatively influence PA participation (Brown & Bray, 2019; Brown et al., 2020; Giboin & Wolff, 2019; Graham & Brown, 2021; Harris & Bray, 2019, 2021; Harris et al., 2022; Holgado et al., 2020, 2021; Staiano et al., 2018). However, only one known study has examined the influence of persuasive messaging as a strategy to enhance PA motivation under conditions of mental fatigue (Harris et al., 2024). Results showed that participants who received persuasive messages aligned with their motivational orientation (i.e., approach or avoidance oriented) reported increased motivation for light intensity PA (Harris et al., 2024). More specific to *planning for PA*, three known studies have purposely examined how exposure to persuasive messaging influences *choice to plan* for PA. Together these studies suggest exposure to persuasive messages regarding PA participation and planning for PA may lead to a greater quantity and quality of PA planning (Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014) and greater PA plan enactment (Mistry et al., 2015). That said, none of these studies examined how persuasive messages may influence PA planning under explicit conditions of mental fatigue.

The health action process approach (HAPA; Schwarzer, 2008) may be useful for developing and evaluating persuasive messaging interventions to enhance motivation for PA planning under conditions of heightened mental fatigue. The HAPA highlights the role of planning in the behaviour change process as a catalyst to translate motivation and intention into behaviour. Specifically, the HAPA describes risk perceptions, outcome expectancies, and self-efficacy as modifiable psychosocial predictors of motivation and intention, which are the proximal determinants of action and coping planning (Schwarzer, 2008). Indeed, the application of the HAPA model (Schwarzer, 2008) and previous research suggests that there may be value in utilizing persuasive messaging to target these antecedents of motivation and intention, and in turn enhance the likelihood of planning for PA (Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014). Persuasive messages that target PA behaviour (i.e., PA participation messages) and PA planning behaviour (i.e., PA planning messages) may be useful in targeting HAPA psychosocial predictors of motivation and intention for PA planning (Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014). Specifically, in the context of PA planning, the psychosocial predictors of the HAPA model are: a) risk perceptions (i.e., perceived likelihood of being affected by engaging or not engaging PA planning), b) outcome expectations (i.e., perceived outcomes attainable by engaging in PA planning), c) action self-efficacy (i.e., confidence to engage in PA planning), d) maintenance self-efficacy (i.e., confidence to continue to engage in PA planning even in the face of barriers), and e) recovery self-efficacy (i.e., confidence to resume PA planning after a lapse). Extant literature has demonstrated the effectiveness of messaging as a strategy to enhance these HAPA variables relative to various health behaviours, including PA (Peng et al., 2024; Zhang et al., 2019). However, there is no

known research that has explored the effects of persuasive messaging on these psychosocial predictors of the HAPA model and planning for PA following a mentally fatiguing task.

Guided by the HAPA model (Schwarzer, 2008), the primary purpose of this study was to examine if exposure to persuasive messaging influences choice to engage in PA planning following a mentally fatiguing task. It was hypothesized that compared to a control group who did not receive any messages, participants who were exposed to persuasive messages would be significantly more likely to choose to create a PA plan following a mentally fatiguing task. The secondary purpose was to examine whether persuasive message exposure influences psychosocial predictors of the HAPA model following a mentally fatiguing task. It was hypothesized that compared to a no-message control group, participants who were exposed to persuasive messages would report significantly greater increases in risk perception, outcome expectancies, action self-efficacy, maintenance self-efficacy, and recovery self-efficacy. The tertiary purpose was to explore whether changes in the psychosocial predictors of the HAPA model predict whether an individual chooses to engage in PA planning following a mentally fatiguing task. It was hypothesized that changes in risk perception, outcome expectancies, action self-efficacy, maintenance self-efficacy, and recovery self-efficacy would significantly predict choice to plan for PA.

4.3 Methods

4.3.1 Participants

A G*Power calculation with the power set to .80 was conducted and determined that a minimum of 158 participants was required to detect a medium effect at $p = .05$ (Serdar et al., 2020). Participants were recruited online through two university undergraduate participant pools. Data were collected online using Qualtrics. Inclusion criteria included: a) being an undergraduate

student, b) having access to a computer and internet, and c) having the ability to participate in English. Study protocol and analyses were approved by the Office of Research Ethics of York University, Toronto, Canada (certificate #: e2022-306).

4.3.2 Procedure

Upon arrival to an on-campus laboratory, participants provided informed consent (Appendix E) and were then randomized to either one of two persuasive messaging intervention groups (i.e., PA participation message group, PA planning message group) or a no-message control group. Once randomized, participants completed a baseline questionnaire assessing demographic variables and baseline psychosocial predictors of the HAPA model. Participants in all groups then completed a mentally fatiguing task; mental fatigue was assessed prior to and immediately following completion of the task. Next, participants in the two messaging intervention groups watched a series of persuasive messages corresponding with their group assignment (i.e., three messages regarding PA participation for the PA participation message group OR three messages regarding PA planning for the PA plan message group). Participants in the control group did not receive any messages. Following persuasive message exposure (or lack thereof for the control group), participants were asked if they would like to create a PA plan for the following week or complete a different task that would require approximately the same amount of time and effort as the PA planning task. Those who chose not to plan for their PA, did not in fact have to complete a different task, and were simply redirected to the final survey consisting of follow-up measures for psychosocial predictors of the HAPA model. Participants who chose to create a PA plan were provided with the planning materials, then completed the same final survey as those who chose to not plan. Finally, all participants were debriefed and received participation credit toward their undergraduate course.

4.3.3 Materials

Messages. Six persuasive messages were utilized in the current study. All persuasive messages were in video/audio format, contained subtitles (both audio and subtitles were in English), and were between 10 to 30 seconds in length. The format of the messages was modelled from recent reviews of messaging research suggesting that health-oriented persuasive messages, including PA participation and PA planning messages, are best delivered using seemingly informal, enticing, short video clips when targeting university aged samples (i.e., 'Tik-Tok style' videos; Joyal-Desmaris, 2020; Williamson et al., 2019, 2020; Williamson, 2022). Three PA participation messages were used, modeled from Bassett-Gunter and colleagues (2014). *PA participation messages* included content that pertained to PA behaviours specifically (e.g., "undergraduate students who meet the physical activity guidelines have better study habits and academic performance than students who do not, so start small and see what happens!"). Three separate PA planning messages were used, which were modeled from Michalovic and colleagues (2018). *PA planning messages* included content specifically focused on planning for PA (e.g., "many university students find planning helpful because planning gets you thinking about your physical activity NOW, instead of forgetting about it later! Make a plan today to help yourself work towards the physical activity guidelines and live a happier - healthier life!"). All messages were designed to influence each of the five psychosocial predictors of the HAPA model. For example, the researchers of the current study attempted to influence: a) risk perception by naming the population of focus in the message (i.e., each message included the term "undergraduate" or "university" student therefore making it clear that the message is meant for them), b) outcome expectations were targeted through content regarding the population-specific benefits of PA and PA planning (i.e., making outcomes feel attainable and beneficial), c)

action self-efficacy was targeted through content focused on boosting confidence for PA or PA planning (e.g., strategies to simplify PA or PA planning), d) maintenance self-efficacy was targeted through content regarding strategies to make it easier to maintain PA, and e) recovery self-efficacy was targeted through content regarding strategies to restart PA or PA planning after a lapse (see Appendix F to watch the persuasive messages used in Study 3).

Mentally Fatiguing Task. The AX-Continuous Performance Task (Cohen et al., 1999) was deployed to elicit heightened mental fatigue among all participants. The task was delivered on a computer screen, in which participants responded to stimulus (in the form of X, A, B, and +) by pressing specific keyboard buttons when a target stimulus appears. This task required participants to maintain their effort and continuously process the stimulus in front of them for 20-minutes. This task has been found to be an effective strategy to evoke mental fatigue in experimental research settings (Brown & Bray, 2019; Marcora et al., 2009; Smith et al., 2019).

PA Planning Task. The PA planning task was informed by an existing planning framework (Rhodes et al., 2010), which describes a six-step PA action planning system concerning PA type, location of activity, date and time, equipment needed, motivation, and incentive. Specifically, participants were provided with a seven-day calendar on Google Docs that included the six-step PA action planning instructions, in which participants were provided with a one-day example and were instructed to directly fill in the rest of the calendar in accordance with the instructions, example, and the Canadian Physical Activity Guidelines for Adults (i.e., at least 150-minutes of moderate to vigorous PA per week). Participants also engaged in coping planning whereby they were asked to identify potential barriers they may experience when attempting to participate in PA (Rhodes et al., 2010) and were provided with examples of physical, psychological, physiological, social, financial, and priority barriers to PA,

as well as a completed example of an "if-then" coping planning statement. Participants were then provided with three fillable sections where they completed their own "if-then" coping planning statements.

4.3.4 Measures

Choice to Plan. The choice to engage in PA planning was measured based on each participant's response to the question, "What activity would you like to do next?" Multiple choice options included: a) plan your PA for the next week, or b) do another activity that will require the same amount of time and effort as the above planning activity. The deception of an alternative task was utilized to mitigate the temptation to choose no activity over any activity (i.e., with a choice to plan or do-nothing model, it is possible that participants would have chosen nothing in order to end the study and receive their course credit). The quality of each participant's plan was also scored to more accurately understand the current results and derive more information for future researchers to consider. PA plan quality was assessed based on previous research (Mistry et al., 2015), whereby the action plan portion was scored on a range from 0-6, and the coping plan portion was scored from 0-3. A total score ranged from 0-9 (i.e., 6 for the action planning aspect and 3 for the coping planning aspect), in which one researcher reviewed each participant's plan. A single point was awarded for each aspect present within the action planning component (i.e., PA type, location of activity, date and time, equipment needed, motivation, and incentive), as well as a single point awarded for completing each of the three if-then statements. Higher scores represented higher quality plans. Participants with a quality score of < 4 were originally intended to be removed as this would have indicated of lack of effort exertion and engagement in the study and requested tasks. In this case, no participants were removed from the analyses as all participants completed the planning task above a score of 4.

Psychosocial Predictors of the HAPA Model. HAPA model variables were measured as psychosocial predictors of PA planning motivation and behaviour. Items regarding risk perception, outcome expectancies, action self-efficacy, maintenance self-efficacy, and recovery self-efficacy were generated for this specific study based on guidance from the creators of the HAPA model (Schwarzer, 2008), as well as previous research examining changes in health behaviours, including PA planning (Bassett-Gunter & Chang, 2016; Lippke et al., 2009; Parkinson et al., 2023; Sniehotta et al., 2005). All items were focused on PA planning (e.g., I am confident that I can continuously: a) find the time to schedule and prioritize my physical activity participation, b) plan and prepare for the barriers that will prevent me from participating in physical activity). Each HAPA variable was assessed via two items with participants responding to each item on a scale from 1 (strongly disagree) to 5 (strongly agree), and final scores used in analyses being averaged.

Mental Fatigue. Participants self-reported their experiences of mental fatigue using a visual analogue scale, ranging from 0 (completely alert and engaged) to 10 (extremely mentally fatigued; LaChappelle & Finlayson, 1998; Lee et al., 1991). Participants' degree of perceived exertion (Borg, 1998) and post-intervention boredom (LaChappelle & Finlayson, 1998) were measured as additional considerations to further understand the experience participants had while completing the mentally fatiguing task. Specifically, perception of effort following the intervention and control tasks was measured using the Borg Rating of Perceived Exertion, ranging from 6 (no exertion at all) to 20 (maximal exertion; Borg, 1998) as perception of effort can be a proxy for mental fatigue (Sjastad & Baumeister, 2018). Boredom was measured using a visual analogue scale, ranging from 0 (completely alert and engaged) to 10 (extremely bored; LaChappelle & Finlayson, 1998). A measure of boredom was included as the subjective

experience of boredom is understood to parallel that of mental fatigue and can assist in bettering understanding the effectiveness of mentally fatiguing task (Mangin et al., 2021; Milyavskaya et al., 2019).

Demographics. Participants self-reported their sex, age, year of undergraduate study, university major, and ethnicity. PA participation was measured through self-report of the average minutes of moderate to vigorous aerobic PA completed per week over the past month. Previous experience with planning was measured using a 9-item scale derived from previous planning research (Cronbach $\alpha > .80$; Pfeffer & Strobach, 2019; Sniehotta et al., 2005), asking participants about their previous PA planning behaviour over the past month. Participants responded to each item on a scale ranging from 1(completely disagree) to 4 (completely agree; e.g., on average over the past month, I have made detailed physical activity plans regarding: a) which good opportunities for moderate to vigorous physical activity I should take...). Full details regarding Study 3 materials and measures can be found in Appendix F.

4.3.5 Data Analyses

The primary hypothesis that compared to a control group with no message exposure, participants exposed to persuasive messages would be significantly more likely to choose to plan for PA following a mentally fatiguing task was analyzed via chi-square test of independence. The secondary hypothesis that compared to a no-message control group, participants exposed to persuasive messages would report significantly greater levels of the psychosocial predictors of the HAPA model was analyzed via a one-way repeated measures MANOVA. Upon a significant MANOVA result, one-way repeated measures ANOVAs were conducted for each psychosocial predictor of the HAPA model to explore each variable at the univariate level, with a Bonferroni adjustment to reduce the risk of Type 1 error. Post-hoc paired sample t-tests were calculated

(once again, utilizing a Bonferroni adjustment to reduce the risk of Type 1 error) to identify which specific group(s) reported significant changes of the psychosocial predictor of the HAPA model. Exploratory post-hoc paired sample t-tests were also calculated in the presence of a non-significant result with a larger than small effect size (i.e., partial eta-squared ≥ .03). The tertiary hypothesis that changes in the five psychosocial predictors of the HAPA model would significantly predict choice to plan for PA following a mentally fatiguing task was analyzed through a binomial logistic regression.

4.4 Results

4.4.1 Data Cleaning and Assumption Testing

Data were analyzed using using SPSS version 28 (IBM Corporation, Armonk, NY, USA). Following cleaning and inspection for violations of statistical assumptions, two participants were removed as they stopped their participation following the initial demographic survey. A total of 110 participants successfully completed the study. There were no missing data points found in the dataset.

4.4.2 Demographic Results

A final sample of 108 participants were included in the analyses (i.e., N = 37 control group, N = 35 PA participation message group, N = 36 PA planning message group). A large proportion of participants self-identified as female (*n* = 75, 69.4%), aged 18 to 23 (*n* = 101, 93.5%), first year university students, (*n* = 66, 61.1%), kinesiology or psychology majors (*n* = 54, 50.0%), and people of colour (*n* = 66, 61.1%). The majority of participants reported they were either intending to engage in regular PA but were currently not (*n* = 45, 41.7%) or were currently engaging in regular PA (*n* = 56, 51.9%), with average minutes per week of moderate to vigorous aerobic PA being 208.3 (*SD* = 224.24), and the average previous experience with

planning for PA score being 2.7 out of 4 (*SD* = 0.6). See Table 1 for a complete description of participant characteristics.

Table 1.

Descriptive Statistics of the Sample

Variable	Overall (*n* = 108)				Control (*n* = 37)		PA Messages (*n* = 35)		Plan Messages (*n* = 36)	
	n	%	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Baseline PA (avg mins per week)			208.3	224.2	249.1	260.2	170.4	192.1	203.2	212.1
Baseline Planning			2.68	0.6	2.71	0.70	2.63	0.32	2.69	0.62
Change in Mental Fatigue			0.94	2.30	1.35	2.64	0.63	2.22	0.83	1.96
Quality of PA Plan			8.37	1.10	8.50	0.76	8.04	1.48	8.62	0.62
Boredom			4.59	2.59	5.14	2.76	4.20	2.73	4.42	2.23
Perception of Effort			7.44	1.48	7.68	1.84	7.49	1.25	7.17	1.23
HAPA Stage										
Pre-Intender	7	6.5								
Intender	45	41.7								
Actor	56	51.9								
Sex										
Male	32	29.6								
Female	75	69.4								
Age										
18 to 23	101	93.5								
24 and above	5	4.6								
Year in University										
First Year	66	61.1								
Second Year	21	19.4								
Third Year or Above	21	19.4								
Major in University										
Psychology	35	32.4								
Kinesiology	40	17.6								
Other	54	50								
Person of Colour										
Yes	66	61.1								
No	39	36.1								
Do not wish to report	3	2.8								

4.4.3 Changes in Mental Fatigue over Time and between Groups

To examine changes in mental fatigue following the AX-Continuous Performance Task, a two (time; baseline vs post-mentally fatiguing task) x three (group; control vs PA message vs plan message) repeated measures ANOVA was calculated with mental fatigue as the dependent variable (see Table 2). There was a significant main effect for time (F (1, 105) = 18, p < .001, partial η^2 = .15), but no significant group effect (F (2, 105) = .10, p = .9, partial η^2 = .002) and no significant time x group effect (F (2, 105) = .95, p = .39, partial η^2 = .02) such that mental fatigue significantly increased from baseline to follow-up, but did not significantly differ between groups. These results indicate a successful manipulation of mental fatigue. Furthermore, a one-way ANOVA comparing differences in perception of effort (F (2, 105) = .51, p = .60, partial η^2 = .06) and boredom (F (2, 105) = 1.3, p = .28, partial η^2 = .10) were nonsignificant, indicating that there were no group differences in perceived effort exertion and boredom.

Table 2.

Results of Repeated Measures ANOVA of Mental Fatigue by Time and Group

Group	**Baseline M*(SD)***	**Follow Up M*(SD)***	**Time**	**Group**	**Time* Group**
Control	4.27 (2.2)	4.62 (2.4)	F (1, 105) = .18, p < 0.001; partial η^2 = .15	F (2, 105) = .10, p = 0.9; partial η^2 = .002	F (2, 105) = .95, p = 0.39; partial η^2 = .02
PA Message	4.77 (2.0)	5.40 (2.3)			
Plan Message	4.47 (2.1)	5.31 (2.1)			

4.4.4 Choice to Engage in Physical Activity Planning

A chi-square test of independence was performed to evaluate the relationship between group and choice to engage in PA planning following the mentally fatiguing task. Results were significant with a large effect size (χ^2 (2) = 29.57, p < .001, V = .52), indicating that the likelihood of choosing to engage in PA planning differed between groups (see Table 3). To

further explore this finding, three separate chi-square tests of independence utilizing a Bonferroni adjustment (alpha level set to .017) were performed comparing each of the three groups to one another. Results showed the PA participation message group (χ^2 (1) = 20.02, p < .001, V = .53) and the PA planning message group (χ^2 (1) = 23.02, p < .001, V = .56) chose to plan at a greater frequency than the control group. The choice to plan for PA did not differ between the two messaging intervention groups (χ^2 (1) = .12, p = .73, V = .04). Indeed, there were stark medium-to-large differences observed in choice to plan between participants in the control group (n = 8, 21.6% chose to plan) and the PA participation message group (n = 26, 74.3% chose to plan) and PA planning message group (n = 28, 77.8% chose to plan). Compared to a no message control group, exposure to persuasive messages significantly increased the odds of choosing to plan for PA. It should also be noted that on average, across all groups, when participants chose to create a plan, they created high-quality PA plans with minimal variation in scores within and between groups (control group: M = 8.50, SD = .76; PA participation message group: M = 8.04, SD = 1.48; PA planning message group: M = 8.62, SD = .62).

Table 3.

Details for Choice of Planning for Physical Activity

Group	**Choice to Plan**			
	Yes	**%**	**No**	**%**
Control	8	21.6	29	78.4
PA Messages	26	74.3	9	25.7
Plan Messages	28	77.8	8	22.2
Total	62	57.4	46	42.6

4.4.5 Changes in Psychosocial Predictors of the HAPA Model Following Persuasive Message Exposure

A one-way repeated measures MANOVA was performed to examine changes in psychosocial predictors of the HAPA model over time and between groups. Using Wilk's Lambda, there was no significant group effect (F (10, 202) = .85, p = .58, Wilk's Λ = .92, partial η^2 = .04), but there was a significant main effect for time (F (5, 101) = 4.63, p < .001, Wilk's Λ = .81, partial η^2 = .19), which was superseded by a significant time x group effect (F (10, 204) = 1.95 p = .04, Wilk's Λ = 1.99, partial η^2 = .09) suggesting that there was a significant change in the psychosocial predictors of PA planning over time and that the change differed between groups.

To further explore differences at the univariate level, one-way repeated measures ANOVAs were then conducted for each of the HAPA model variables (see Table 4). A Bonferroni adjustment was applied ($p < .01$), with paired-sampled t-tests utilized as post-hoc analyses for any significant time x group effects (Bonferroni adjustment of $p < .017$). Given the limited power of the current study, post-hoc tests were also calculated for non-statistically significant time x group results in the presence of a larger than small effect (i.e., partial eta-squared $\geq .03$).

Action Self-Efficacy. A significant main effect for time was observed (F (1, 105) = 9.6 p = .003, partial η^2 = .08), but group (F (2, 105) = 2.1, p = .13, partial η^2 = .04) and time x group effects (F (2, 105) = 3.3, p = .04, partial η^2 = .06) were not significant at the Bonferroni adjusted value of $p < .01$. These results suggest that action self-efficacy levels for PA planning significantly increased over time across all groups. It should be noted that the time x group interaction was found to have a medium effect size and thus exploratory post-hoc paired-sample

t-tests were calculated. A statistically significant increase in action self-efficacy was not observed for the control ($t(36) = .92$, $p = .93$, $d = .02$, CI = -.31 to .34) or PA planning message group ($t(35) = 1.65$, $p = .54$, $d = .27$, CI = -.06 to .59), but was observed for participants in the PA participation message group only ($t(34) = 3.91$, $p < .001$, $d = .66$, CI = .29 to 1.0).

Maintenance Self-Efficacy. No significant main effects for group were observed (F (2, 105) = 1.7, $p = .19$, partial $\eta^2 = .03$). A significant main effect for time (F (1, 105) = 17.96 $p < .001$, partial $\eta^2 = .15$) was superseded by a significant time x group effect (F (2, 105) = 7.67, $p < .001$, partial $\eta^2 = .13$). Post-hoc paired sample t-tests identified a significant increase in maintenance self-efficacy for participants in the PA participation message group ($t(34) = 4.01$, $p < .001$, $d = .69$, CI = .31 to 1.05) and the PA planning message group ($t(35) = 4.01$, $p < .001$, $d = .68$, CI = .30 to 1.04), but not the control group ($t(36) = .66$, $p = .52$, $d = .11$, CI = -.43 to .22).

*Recovery Self-*Efficacy. No significant main effects for group F (2, 105) = 1.4, $p = .21$, partial $\eta^2 = .03$) or time x group effect (F (2, 105) = 2.44, $p = .09$, partial $\eta^2 = .04$) were found. A significant main effect for time (F (1, 105) = 10.75 $p = .001$, partial $\eta^2 = .09$) was observed and suggests that recovery self-efficacy levels for PA planning significantly increased over time across all groups. Exploratory post-hoc paired sample t-tests were calculated due to the medium effect size observed for the time x group effect. A significant increase in recovery self-efficacy was observed for participants in the PA participation message group $t(34) = 2.72$, $p = .01$, $d = .46$, CI = .11 to .81) and the PA planning message group $t(35) = 3.65$, $p < .001$, $d = .61$, CI = .25 to .96), but not the control group ($t(36) = .10$, $p = .91$, $d = .02$, CI = -.31 to .34).

Outcome Expectancies. No significant effect for time (F (1, 105) = 1.04, $p = .31$, partial $\eta^2 = .01$), group (F (2, 105) = .63, $p = .54$, partial $\eta^2 = .01$), time x group (F (2, 105) = 2.08, $p = .13$, partial $\eta^2 = .04$) were observed. These results suggest that outcome expectancies levels for

PA planning did not significantly change over time within or between groups. That said, exploratory post-hoc paired sample t-tests were calculated for each group as a result of the medium effect size observed for the time x group effect. No significant changes in outcome expectancies were observed over time for any group.

Risk Perception. No significant main effect for time (F (1, 105) = .46, p = .83, partial η^2 = .00), group (F (2, 105) = .67, p = .51, partial η^2 = .01), or time x group (F (2, 105) = .26, p = .77, partial η^2 = .01) were observed. These results suggest that overall levels of risk perception for PA planning did not change over time within or between groups.

Table 4.

Means of Psychosocial Predictors of the HAPA Model Across Time and Group

Group	**Psychosocial Predictors of HAPA**									
	Pre ASE M*(SD)*	**Post ASE M*(SD)***	**Pre MSE M*(SD)***	**Post MSE M*(SD)***	**Pre RSE M*(SD)***	**Post RSE M*(SD)***	**Pre RP M*(SD)***	**Post RP M*(SD)***	**Pre OE M*(SD)***	**Post OE M*(SD)***
Control	3.8 (0.8)	3.9 (1.0)	3.7 (0.8)	3.5 (1.0)	3.8 (1.0)	3.9 (1.0)	3.6 (1.1)	3.4 (1.3)	4.3 (0.8)	4.1 (0.9)
PA Messages	3.5 (0.8)	4.1 (0.7)	3.4 (1.0)	3.9 (0.5)	3.8 (0.8)	4.1 (0.7)	3.2 (0.9)	3.3 (1.0)	4.0 (0.7)	4.2 (0.5)
Plan Messages	4.0 (0.8)	4.2 (0.6)	4.1 (0.7)	4.7 (0.8)	3.9 (0.8)	4.3 (0.7)	3.4 (1.0)	3.4 (1.0)	4.2 (0.6)	4.4 (0.6)

Note. ASE = action self-efficacy, MSE = maintenance self-efficacy, RSE = recovery self-efficacy, RP = risk perception, OE = outcome expectancies

4.4.6 Change in Psychosocial Variables of HAPA as Predictors of Choice to Engage in Physical Activity Planning

A binomial logistic regression was computed to explore the effects of changes in risk perception, outcome expectancies, action self-efficacy, maintenance self-efficacy, and recovery self-efficacy on the likelihood of participants' choice to plan for PA following a mentally fatiguing task. PA planning was coded as 0 (no plan) and 1 (yes plan). After controlling for

baseline scores, the overall model was significant (χ^2 (5) = 29.27, $p < .001$) and explained 23.7% (Cox & Snell R^2) to 31.9% (Nagelkerke R^2) of the variance in PA planning (see Table 5). There was a significant effect for outcome expectancies (Odds Ratio = .18, SE = .55, $p = .002$, CI = .06 to .54), maintenance self-efficacy (Odds Ratio = 3.3, SE = .55, $p = .03$, CI = 1.14 to 9.67), and recovery self-efficacy (Odds Ratio = 3.1, SE = .49, $p = .02$, CI = 1.19 to 8.21) on the choice to engage in PA planning. These results suggest that changes in HAPA psychosocial predictors of PA planning significantly predicted choice to plan for PA, specifically increased levels of maintenance self-efficacy and recovery self-efficacy significantly predicted increased odds of engaging in PA planning, while increased levels of outcome expectancies significantly predicted decreased odds of choosing to plan for PA.

Table 5.

Binomial Logistic Regression for Change in Psychosocial Variables of HAPA as Predictors of Choice to Engage in Physical Activity Planning

Change in HAPA Predictors	Odds Ratio	SE	*P*	95% CI
Risk Perception	1.0	.26	.93	.62 – 1.69
Outcome Expectancies	.18	.55	.002	.06 – .54
Action Self-Efficacy	1.6	.47	.33	.64 – 3.93
Maintenance Self-Efficacy	3.3	.55	.03	1.14 – 9.67
Recovery Self-Efficacy	3.1	.49	.02	1.19 – 8.21

4.5 Discussion

The current study was guided by the HAPA model (Schwarzer, 2008) and previous research exploring: a) the critical role of planning as a strategy to catalyze PA behaviour change (Moyers & Hagger, 2021; Pfeffer & Strobach 2019; Schwarzer et al., 2011; Schwarzer & Hamilton, 2020), b) the common observation that only ~50% of participants choose to plan for

or engage in PA, irrespective of other factors, including levels of mental fatigue (Harris & Bray, 2019; Martin-Ginis & Bray, 2009; Santino et al., Under Review), and c) how persuasive message exposure may influence choice to plan for PA (Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014).

4.5.1 Persuasive Message Exposure and Choice to Engage in Physical Activity Planning

In line with the primary hypothesis, participants who received persuasive messages were significantly more likely to choose to plan for PA than those in the no-message control group. The effect was found to be moderate-to-large despite all participants having completed a mentally fatiguing task prior to message exposure and PA planning. Indeed, the manipulation of mental fatigue was effective with no group differences observed in mental fatigue, perception of effort or boredom. And yet, differences in choice to plan for PA were observed between groups. These results suggest that persuasive messaging can increase the likelihood of choosing to plan for PA. A persuasive messaging intervention, therefore, has the potential to impact choice to plan for PA in as little as a few minutes, even after experiencing heightened feelings of mental fatigue. Both research and pragmatic settings that use PA planning may benefit from the inclusion of persuasive messaging to optimize engagement. Among those who chose to plan, plan quality was relatively high and consistent, regardless of group and the heightened feelings of mental fatigue. This finding aligns with past research suggesting that with adequate support, individuals are able to complete high quality plans, and adds to the literature by suggesting that this is the case irrespective of heightened feelings of mental fatigue (Santino et al., Under Review). That is, once individuals are sufficiently motivated to choose to plan for PA, they seem to be able to create high quality plans so long as adequate instruction and support are provided.

This study directly explored the relationship between message exposure and choice to plan for PA following a mentally fatiguing task. That said, previous research examining the relationship between message exposure and choice to plan for PA provides an interesting context for discussion. Consistent with the current study, Sweet and colleagues (2014) found that motivational effects were similar between PA participation messages (i.e., emphasizing the benefits of PA) and PA planning messages (i.e., emphasizing the benefits of PA planning). However, participants who received both PA participation messages *and* PA planning messages were found to complete higher quality plans than participants who received PA participation messages only (Sweet et al., 2014). In the current study, plan quality was consistent regardless of the type of messages received. Across studies, differences in plan quality may be related to: a) message content (e.g., unlike the Sweet and colleague (2014) study, the current study did not have a group who were exposed to both PA participation *and* PA planning messages), b) message delivery (e.g., the TikTok style messages may influence PA planning differently than traditional text-based messages), c) sample characteristics (e.g., variations in baseline motivation for PA), and d) planning task difficulty. More specifically, with regard to sample characteristics, participants in the study conducted by Sweet and colleagues (2014) were either PA pre-intenders (i.e., no intention to increase PA behaviour) or intenders (i.e., not engaging in PA but wanting to increase their participation), whereas the majority of participants in the current study were PA intenders or actors (i.e., engaging in 'regular' PA; Schwarzer, 2008). Participants may respond differently to persuasive messages depending on such sample characteristics. Furthermore, although the planning task of the current study was modelled from previous research (Sweet et al., 2014), the current study provided instructions that were arguably clearer and more detailed, which may have made it easier to complete the PA plan at a higher quality. In addition, the

current sample's experience with PA planning may have enhanced their abilities to create high quality plans regardless of the types of messages received. The combination of analyzing a sample comprised of more experienced PA planners plus potentially more effective planning task instructions may have nullified any potential differential effects of message type on plan quality. It would be interesting for future studies to be focused on further exploring not only sample characteristics, but also planning task characteristics that may interact with persuasive messages to motivate planning for PA.

Although persuasive messaging is a well-known strategy to motivate various health behaviours including PA participation and PA planning, the effect sizes of such interventions are typically small to medium (Bassett-Gunter et al., 2014; Covey, 2014; Hatchell et al., 2013; Joyal-Desmarais et al., 2020; Michalovic et al., 2018; Mistry et al., 2015). A review and meta-analysis of over 600 experimental persuasive messaging studies outside of and within the PA context demonstrates that the effects of persuasive messages typically range from r = .03 to r =.34, indicating an average small to medium effect of messaging on various health behaviours (Joyal-Desmarais et al., 2020). This pattern of small-to-medium effects remains consistent in the specific studies examining message exposure and PA planning (Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014). Medium-to-large effects of persuasive message exposure were observed for choice to plan among mentally fatigued university students in the current study. A possible explanation for the medium to large effects observed in the current study may be the mode of message delivery (i.e., Tik Tok style messages). The vast majority of previous persuasive messaging research (including PA participation and PA planning) deploy written messages to be read by participants (Joyal-Desmarais et al., 2020; Michalovic et al., 2018; Mistry et al., 2014; Sweet et al., 2014). The current study took into consideration the

recommendations of multiple recent reviews (Budzynski-Seymour et al., 2020; Joyal-Desmaris, 2020; Teeny et al., 2021; Williamson et al., 2019, 2020; Williamson, 2022) and created informal, enticing, short video clips that may be particularly effective for young adults. This approach may have significantly impacted the effect of persuasive message exposure on participants' choice to plan for PA. Future studies should continue to include a modernized modality of delivery of persuasive messages to better determine if such alterations may repeatedly enhance the effectiveness of messages within and beyond the context of PA planning.

4.5.2 Persuasive Message Exposure and Changes in Psychosocial Predictors of the HAPA

In accordance with the secondary hypothesis, compared to participants in the no message control group, participants who received persuasive messages had greater changes in the psychosocial predictors of the HAPA model over time. These results suggest exposure to persuasive messages positively impacted at least some of the HAPA psychosocial variables related to PA planning. In particular, exposure to persuasive messages lead participants to report an enhanced confidence in their ability to maintain their PA planning behaviour (i.e., maintenance self-efficacy). The current sample was comprised of predominantly active participants (i.e., 'PA actors'); it is therefore not surprising that the persuasive messages may have had the greatest effect on participants' *confidence to maintain* PA planning behaviour (i.e., maintenance self-efficacy) as this form of self-efficacy may be most relevant among active individuals. As such, future researchers who set out to explore PA planning behaviour among a physically active sample should deliberately take into consideration how maintenance self-efficacy may be further enhanced to support continued PA planning behaviour.

Although these results should be taken with caution, post-hoc analyses demonstrated that action self-efficacy increased following PA participation message exposure, whereas recovery

self-efficacy increased following PA participation and PA planning message exposure. Future research should be conducted to further explore how persuasive messages affect various aspects of self-efficacy. In particular, research consisting of larger sample sizes and more diverse participants with regard to PA and planning behaviour is recommended (e.g., preintender, intender, actor; Schwarzer, 2008). In alignment with the HAPA model (Schwarzer, 2008), future researchers may also benefit from targeting 'PA intenders' more specifically (i.e., individuals who want to engage in more regular PA, but currently do not) to better understand how persuasive message exposure may influence action self-efficacy. Researchers can also target individuals who are experiencing a lapse in PA planning (i.e., those who used to plan for PA but no longer do) to better understand how persuasive message exposure may more specifically influence recovery self-efficacy in this context.

Outcome expectancies and risk perceptions did not change over time or between groups. It is speculated that the null effects of the messages on outcome expectancies could have been due to a lack of relatability of the outcomes in the message to the participants (i.e., participants may not have resonated with the outcomes promoted in the messages), or ceiling effects (i.e., on average participants had high baseline scores for outcome expectancies). With regard to risk perceptions, the gain-framed nature of the messages may have been responsible for the null effects observed. The persuasive messages included only gain-framed content that emphasized the benefits of PA planning and PA participation. It is possible that loss-framed messages (i.e., emphasizing the risks of not engaging in PA planning or PA) may have differentially affected risk-perceptions. Gain-framed messages are recommended as a strategy to motivate health promotion behaviours such as PA (Joyal-Desmaris, 2020; Williamson et al., 2019, 2020; Williamson, 2022); however, they may not be optimal for targeting the concept of risk

perception explicitly. Future research should further explore how specific persuasive messaging content and framing may affect various HAPA constructs.

4.5.3 Change in Psychosocial Variables of HAPA as Predictors of Choice to Engage in Physical Activity Planning

Regarding the tertiary purpose, results were partially supportive of the hypothesis that changes in HAPA variables would predict choice to plan for PA (Schwarzer, 2008). Specifically, changes in maintenance self-efficacy and recovery self-efficacy were significant positive predictors of choice to plan for PA, with participants being over three times more likely to choose to plan for every one unit increase in maintenance and recovery self-efficacy. Future research should be conducted to explore messaging content that deliberately targets maintenance and recovery self-efficacy when motivating PA planning among PA actor and should explore how such results compare to messages targeting PA intenders. Such research would be an expansion of extant literature that consistently recommends message tailoring (i.e., matching messages to individual characteristics) as a viable strategy to enhance the persuasiveness of messages (Joyal-Desmaris, 2020; Williamson et al., 2019, 2020; Williamson, 2022).

Changes action self-efficacy and risk perception were not found to significantly predict the choice to plan for PA. Again, this finding may reflect characteristics of the sample and the observation that action self-efficacy and risk perception did not have a meaningful change as a result of message exposure. Counter to the predictions of the HAPA model (Schwarzer, 2008), outcome expectancies was a significant negative predictor of choice to plan for PA with increases in outcome expectancies predicting lower odds of choosing to plan for PA. This is an unexpected finding with no reasonable explanation and the authors urge researchers to further unpack this result in future studies.

Future researchers should also attempt to randomize participants into more specific messaging groups (i.e., each group receives messages aimed at targeting a singular HAPA predictor), to better curate message content with each predictor of the HAPA. This strategy may enhance the researchers' ability to target individual HAPA predictors and compare results between groups. Irrespective, this study presents a novel perspective by specifically examining how exposure to persuasive messages may influence psychosocial predictors of the HAPA model in the context of PA planning and mental fatigue. Exposure to persuasive messaging may enhance overall and specific types of self-efficacy for PA planning. Further research is needed to better understand the nuance of using HAPA-based persuasive messaging to motivate PA planning.

4.5.4 Limitations and Future Directions

The current study made several novel contributions to the extant literature concerning mental fatigue, PA planning, and persuasive messaging. Nonetheless there are limitations to consider. First, the study was underpowered which increases the chances Type 1 and 2 error (Button et al., 2013; Christley, 2010), that said, each of the three groups met the common rule of thumb of at least 30 participants, therefore meeting the minimum sample needed for the sample mean to be approximately distributed, as described by central limit theorem (Nolan & Heinzen, 2011; Zhang et al., 2023). Larger than small effect sizes were also utilized as indicators to further explore and better understand the data in the face of a smaller than desirable sample size. Second, although the current study expands on previous research by including a no message control group (Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014), participants in the control group were not given a place holder task and simply progressed through the questionnaires. It is not known if place holder messages regarding content irrelevant to PA

participation or PA planning would have any effect on the results. Furthermore, the current study was conducted in a laboratory, provided a singular message exposure (i.e., three short messages back-to-back), and did not explore plan follow through or PA behaviour change. Future research should be shaped to attempt to better understand the relationship between mental fatigue, PA planning, and persuasive messaging by conducting longitudinal studies outside of the laboratory setting where individuals are exposed to multiple PA participation and PA planning messages across multiple weeks or months in which both quantitative and qualitative data are collected, including plan follow-through.

4.6 Conclusion

The present study examined the effects of persuasive message exposure on choice to plan for PA following a mentally fatiguing task. Participants who received persuasive messages were much more likely to engage in PA planning than those who did not, suggesting that persuasive messaging can increase the likelihood of choosing to plan for PA. The size of the effect observed in this study was larger than expected, which speaks to the potential value of integrating persuasive messaging into PA interventions that include PA planning. Participants who received persuasive messages also had increased maintenance self-efficacy which may be valuable in supporting continued PA planning among individuals who have previously engaged in PA planning behaviour. Although exploratory post-hoc analyses of the effects of persuasive message exposure on action and recovery self-efficacy should be considered with caution, such results do suggest there is value in further examination in future research. Additionally, participants were over three times more likely to choose to plan when reporting a significant increase in maintenance and recovery self-efficacy following persuasive message exposure suggesting these may be particularly influential constructs to target for some populations. The improvements and

modernization of the persuasive messages delivered in the current study may have impacted the effects of message exposure on PA planning. Future research should be conducted to attempt to better understand the relationship between mental fatigue, PA planning, and persuasive messaging by designing and conducting studies that are mixed-method and naturalistic with longer follow up periods to better analyze plan follow through and PA behaviour change.

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Chapter 5: General Discussion

This dissertation takes the perspective that although planning is often touted as a panacea for enhancing PA participation, it is a complex behaviour unto itself. This is evident by the observed difficulty past researchers have had when attempting to engage participants in planning for PA (i.e., ~50% of samples often choose not to plan for PA when given the chance; Bassett-Gunter & Chang, 2016; Guthold et al., 2018; Hutchinson & Bassett-Gunter, 2016; Larocca et al., 2023; Michalovic et al., 2018; Mistry et al., 2015; Moyers & Hagger, 2021; Sweet et al., 2014; Tanna et al., 2017). In order to better understand the complexities of PA planning as a behaviour, this dissertation was guided by the psychobiological (Marcora, 2010) and HAPA (Schwarzer, 2008) models to uniquely examine the interplay between mental fatigue, PA planning, and persuasive message exposure. This work specifically contributes to an improved understanding regarding strategies to bridge the PA intention-behaviour gap, motivate planning for PA, and enhance the viability of multicomponent PA interventions. The dissertation examined: a) the effects of a PA planning intervention on experiences of mental fatigue (Study 1), b) the effects of mental fatigue on choice to plan for PA and PA plan quality (Study 2), and c) the effects of persuasive message exposure on choice to plan for PA following a mentally fatiguing task (Study 3).

5.1 The Mentally Fatiguing Effects of a Physical Activity Planning Task

Previous research has repeatedly and extensively demonstrated that action and coping planning are valuable self-regulation strategies that can catalyze the process of translating PA intentions into PA behaviour (Belanger-Gravel et al., 2013; Courtney et al., 2021; Gollwitzer & Sheeran, 2025; Gourlan et al., 2019; Hamilton & Schwarzer, 2018; Moyers & Hagger, 2021; Peng et al., 2022; Peng et al., 2023; Pfeffer et al., 2020; Pfeffer & Strobach, 2019; 2020;

Schwarzer, 2008; Schwarzer et al., 2011). However, the potential degree of effort exertion required, and therefore experiences of mental fatigue that may arise when planning for PA, could lead some individuals to avoid PA planning entirely or complete low-quality plans. Although existing research suggests individuals are less likely to engage in planning when experiencing a state of mental fatigue (Harris & Bray, 2019; 2021; Martin-Ginis & Bray, 2009; Sjastad & Baumeister, 2018), it has remained unknown until the current dissertation if participating in PA planning itself may require enough effort to *cause* a state of mental fatigue. Study 1 specifically explored this idea, with findings highlighting that although planning for PA may not be *more* mentally fatiguing than engaging in another daily task, planning for PA has the potential to create a psychophysiological state of tiredness or lack of energy (Boksem & Tops, 2008). This is important to consider as experiences of heightened mental fatigue during and after planning for PA could at least in part explain why many people are unwilling to choose to plan for PA, create low quality plans, and often do not follow through on PA plans (i.e., mental fatigue from PA planning may widen the PA intention-behaviour gap; Moyers & Hagger, 2021; Rhodes & Rebar, 2017; Rhodes et al., 2020).

In addition to exploring the effects of planning for PA on mental fatigue, the psychobiological model (Marcora, 2010) along with several other models of self-regulation and effort (Anderson et al., 2004; Aston-Jones & Cohen, 2005; Biggs et al., 2023; Hagger, 2025; Inzlicht et al., 2018; Keller, 1987; Kool & Botvinick, 2014; Kurzban et al., 2013; Muller & Apps, 2019; Paas et al., 2005; Sjastad & Baumeister, 2018; Taatgen, 2013; Westbrook et al., 2013) reinforce that differences in individual psychological characteristics (innate or learned) lead some individuals to be more inclined than others to exert effort, even when mentally fatigued. Study 1 findings highlight trait self-control as a significant and negative correlate of

follow up mental fatigue, and trait grit as significant and negative correlate of both baseline mental fatigue as well as post PA planning mental fatigue. These findings suggest individuals with higher levels of trait self-control and trait grit may experience lower levels of mental fatigue, which aligns with previous research highlighting 'interest for PA' (Milyavskaya et al., 2021) and trait self-control (Sjastad & Baumeister, 2018) as important individual psychological characteristics on planning behaviour. Given that both self-control and grit can be considered malleable psychological characteristics that can be improved upon to allow for greater persistence toward a desired goal (Duckworth & Quinn, 2009; Sjastad & Baumeister, 2018; Tangney et al., 2004); future PA planning research should explore how to best support individuals with lower levels of self-control and grit as well as enhance such experiences, particularly following a mentally fatiguing task. In addition, there is value in designing future studies to include moderation and mediation analyses (and moderated mediation analyses) to better examine when and how individuals are more likely to choose to plan for PA, create higher quality plans, and follow through on their PA plans, particularly in the context of mental fatigue.

5.2 The Effects of Mental Fatigue on a Physical Activity Planning Task

In addition to understanding how planning for PA may affect mental fatigue, this dissertation sought to examine the effects of mental fatigue on planning for PA. Within the context of the psychobiological model (Marcora, 2010) and extant literature (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Hunte et al., 2024; Pageaux & Lepers, 2016; Schampheleer & Roelands, 2024), it is reasonable to suggest that mental fatigue serves as a potentially adaptive experience that makes one inclined to modify both the *quantity* and *quality* of effort exerted during PA. Specific to PA participation and PA planning, existing research has suggested that experiences of heightened mental fatigue can negatively influence not only the

choice to participate in PA and future plans to participate in PA (Martin-Ginis & Bray, 2009; Harris & Bray, 2019; 2021; Harris et al., 2024), but also the quantity and quality of PA participation (Brown et al., 2020; Giboin & Wolff, 2019; Holgado et al., 2020; 2021; Staiano et al., 2018). However, prior to Study 2 of this dissertation, previous research had not directly examined the potential negative effect of a mentally fatiguing task on the critical antecedent of PA that is *planning*. Findings from Study 2 demonstrate that although mental fatigue was successfully manipulated, there were no group differences in choice to plan for PA. That is, participants who did or did not complete a mentally fatiguing task were equally likely (or unlikely) to choose to create a PA plan, indicating experiences of heightened mental fatigue may not negatively affect choice to create a PA plan. Indeed, experimentally enhancing the probability of choice to plan has been historically difficult (Moyers & Hagger, 2021), further supporting the idea that planning for PA is a complex behaviour unto itself. Pragmatically, it may be difficult to deliver effective planning-based PA interventions when it is challenging to motivate individuals to *choose* to plan for PA, irrespective of experiences of mental fatigue. Study 3 worked to address the concern of choosing to plan for PA through persuasive message exposure targeting of psychosocial predictors of the HAPA model (i.e., risk perception, outcome expectancies, and self-efficacy; Schwarzer, 2008).

That said, in addition to exploring the effects of mental fatigue on choice to engage in PA planning, Study 2 of the current dissertation also set out to explore the effects of a mentally fatiguing task on the *quality of PA planning*. Similar to results concerning choice to plan for PA, there were no differences found in PA plan quality between individuals who did or did not complete a mentally fatiguing task, with plans being completed at a relatively high quality. These results regarding plan quality align with that of Study 1 and suggest that once individuals choose

to plan for PA and are provided with enough structure and instructions, they are likely to complete said PA plan at a relatively high quality. Again, these results highlight that the pragmatic hurdle in using PA planning as a self-regulation strategy is likely in motivating individuals to *choose to create a plan for PA* (addressed in Study 3). Nevertheless, researchers should further explore the effects of heightened mental fatigue on PA planning, specifically among inactive individuals with limited PA participation and PA planning experience as it is possible that mental fatigue may have a stronger negative effect on PA preintenders and intenders, compared to the large number of PA actors found in the sample of Study 2 (Schwarzer, 2008). Findings from Study 2 also substantiate findings from Study 1, with trait self-control and trait-grit being the only significant negative correlates of mental fatigue. Specifically, higher levels of trait self-control and trait-grit were observed among individuals who reported lower levels of baseline mental fatigue. Researchers should further explore how the modification of self-control and grit may interact with mental fatigue in the context of PA participation and PA planning (e.g., moderation and mediation analyses; Hagger, 2025).

5.3 The Value of Including Persuasive Messaging in Physical Activity Planning Interventions

Additionally, previous research has shown that increased rates of a desired behaviour change are often observed when persuasive messaging is included as part of multicomponent health interventions targeting behaviours such as PA (Budzynski-Seymour et al., 2020; Milton et al., 2020). Although existing literature has demonstrated the effectiveness of persuasive messaging as a strategy to enhance PA participation and PA planning (Harris et al., 2024; Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014) as well as positively influence the psychosocial predictors of PA based on the HAPA model (i.e., risk perception, outcome

expectancies, and self-efficacy; Peng et al., 2024; Zhang et al., 2019), Study 3 explored the effects of persuasive messaging on these psychosocial predictors of the HAPA model and *choice to plan for PA following a mentally fatiguing task*. Findings from Study 3 were found to be quite robust with a moderate-to-large effect of persuasive message exposure on choice to plan for PA, despite participants having just completed a mentally fatiguing task. In comparison to previous research generally demonstrating an approximate 50% of samples choosing not to plan for PA when given the chance (Bassett-Gunter & Chang, 2016; Guthold et al., 2018; Hutchinson & Bassett-Gunter, 2016; Larocca et al., 2023; Michalovic et al., 2018; Mistry et al., 2015; Moyers & Hagger, 2021; Sweet et al., 2014; Tanna et al., 2017), Study 3 was able to demonstrate an over 70% likelihood of choosing to plan for PA, despite increased feelings of mental fatigue. Such results are of upmost interest as effect sizes of persuasive messaging interventions inside and outside the PA context have typically been small-to-medium, whereas Study 3 revealed moderate-to-large effects (Bassett-Gunter et al., 2014; Covey, 2014; Flusberg et al., 2024; Hatchell et al., 2013; Joyal-Desmarais et al., 2020; Michalovic et al., 2018; Mistry et al., 2015; Sweet et al., 2014). A potential reason for the discrepancy between previous effect sizes in the literature and the current study may be due to the delivery method of the messages. Most previous research pertaining to the effects of persuasive message exposure on various health behaviours (including PA participation and PA planning) deploy written messages to be read by participants (Joyal-Desmarais et al., 2020; Michalovic et al., 2018; Mistry et al., 2014; Sweet et al., 2014). The current study took into consideration multiple recent reviews and created 'Tik-Tok' style video messages that were informal and enticing, therefore rendering the messages more likely to be persuasive when delivered to young adults like the undergraduate students that comprised the sample of the Study 3 (Budzynski-Seymour et al., 2020; Joyal-Desmaris, 2020;

Mailey et al., 2024; Teeny et al., 2021; Williamson et al., 2019, 2020; Williamson, 2022). Moreover, such messages may be particularly effective while experiencing heightened levels of mental fatigue as they may be easier to cognitively process relative to written messages that may require greater effort expenditure to interact with. These improvements may have significantly impacted the effect of persuasive message exposure on participants' choice to plan for PA, even after completing a mentally fatiguing task. It should also be noted that analogous with Study 1 and 2, plan quality was relatively high and consistent, regardless of message exposure and heightened feelings of mental fatigue. Future research should continue to modernize the delivery method of persuasive messages to better determine if such alterations may repeatedly and reliability enhance the effectiveness of messages within and outside of the context of mental fatigue.

Study 3 also attempted to further the understanding of how persuasive messaging may support behaviour change in the context of PA planning through the examination of changes in the psychosocial predictors of the HAPA model from pre to post message exposure. Results from Study 3 affirmed that while perceptions of action and recovery self-efficacy increased over time for all participants, perceptions of maintenance self-efficacy increased over time only for those who received persuasive messages. This finding may reflect the significantly large number of participants in the sample who reported regularly participating in PA (i.e., 'PA actors'); for these individuals the *confidence to maintain* PA planning behaviour (i.e., maintenance self-efficacy) may be considered the most relevant form of self-efficacy. That said, larger than small effect sizes were followed by exploratory post-hoc analyses which suggested that exposure to persuasive messages may also heighten feelings of both action and recovery self-efficacy. It is, therefore, likely that exposure to persuasive messages may enhance feelings of self-efficacy

overall, but do so at a greater magnitude for the specific type of self-efficacy most relevant to the sample and the stage of behaviour change in which participants exist (e.g., preintender, intender, actor; Greenhouse-Tucknott et al., 2025; Schwarzer, 2008; Wu et al., 2024). Future research outside of and within the context of mental fatigue should further align with the HAPA (Schwarzer, 2008) by more specifically targeting 'PA intenders' to better understand how persuasive message exposure may more specifically influence action self-efficacy, and 'PA actors' who have recently stopped planning for PA to better understand how persuasive message exposure may more specifically influence recovery self-efficacy, within and outside of the context of mental fatigue.

Beyond the examination of how persuasive message exposure may influence the psychosocial predictors of the HAPA model (Schwarzer, 2008), Study 3 also endeavoured to examine how changes in these variables may predict choice to plan for PA. Maintenance self-efficacy and recovery self-efficacy were the only two significant positive predictors of choice to plan for PA, with participants being over three times more likely to choose to plan when reporting an increase in maintenance and recovery self-efficacy. These results suggest that future research should deliberately target maintenance and recovery self-efficacy when analyzing samples comprised of PA actors (i.e., samples similar to that of Study 3) and should explore how such results compare to samples comprised of PA intenders and preintenders. Counter to the predictions of the HAPA model (Schwarzer, 2008), outcome expectancies were a significant negative predictor of choice to plan for PA with increases in outcome expectancies predicting lower odds of choosing to plan for PA. This is an unexpected finding with no reasonable explanation in which the authors urge researchers to further unpack in future studies. Future research can also attempt to conduct persuasive messaging studies more specific to a singular

HAPA predictor in order to better curate message content for a given psychosocial predictor of the HAPA (e.g., only risk perception being the focus of a study). Such an alteration may enhance the researchers' ability to target individual HAPA predictors, and compare and contrast results between groups. Irrespective, Study 3 provides a novel insight through the specific examination of how exposure to persuasive messages may influence the five psychosocial predictors of the HAPA model in the context of mental fatigue and PA planning.

5.4 Strengths, Limitations, and Future Directions

The studies within this dissertation have multiple notable strengths and unique characteristics that provide insightful considerations for future researchers. Specifically, Study 1 directly examined if planning for PA itself may require enough effort to *cause* an increase in mental fatigue. A challenge in fully understanding the results of this study lays in the fact that the control task also evoked mental fatigue. The specific control task was employed as a novel and unique response to previous research and a recent meta-analysis suggesting that researchers should move away from control tasks that are typically three-to-five-minute documentaries that often induce a state of boredom (Fortes et al., 2020; Graham & Brown, 2021; Mangin et al., 2021; Milyavskaya et al., 2019). This change in control task in the context of mental fatigue pushes boundaries of extant literature and steps into a more modern path for future researchers to consider. Although the specific task used in the current research did not prove to be completely effective as a control, this work does further the discussion around the challenges of control tasks in mental fatigue research. Indeed, the manipulation of mental fatigue has been a challenge for previous researchers as it is effectively near impossible to have a control group with absolutely zero mental fatigue. It is suggested that future researchers shift from a focus on identifying a control task that evokes zero mental fatigue among participants, and instead work to understand

how the degree of one's experience of mental fatigue (i.e., thresholds of mental fatigue) may influence choice to plan for PA and plan quality.

Study 2 uniquely examined not only the negative effect of a mentally fatiguing task on *choice to plan for PA* and the *quality of that PA plan*, but also the correlation between various individual psychological characteristics and one's choice to plan for PA and PA plan quality when mentally fatigued. The inclusion of a measure of boredom in Study 2 as a manipulation and robustness check for mental fatigue is yet another relatively unique inclusion of the current work (Pickering, 2023). Boredom was found to significantly and positively correlate with pre-intervention, post-intervention, and change in mental fatigue; indicating that participants may have been clouding their reports of mental fatigue with reports of boredom. Future researchers should further explore similarities and differences between experiences of mental fatigue and boredom, and more deliberately design studies to account for and offset the potential confounding effect of boredom on mental fatigue and vice versa. However, both Study 2 and Study 3 were underpowered and lacked ideal diversity in regard to previous PA experience (e.g., a large number of PA actors). Future researchers should explore the effects of mental fatigue on PA planning specifically among more physically inactive individuals with limited previous PA participation and PA planning experience as it is possible that experiences of mental fatigue may uniquely affect choice to plan for PA and plan quality among such individuals (i.e., PA preintenders and intenders).

Furthermore, Study 3 not only distinctively explored the relationship between message exposure and choice to plan for PA following a mentally fatiguing task, but also examined how exposure to persuasive messages may influence the five psychosocial predictors of the HAPA model in the context of PA planning and mental fatigue. Study 3 also provides the extant PA

literature with a unique delivery method of persuasive messages by going beyond the commonly deployed written messages to be read by participants (Joyal-Desmarais et al., 2020; Michalovic et al., 2018; Mistry et al., 2014; Sweet et al., 2014). Future research should continue to modernize the delivery method of persuasive messages to better determine if such alterations may repeatedly enhance the effectiveness of messages, within and outside of the context of mental fatigue. Further exploration around message modality is particularly interesting in the context of the medium-to-large effects observed in Study 3. Nonetheless, Study 3 was conducted in a laboratory, provided a singular message exposure with three back-to-back messages, did not include qualitative data, and did not explore plan follow through. Although still valuable, this suggests Study 3 may have limitations in generalizability to real-world circumstances. Future researchers should attempt to better understand the relationship between mental fatigue, PA planning, and persuasive messaging by designing and conducting studies that are mixed-method and naturalistic with longer follow up periods to better analyze plan follow through.

5.5 Theoretical Implications

Theoretically, this dissertation expands on previous psychobiological (Marcora, 2010) and HAPA (Schwarzer, 2008) research in a number of ways. Primarily, to the author's knowledge, this is the first known series of studies to be co-guided by the psychobiological (Marcora, 2010) and HAPA (Schwarzer, 2008) models. The novel combination of these models provided a unique framework for the examination of the interplay between mental fatigue, PA planning, and persuasive messaging. Although previous researchers have deployed the psychobiological model to guide PA research concerning the relationship between mental fatigue and PA performance (particularly endurance performance; Brown et al., 2020; Pageaux et al., 2014; Pageaux & Lepers, 2016; 2018), the current series of studies has gone beyond that by

utilizing the psychobiological model to guide research concerning mental fatigue and critical antecedents of PA participation, like planning in this instance. Furthermore, the current dissertation expands on a previous planning study that was guided by the strength model of self-regulation (Baumeister et al., 1998) and examined the relationship between ego-depletion (a construct parallel to mental fatigue) and planning behaviour (Sjastad & Baumeister, 2018). A debate has recently begun in extant PA literature on whether the strength model (Baumeister et al., 1998) or psychobiological model (Marcora, 2010) is better equipped to guide future PA and mental fatigue research (Friese et al., 2019; Gieseler et al., 2019; Graham & Brown, 2021). Results from the current dissertation therefore provide an opposing theoretical framing to the work of Sjastad and Baumeister (2018) for future researchers to continue to compare and contrast the strength model of self-control (Baumeister et al., 1998) and the psychobiological model (Marcora, 2010).

5.6 Pragmatic Implications

Pragmatically, this series of studies aimed to further our understanding of how to enhance the ability of multicomponent PA interventions to support the translation of PA motivation into intention and intention into PA participation through planning. Results from this dissertation practically highlight that although planning for PA may not be more mentally fatiguing than other daily tasks, that it can still be a mentally fatiguing endeavour which may ultimately hinder PA planning and PA participation for some individuals. Future PA interventions should account for this potential experience of heightened mental fatigue from planning for PA and attempt to offset such experiences (e.g., through persuasive messaging). Moreover, this dissertation expands on novel boredom research (Mangin et al., 2021; Milyavskaya et al., 2019) and other research concerning individual characteristics related to effort and mental fatigue (Inzlicht et al.,

2018; Milyavskaya et al., 2021; Sjastad & Baumeister, 2018). This work reaffirms that when considering experiences of mental fatigue in relation to positive PA behaviour change, that experiences of boredom should also be attempted to be minimized, while experiences of self-control and grit should be amplified (again, potentially through persuasive messaging). This series of studies also practically suggests the primary difficulty for planning-based PA interventions is likely not the ability to support the creation of high-quality PA plans, but instead, the ability to motivate people to *choose to plan for PA*, especially while experiencing heightened mental fatigue. It should be noted that these pragmatic considerations could have been influenced by sample characteristics (i.e., the large number of PA actors across the three studies) and therefore may be different when analyzing PA preintenders or intenders. The capstone project that was Study 3 pragmatically demonstrated that future PA interventions within and outside of the mental fatigue context should prioritize the modernization of message delivery in order to further enhance the effectiveness of persuasive messaging on not only choice to plan for PA, but also any other critical antecedent of PA participation.

5.7 Conclusion

Guided by the psychobiological (Marcora, 2010) and HAPA (Schwarzer, 2008) models, this dissertation brings a unique perspective to the examination of the relationship between mental fatigue, planning for PA, and persuasive message exposure. Findings in this work highlight that although planning for PA may not be more mentally fatiguing than engaging in another daily task, participation in PA planning can lead to heightened feelings of mental fatigue. Interestingly, heightened feelings of mental fatigue may not directly influence choice to plan for PA or plan quality. However, once individuals choose to plan for PA (and are provided with enough structure and instructions), they are likely to complete relatively high-quality plans,

particularly individuals who are regularly physically active. Levels of trait self-control and trait grit should be considered when examining the bidirectional relationship between mental fatigue and planning for PA. The capstone study of this dissertation also suggests that persuasive message exposure can have a moderate-to-large effect on choice to plan for PA, despite increased feelings of mental fatigue. Further, exposure to persuasive messages can lead to an increase in maintenance self-efficacy, while increased feelings of maintenance and recovery self-efficacy following persuasive message exposure may predict choice to plan for PA. Sample characteristics, specifically previous PA planning and PA participation experience should be taken into consideration when interpreting the finding of this dissertation; while the modernization of persuasive message delivery should be further explored to determine if results are repeatable and reliable. Future researchers should attempt to better understand the relationship between mental fatigue, PA planning, and persuasive messaging by designing and conducting studies that are mixed-method and naturalistic, with longer follow up periods to better analyze plan follow through.

5.8 References

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APPENDIX A – Study 1 Consent Form

Date:

Study Name: The Relationship Between Planning for Physical Activity and Experiences of Mental Fatigue: An Exploratory Study

Researcher name: The Principal Investigator of this study is Nicholas Santino, a PhD candidate in the department of Kinesiology and Health Science at York University. You can contact Nicholas directly at nsantino@my.yorku.ca

Purpose of the Research: The purpose of this research is to have a novel examination of the relationship between planning for physical activity and experiences of mental fatigue. This research study is to be completed online, and will be part of Nicholas Santino's doctoral dissertation. Results from this study will be published in an academic journal and presented at academic conferences

What You Will Be Asked to Do in the Research: All participants are responsible for reading the consent form and other documentation in detail, as well as ask questions if they do not understand something about the study or their rights as a research participant. Participants will be required to complete an online survey in addition to an online physical activity planning exercise (or a simple task if in the control group). The study will take approximately 30 to 45 minutes to complete. Participants will receive academic credit for their Psychology or Kinesiology course.

Risks and Discomforts: We do not foresee any risks or discomfort from your participation in the research.

Benefits of the Research and Benefits to You: As an individual, your participation in the study will benefit you by: (a) academic credit for their Psychology or Kinesiology course, (b) practical experience of academic research in their field of study, and (c) being exposed to physical activity planning, potentially increasing the likelihood that you participate in more physical activity and therefore experience the psychobiological benefits of doing so.
In a broader perspective, your participation in this study will contribute to a novel perspective on physical activity planning. If the hypotheses are found to be true, then we have evidence to support the idea that planning is effortful and mentally fatiguing and therefore we need to shift how we deliver physical activity planning interventions towards the inclusion of additional strategies that minimize perceptions of effort and mitigate feelings of mental fatigue. This is for the ultimate goal of making people more physically active.

Voluntary Participation and Withdrawal: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer, to stop participating, or to refuse to answer particular questions will not influence the nature of your relationship with York University either now, or in the future. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Confidentiality: Confidentiality of participant data will be ensured through the elimination of identifiable data on any and all working datasets (e.g., name and student number). Data will be stored on a password-protected USB key and will be permanently deleted and the USB will be physically destroyed as of September 2025.
All information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research. Your online data will be safely stored on a password-protected USB key and only research team members will have access to this information. Confidentiality will be provided to the fullest extent possible by law.

The researcher(s) acknowledge that the host of the online survey may automatically collect participant data without their knowledge (i.e., IP addresses.) Although this information may be provided or made accessible to the researchers, it will not be used or saved without participant's consent on the researchers' system. Further, "Because this project employs e-based collection techniques, data may be subject to access by third parties as a result of various security legislation now in place in many countries and thus the confidentiality and privacy of data cannot be guaranteed during web-based transmission.

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact me at nsantino@my.yorku.ca or my supervisor, Dr. Rebecca Bassett-Gunter at rgunter@yorku.ca and/or 416-736-2100 Ext. 22072. You may also contact the Program in The School of Kinesiology and Health Science at kahs@yorku.ca and/or 416-736-5807.

This research has received ethics review and approval by the Delegated Ethics Review Committee, which is delegated authority to review research ethics protocols by the Human Participants Review Sub-Committee, York University's Ethics Review Board, and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Director, Research Ethics in the Office of Research Ethics, 5th Floor, Kaneff Tower, York University (telephone 416-736-5914 or e-mail ore@yorku.ca).

Legal Rights and Signatures:

I consent to participate in A Different Perspective on Planning: How Planning and Messaging Interventions Relate to Experiences of Mental Fatigue in the Context of Physical Activity conducted by Dr. Rebecca Bassett-Gunter. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form.

- ☐ I consent to participating (takes participant to demographic survey)
- ☐ I do not wish to participate (takes participant out of survey)

APPENDIX B – Study 1 Materials and Measures

Demographics

1. What is your sex at birth?
    - Male
    - Female
    - Other
    - Do not wish to report

2. What is your age?
    - 18 to 20
    - 21 to 23
    - 23-25
    - 26 or above
    - Do not wish to report

3. What is your current year of university?
    - First year
    - Second year
    - Third year
    - Fourth year
    - Five plus years

4. What is your university major?
    - Psychology
    - Kinesiology
    - Other: _____

A member of a visible minority group in Canada is someone who self-identifies as a non-white in colour or non-Caucasian in racial origin, regardless of birthplace or citizenship. Members of ethnic or national groups (such as Portuguese, Italian, Greek, etc.) are not considered to be racially visible unless they also meet the criteria above.

5. Do you identify as a member of a visible minority group?
    - Yes
    - No
    - Do not wish to report

Baseline Physical Activity Participation

1. On average over the past month, how many minutes of moderate to vigorous physical activity did you participate in throughout a week (i.e., any physical activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so)?

Baseline Planning for Physical Activity Participation

Indicate how much you agree with the following statements:

On average over the past month, I have made detailed physical activity plans regarding....

Item	Completely Disagree	Disagree	Agree	Completely Agree
1. when to exercise	1	2	3	4
2. where to exercise	1	2	3	4
3. how to exercise	1	2	3	4
4. how often to exercise	1	2	3	4
5. what to do if something interferes with my plan to exercise	1	2	3	4
6. how to cope with possible setbacks in my plan	1	2	3	4
7. what to do in difficult situations in order to act according to my intentions in my plan	1	2	3	4
8. which good opportunities for action to take	1	2	3	4
9. when to have to pay extra attention to prevent lapses in following through with my plan	1	2	3	4

Action Planning Intervention

1. On the below calendar, create a physical activity plan for this upcoming week. You will not be assessed on the follow through of your plan, that said, we do encourage you do create a plan that you would want to enact over the next week.

Ensure that your plan meets the Canadian Physical Activity Guidelines for Adults described below.

- Moderate to vigorous aerobic physical activities for at least 150 minutes per week (i.e., any activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so)
- Muscle strengthening activities using major muscle groups at least twice a week (e.g., lifting weights, body weight exercises, and resistant band exercises)

An example day is provided in the Calendar below.

Example	**Sun**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**
Type: Hot Yoga *Location:* Local Yoga Studio *Time:*							

7:30pm *Equipment:* Yoga matt, towel, bag, clothes *Motivation:* Feeling strong and flexible, having functional movement *Incentive:* Watch an episode of a show before bed							

Coping Planning
Here are examples of different types of barriers to physical activity.

Physical Barriers: Do not have a car to get to the gym
Psychological Barriers: Feel embarrassed at the gym
Physiological Barriers: My knee has been hurting me lately
Social Barriers: I don't have people who want to participate with me
Financial Barriers: I can't afford a gym membership
Priority Barriers: I have to go to school and work so I don't have time

1. Write down three barriers to physical activity you *may* experience if you *tried* to carry out your physical activity plan over the next week. Use an 'if-then' planning structure to do so. See structure and example below:

If-then Planning Structure:
If *INSERT BARRIER TO PHYSICAL ACTIVITY*, **then** *INSERT SOLUTION TO BARRIER*.

Completed Example:
If *I get nervous about exercising in front of other people at the gym*, **then** *I will go to yoga instead because it feels more welcoming to me*.

Insert Your Three 'If-Then' Planning Strategies:

- _____
- _____
- _____

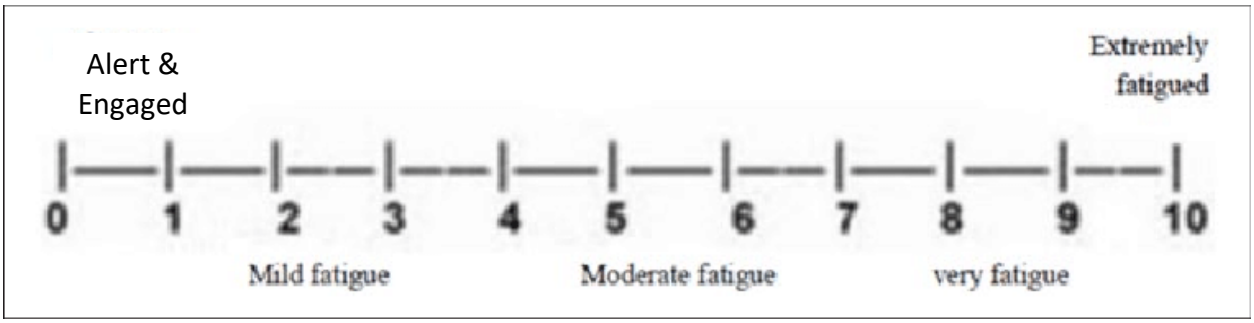
Control Task

Please watch this cooking show. Click play on the below video to watch a cooking show. You will be asked questions about some aspects of the video after it finishes so make sure to **watch the full video**. It is only 13-minutes long and is quite funny so not to worry!

https://www.youtube.com/watch?v=nRWIPKYuBRg

Mental Fatigue

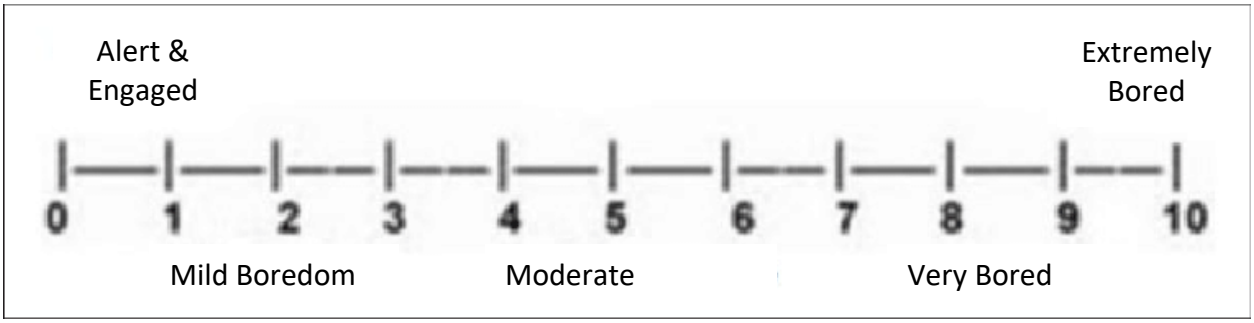
On a scale from 0 (i.e., alert and engaged) to 10 (i.e., extremely fatigued), rate how mentally fatigued you feel. There is no right or wrong answer, your personal opinion of how alert versus mentally fatigued you are feeling at this very moment is all that matters.



Manipulation Checks

Boredom

On a scale from 0 (i.e., alert and engaged) to 10 (i.e., extremely bored), rate how bored you feel. There is no right or wrong answer, your personal opinion of how alert versus bored you are feeling at this very moment is all that matters.



Attention

1. Please indicate which activity you completed during the online experiment.
    - I created an action plan for physical activity
    - I created a coping plan for healthy eating
    - I watched a cooking show
    - I played Pac-Man
    - I used my phone
    - I created an action and coping plan for physical activity
    - I created an action plan for healthy eating
    - None of the above

Plan Quality

Action Planning:
Quality of planning was assessed based on the alignment of the plan relative to Canadian physical activity guidelines. Participants were awarded a score of 1 for including each of the 6 categories (i.e., PA type, location of activity, date and time, equipment needed, motivation, and incentive) in the planning exercise for at least 150 minutes of moderate to vigorous physical activity. A total score of 6 was a perfect score.

Coping Planning:
There were 3 coping plan inputs for the week. A total score for quality of coping planning was therefore calculated by dividing the number of successfully completed coping plans out of 3.

Psychological Characteristics

Motivation for Physical Activity

CRAVE Scale for Physical Activity – Modified Do NOT think about how much you "should" want or desire each activity. Instead, indicate how much you **WANT** or **DESIRE** to perform the following activities this week by circling the number along each line between 0 (NOT AT ALL) and 10 (MORE THAN EVER).			
Item	Not at All	Middle	More Than Ever
1.Move my body	1	2,3,4,5,6,7,8,9	10
2.Be physically active	1	2,3,4,5,6,7,8,9	10
3.Do nothing active	1	2,3,4,5,6,7,8,9	10

4.Just sit down	1	2,3,4,5,6,7,8,9	10
5.Expend some energy	1	2,3,4,5,6,7,8,9	10
6.Be still	1	2,3,4,5,6,7,8,9	10
7.Be a couch potato	1	2,3,4,5,6,7,8,9	10
8.Exert my muscles	1	2,3,4,5,6,7,8,9	10
9.Be motionless	1	2,3,4,5,6,7,8,9	10
10. Move around	1	2,3,4,5,6,7,8,9	10

Perception of Effort

Borg Rating of Perceived Exertion (RPE) Scale Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual cognitive load was while completing the activity. Your own feeling of effort and exertion is important, not how it compares to other people's. Choose a below rating that best describes your experience after completing the previous activity.	
Rating	Experience
6	No exertion at all
7	Extremely light (7.5)
8	
9	Very Light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very Hard
18	
19	Extremely Hard
20	Maximal Exertion

Need for Cognition

Participants will rate how much they agree that the following statements seem like them using the Need for Cognition Scale (Cacioppo et al., 1984).

Item	Extremely Uncharacteristic	Somewhat Uncharacteristic	Uncertain	Somewhat Characteristic	Extremely Characteristic
1. I would prefer complex to simple problems.	1	2	3	4	5
2. I like to have the responsibility of handling a situation that requires a lot of thinking.	1	2	3	4	5

3. Thinking is not my idea of fun	1	2	3	4	5
4. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.	1	2	3	4	5
5. I try to anticipate and avoid situations where there is likely a chance I will have to think in depth about something.	1	2	3	4	5
6. I find satisfaction in deliberating hard and for long hours.	1	2	3	4	5
7. I only think as hard as I have to.	1	2	3	4	5
8. I prefer to think about small, daily projects to long-term ones.	1	2	3	4	5
9. I like tasks that require little thought once I've learned them.	1	2	3	4	5
10. The idea of relying on thought to make my way to the top appeals to me.	1	2	3	4	5
11. I really enjoy a task that involves coming up with new solutions to problems.	1	2	3	4	5
12. Learning new ways to think doesn't excite me very much.	1	2	3	4	5
13. I prefer my life to be filled with puzzles that I must solve.	1	2	3	4	5
14. The notion of thinking abstractly is appealing to me.	1	2	3	4	5
15. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.	1	2	3	4	5
16. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.	1	2	3	4	5
17. It's enough for me that something gets the job done; I don't care how or why it works.	1	2	3	4	5
18. I usually end up deliberating about issues even	1	2	3	4	5

when they do not affect me personally.					

Trait Self-Regulation

Participants will rate how much they agree with the following statement using the Short Form Self-Regulation Questionnaire (Brown et al., 1999).

Item	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I usually keep track of my progress towards my goals.	1	2	3	4	5
2. I have trouble making up my mind about things.	1	2	3	4	5
3. I get easily distracted from my plans.	1	2	3	4	5
4. I don't notice the effects of my actions until it is too late.	1	2	3	4	5
5. I am able to accomplish goals I set for myself.	1	2	3	4	5
6. I put off making decisions.	1	2	3	4	5
7. It's hard for me to notice when I've "had enough" (alcohol, food, sweets).	1	2	3	4	5
8. If I wanted to change, I am confident that I could do it.	1	2	3	4	5
9. When it comes to deciding about a change, I feel overwhelmed by the choices.	1	2	3	4	5
10. I have trouble following through with things once I've made up my mind to do something.	1	2	3	4	5
11. I don't seem to learn from my mistakes.	1	2	3	4	5
12. I can stick to a plan that's working well.	1	2	3	4	5
13. I usually only have to make a mistake one time in order to learn from it.	1	2	3	4	5
14. I have personal standards, and try to live up to them.	1	2	3	4	5
15. As soon as I see a problem or challenge, I start looking for all possible solutions.	1	2	3	4	5
16. I have a hard time setting goals for myself.	1	2	3	4	5

17. I have a lot of willpower.	1	2	3	4	5
18. When I'm trying to change something, I pay a lot of attention to how I'm doing.	1	2	3	4	5
19. I have trouble making plans to help me reach my goals.	1	2	3	4	5
20. I am able to resist temptation.	1	2	3	4	5
21. I set goals for myself and keep track of my progress.	1	2	3	4	5
22. Most of the time I don't pay attention to what I'm doing.	1	2	3	4	5
23. I tend to keep doing the same thing, even when it doesn't work.	1	2	3	4	5
24. I can usually find several different possibilities when I want to change something.	1	2	3	4	5
25. Once I have a goal, I can usually plan how to reach it.	1	2	3	4	5
26. If I make a resolution to change something, I pay a lot of attention to how I'm doing.	1	2	3	4	5
27. Often I don't notice what I'm doing until someone calls it to my attention.	1	2	3	4	5
28. I usually think before I act.	1	2	3	4	5
29. I learn from my mistakes.	1	2	3	4	5
30. I know how I want to be.	1	2	3	4	5
31. I give up quickly.	1	2	3	4	5

Self-Control

Participants will rate how much they agree that the following statements seem like them using the Brief Self-Control Scale (Tangney et al., 2004).

Item	Very Much Like Me	Mostly Like Me	Somewhat Like Me	Not Much Like Me	Not like me at all
1. I am good at resisting temptation.	1	2	3	4	5
2.I have a hard time breaking bad habits.	1	2	3	4	5
3. I am lazy.	1	2	3	4	5
4. I say inappropriate things	1	2	3	4	5
5. I do certain things that are bad for me, if they are fun.	1	2	3	4	5

6. I have difficulty maintaining my focus on projects that take more than a few months to complete.	1	2	3	4	5
7. I refuse things that are bad for me	1	2	3	4	5
8. I wish I had more self-discipline.	1	2	3	4	5
9. People would say that I have iron self- discipline	1	2	3	4	5
10. Pleasure and fun sometimes keep me from getting work done.	1	2	3	4	5
11. I have trouble concentrating.	1	2	3	4	5
12. I am able to work effectively toward long-term goals	1	2	3	4	5
14. Sometimes I can't stop myself from doing something, even if I know it is wrong.	1	2	3	4	5
15. I often act without thinking through all the alternatives.	1	2	3	4	5

Grit

Participants will rate how much they agree that the following statements seem like them using the Short Grit Scale (Duckworth & Quinn, 2009).

Item	Very Much Like Me	Mostly Like Me	Somewhat Like Me	Not Much Like Me	Not like me at all
1. New ideas and projects sometimes distract me from previous ones.	1	2	3	4	5
2. Setbacks don't discourage me.	1	2	3	4	5
3. I have been obsessed with a certain idea or project for a short time but later lost interest.	1	2	3	4	5
4. I am a hard worker.	1	2	3	4	5
5. I often set a goal but later choose to pursue a different one.	1	2	3	4	5
6. I have difficulty maintaining my focus on projects that take more than a few months to complete.	1	2	3	4	5
7. I finish whatever I begin.	1	2	3	4	5
8. I am diligent.	1	2	3	4	5

Meaningfulness of Effort

Participants will rate how much they agree that the following statements seem like them using the Meaningfulness of Effort Scale (Campbell et al., 2022).

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Pushing myself helps me see the bigger picture.	1	2	3	4	5
2. I often don't understand why I am working so hard.	1	2	3	4	5
3. When I put forth lots of effort, I understand things better.	1	2	3	4	5
4. Life feels orderly or under control when I push myself.	1	2	3	4	5
5. I learn the most about myself when I am trying my hardest.	1	2	3	4	5
6. Things make more sense when I can put my all into them.	1	2	3	4	5
7. What I put a lot of effort into often ends up being meaningless to me.	1	2	3	4	5
8. When I work hard, it rarely makes a difference.	1	2	3	4	5
9. When I push myself, what I'm doing feels important.	1	2	3	4	5
10. When I try my hardest, no one cares.	1	2	3	4	5
11. When I push myself, I feel like I'm part of something bigger than me.	1	2	3	4	5
12. Life would have no purpose if I never had to try	1	2	3	4	5
13. Life would be ideal if I never had to push myself.	1	2	3	4	5
14. Doing my best gives me a clear purpose in life.	1	2	3	4	5
15. When I try my hardest, my life has meaning.	1	2	3	4	5
16. When I exert myself, I feel connected to my ideal life.	1	2	3	4	5
17. I do not find working for others meaningful.	1	2	3	4	5

18. When unexpected work comes up, I feel it is a waste of my time	1	2	3	4	5

APPENDIX C – Study 2 Consent Form

Date:

Study Name: The Effects of a Mentally Fatiguing Task on Physical Activity Plan Choice and Plan Quality

Researcher name: The Principal Investigator of this study is Nicholas Santino, a PhD candidate in the department of Kinesiology and Health Science at York University. You can contact Nicholas directly at nsantino@my.yorku.ca

Purpose of the Research: The purpose of this research is to explore to what extent experiences of mental fatigue may influence planning for PA and PA participation. This research study is to be completed in person, and will be part of Nicholas Santino's doctoral dissertation. Results from this study will be published in an academic journal and presented at academic conferences

What You Will Be Asked to Do in the Research: All participants are responsible for reading the consent form and other documentation in detail, as well as ask questions if they do not understand something about the study or their rights as a research participant. Participants will be required to complete a survey in addition to a planning exercise (or a simple task if in the control group). The study will take approximately 30 to 45 minutes to complete. Participants will receive academic credit for their Psychology or Kinesiology course.

Risks and Discomforts: We do not foresee any risks or discomfort from your participation in the research.

Benefits of the Research and Benefits to You: As an individual, your participation in the study will benefit you by: (a) academic credit for their Psychology or Kinesiology course, (b) practical experience of academic research in their field of study, and (c) being exposed to physical activity planning, potentially increasing the likelihood that you participate in more physical activity and therefore experience the psychobiological benefits of doing so.
In a broader perspective, your participation in this study will contribute to a novel perspective on physical activity planning. If the hypotheses are found to be true, then we have evidence to support the idea that planning is effortful and mentally fatiguing and therefore we need to shift how we deliver physical activity planning interventions towards the inclusion of additional strategies that minimize perceptions of effort and mitigate feelings of mental fatigue. This is for the ultimate goal of making people more physically active.

Voluntary Participation and Withdrawal: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer, to stop participating, or to refuse to answer particular questions will not influence the nature of your relationship with York University either now, or in the future. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Confidentiality: Confidentiality of participant data will be ensured through the elimination of identifiable data on any and all working datasets (e.g., name and student number). Data will be stored on a password-protected USB key and will be permanently deleted and the USB will be physically destroyed as of September 2025.
All information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research. Your online data will be safely stored on a password-protected USB key and only research team members will have access to this information. Confidentiality will be provided to the fullest extent possible by law.

The researcher(s) acknowledge that the host of the online survey may automatically collect participant data without their knowledge (i.e., IP addresses.) Although this information may be provided or made accessible to the researchers, it will not be used or saved without participant's consent on the researchers' system. Further, "Because this project employs e-based collection techniques, data may be subject to access by third parties as a result of various security legislation now in place in many countries and thus the confidentiality and privacy of data cannot be guaranteed during web-based transmission.

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact me at nsantino@my.yorku.ca or my supervisor, Dr. Rebecca Bassett-Gunter at rgunter@yorku.ca and/or 416-736-2100 Ext. 22072. You may also contact the Program in The School of Kinesiology and Health Science at kahs@yorku.ca and/or 416-736-5807.

This research has received ethics review and approval by the Delegated Ethics Review Committee, which is delegated authority to review research ethics protocols by the Human Participants Review Sub-Committee, York University's Ethics Review Board, and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Director, Research Ethics in the Office of Research Ethics, 5th Floor, Kaneff Tower, York University (telephone 416-736-5914 or e-mail ore@yorku.ca).

Legal Rights and Signatures:

I consent to participate in A Different Perspective on Planning: How Planning and Messaging Interventions Relate to Experiences of Mental Fatigue in the Context of Physical Activity conducted by Dr. Rebecca Bassett-Gunter. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form.

- ☐ I consent to participating (takes participant to demographic survey)
- ☐ I do not wish to participate (takes participant out of survey)

APPENDIX D – Study 2 Materials and Measures

Demographics

1. What is your sex at birth?
    - Male
    - Female
    - Other
    - Do not wish to report

2. What is your age?
    - 18 to 20
    - 21 to 23
    - 23-25
    - 26 or above
    - Do not wish to report

3. What is your current year of university?
    - First year
    - Second year
    - Third year
    - Fourth year
    - Five plus years

4. What is your university major?
    - Psychology
    - Kinesiology
    - Other: _____

A person of colour in Canada is someone who self-identifies as a non-white in colour or non-Caucasian in racial origin, regardless of birthplace or citizenship.

5. Do you identify as a person of colour group?
    - Yes
    - No
    - Do not wish to report

Baseline Physical Activity Participation

1. On average over the past month, how many minutes of moderate to vigorous physical activity did you participate in throughout a week (i.e., any physical activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so)?

Baseline Planning for Physical Activity Participation

Indicate how much you agree with the following statements:

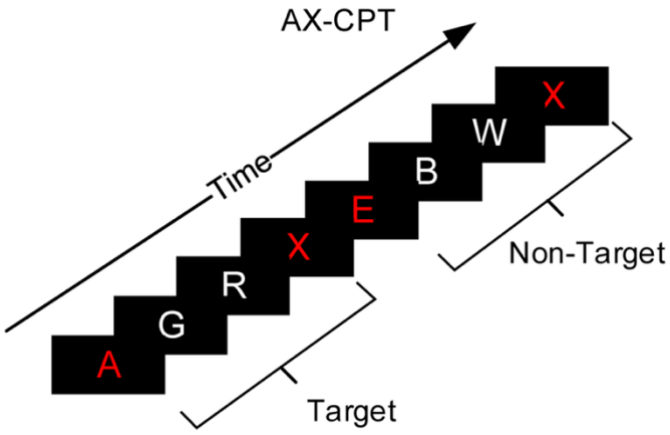
On average over the past month, I have made detailed physical activity plans regarding....

Item	Completely Disagree	Disagree	Agree	Completely Agree
1. when to exercise	1	2	3	4
2. where to exercise	1	2	3	4
3. how to exercise	1	2	3	4
4. how often to exercise	1	2	3	4
5. what to do if something interferes with my plan to exercise	1	2	3	4
6. how to cope with possible setbacks in my plan	1	2	3	4
7. what to do in difficult situations in order to act according to my intentions in my plan	1	2	3	4
8. which good opportunities for action to take	1	2	3	4
9. when to have to pay extra attention to prevent lapses in following through with my plan	1	2	3	4

Mentally Fatiguing Task

Please follow the instructions on the screen and complete the task by pressing specific keyboard buttons when the target stimulus appears.

AX-Continuous Performance Task Example:



Action & Planning Intervention

1. *Action Planning:* On the below calendar, create a physical activity plan for this upcoming week. You will not be assessed on the follow through of your plan, that said, we do encourage you do create a plan that you would want to enact over the next week.

Ensure that your plan meets the Canadian Physical Activity Guidelines for Adults described below.

- Moderate to vigorous aerobic physical activities for at least 150 minutes per week (i.e., any activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so)
- Muscle strengthening activities using major muscle groups at least twice a week (e.g., lifting weights, body weight exercises, and resistant band exercises)

An example day is provided in the Calendar below.

Example	**Sun**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**
Type: Hot Yoga *Location:* Local Yoga Studio *Time:* 7:30pm *Equipment:* Yoga matt, towel, bag, clothes *Motivation:* Feeling strong and flexible, having functional movement *Incentive:* Watch an episode of a show before bed							

2. *Coping Planning*: Here are examples of different types of barriers to physical activity.

Physical Barriers: Do not have a car to get to the gym
Psychological Barriers: Feel embarrassed at the gym
Physiological Barriers: My knee has been hurting me lately
Social Barriers: I don't have people who want to participate with me

Financial Barriers: I can't afford a gym membership
Priority Barriers: I have to go to school and work so I don't have time

Write down three barriers to physical activity you *may* experience if you *tried* to carry out your physical activity plan over the next week. Use an 'if-then' planning structure to do so. See structure and example below:

If-then Planning Structure:
If *INSERT BARRIER TO PHYSICAL ACTIVITY*, **then** *INSERT SOLUTION TO BARRIER*.

Completed Example:
If *I get nervous about exercising in front of other people at the gym*, **then** *I will go to yoga instead because it feels more welcoming to me*.

Insert Your Three 'If-Then' Planning Strategies:

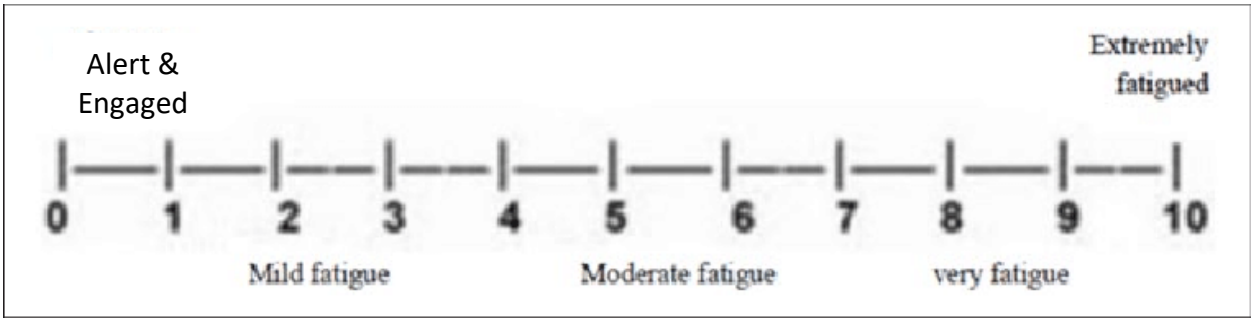
- _____
- _____
- _____

Control Tasks

Please choose one of the following options to do for the next 20 minutes:

1. Use your phone as you wish
2. Play Pac-Man by clicking here
3. Watch a natural documentary by clicking here

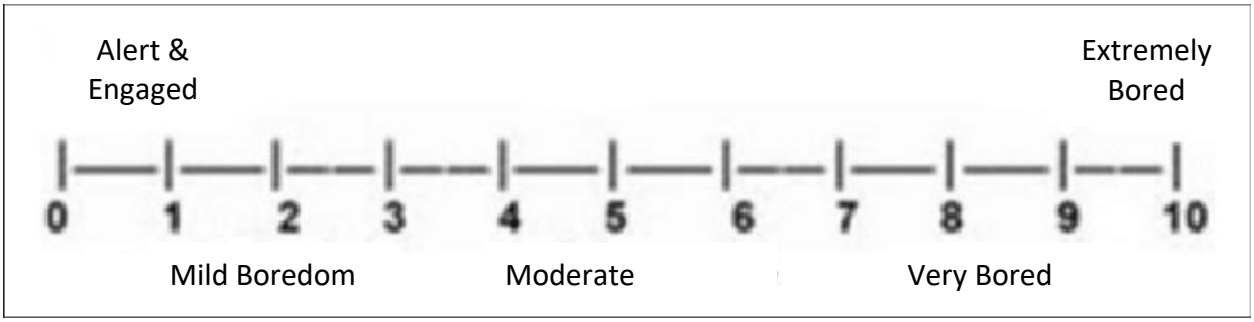
Mental Fatigue
On a scale from 0 (i.e., alert and engaged) to 10 (i.e., extremely fatigued), rate how mentally fatigued you feel. There is no right or wrong answer, your personal opinion of how alert versus mentally fatigued you are feeling at this very moment is all that matters.



Manipulation Checks

Boredom

On a scale from 0 (i.e., alert and engaged) to 10 (i.e., extremely bored), rate how bored you feel. There is no right or wrong answer, your personal opinion of how alert versus bored you are feeling at this very moment is all that matters.



Plan Quality

Action Planning:

Quality of planning was assessed based on the alignment of the plan relative to Canadian physical activity guidelines. Participants were awarded a score of 1 for including each of the 6 categories (i.e., PA type, location of activity, date and time, equipment needed, motivation, and incentive) in the planning exercise for at least 150 minutes of moderate to vigorous physical activity. A total score of 6 was a perfect score.

Coping Planning:

There were 3 coping plan inputs for the week. A total score for quality of coping planning was therefore calculated by dividing the number of successfully completed coping plans out of 3.

Psychological Characteristics

Motivation for Physical Activity

CRAVE Scale for Physical Activity – Modified
Do NOT think about how much you "should" want or desire each activity.
Instead, indicate how much you **WANT** or **DESIRE** to perform the following activities this week by circling the number along each line between 0 (NOT AT ALL) and 10 (MORE THAN EVER).

Item	Not at All	Middle	More Than Ever
1.Move my body	1	2,3,4,5,6,7,8,9	10
2.Be physically active	1	2,3,4,5,6,7,8,9	10
3.Do nothing active	1	2,3,4,5,6,7,8,9	10
4.Just sit down	1	2,3,4,5,6,7,8,9	10
5.Expend some energy	1	2,3,4,5,6,7,8,9	10
6.Be still	1	2,3,4,5,6,7,8,9	10
7.Be a couch potato	1	2,3,4,5,6,7,8,9	10
8.Exert my muscles	1	2,3,4,5,6,7,8,9	10
9.Be motionless	1	2,3,4,5,6,7,8,9	10
10. Move around	1	2,3,4,5,6,7,8,9	10

Perception of Effort

Borg Rating of Perceived Exertion (RPE) Scale Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual cognitive load was while completing the activity. Your own feeling of effort and exertion is important, not how it compares to other people's. Choose a below rating that best describes your experience after completing the previous activity.	
Rating	Experience
6	No exertion at all
7	Extremely light (7.5)
8	
9	Very Light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very Hard
18	
19	Extremely Hard
20	Maximal Exertion

Need for Cognition

Participants will rate how much they agree that the following statements seem like them using the Need for Cognition Scale (Cacioppo et al., 1984).

Item	Extremely Uncharacteristic	Somewhat Uncharacteristic	Uncertain	Somewhat Characteristic	Extremely Characteristic
1. I would prefer complex to simple problems.	1	2	3	4	5
2. I like to have the responsibility of handling a situation that requires a lot of thinking.	1	2	3	4	5
3. Thinking is not my idea of fun	1	2	3	4	5
4. I would rather do something that requires little thought than something that is sure to challenge my thinking abilities.	1	2	3	4	5
5. I try to anticipate and avoid situations where there is likely	1	2	3	4	5

a chance I will have to think in depth about something.					
6. I find satisfaction in deliberating hard and for long hours.	1	2	3	4	5
7. I only think as hard as I have to.	1	2	3	4	5
8. I prefer to think about small, daily projects to long-term ones.	1	2	3	4	5
9. I like tasks that require little thought once I've learned them.	1	2	3	4	5
10. The idea of relying on thought to make my way to the top appeals to me.	1	2	3	4	5
11. I really enjoy a task that involves coming up with new solutions to problems.	1	2	3	4	5
12. Learning new ways to think doesn't excite me very much.	1	2	3	4	5
13. I prefer my life to be filled with puzzles that I must solve.	1	2	3	4	5
14. The notion of thinking abstractly is appealing to me.	1	2	3	4	5
15. I would prefer a task that is intellectual, difficult, and important to one that is somewhat important but does not require much thought.	1	2	3	4	5
16. I feel relief rather than satisfaction after completing a task that required a lot of mental effort.	1	2	3	4	5
17. It's enough for me that something gets the job done; I don't care how or why it works.	1	2	3	4	5
18. I usually end up deliberating about issues even when they do not affect me personally.	1	2	3	4	5

Trait Self-Regulation

Participants will rate how much they agree with the following statement using the Short Form Self-Regulation Questionnaire (Brown et al., 1999).

Item	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
1. I usually keep track of my progress towards my goals.	1	2	3	4	5
2. I have trouble making up my mind about things.	1	2	3	4	5
3. I get easily distracted from my plans.	1	2	3	4	5
4. I don't notice the effects of my actions until it is too late.	1	2	3	4	5
5. I am able to accomplish goals I set for myself.	1	2	3	4	5
6. I put off making decisions.	1	2	3	4	5
7. It's hard for me to notice when I've "had enough" (alcohol, food, sweets).	1	2	3	4	5
8. If I wanted to change, I am confident that I could do it.	1	2	3	4	5
9. When it comes to deciding about a change, I feel overwhelmed by the choices.	1	2	3	4	5
10. I have trouble following through with things once I've made up my mind to do something.	1	2	3	4	5
11. I don't seem to learn from my mistakes.	1	2	3	4	5
12. I can stick to a plan that's working well.	1	2	3	4	5
13. I usually only have to make a mistake one time in order to learn from it.	1	2	3	4	5
14. I have personal standards, and try to live up to them.	1	2	3	4	5
15. As soon as I see a problem or challenge, I start looking for all possible solutions.	1	2	3	4	5
16. I have a hard time setting goals for myself.	1	2	3	4	5
17. I have a lot of willpower.	1	2	3	4	5
18. When I'm trying to change something, I pay a lot of attention to how I'm doing.	1	2	3	4	5
19. I have trouble making plans to help me reach my goals.	1	2	3	4	5
20. I am able to resist temptation.	1	2	3	4	5

21. I set goals for myself and keep track of my progress.	1	2	3	4	5
22. Most of the time I don't pay attention to what I'm doing.	1	2	3	4	5
23. I tend to keep doing the same thing, even when it doesn't work.	1	2	3	4	5
24. I can usually find several different possibilities when I want to change something.	1	2	3	4	5
25. Once I have a goal, I can usually plan how to reach it.	1	2	3	4	5
26. If I make a resolution to change something, I pay a lot of attention to how I'm doing.	1	2	3	4	5
27. Often I don't notice what I'm doing until someone calls it to my attention.	1	2	3	4	5
28. I usually think before I act.	1	2	3	4	5
29. I learn from my mistakes.	1	2	3	4	5
30. I know how I want to be.	1	2	3	4	5
31. I give up quickly.	1	2	3	4	5

Self-Control

Participants will rate how much they agree that the following statements seem like them using the Brief Self-Control Scale (Tangney et al., 2004).

Item	Very Much Like Me	Mostly Like Me	Somewhat Like Me	Not Much Like Me	Not like me at all
1. I am good at resisting temptation.	1	2	3	4	5
2.I have a hard time breaking bad habits.	1	2	3	4	5
3. I am lazy.	1	2	3	4	5
4. I say inappropriate things	1	2	3	4	5
5. I do certain things that are bad for me, if they are fun.	1	2	3	4	5
6. I have difficulty maintaining my focus on projects that take more than a few months to complete.	1	2	3	4	5
7. I refuse things that are bad for me	1	2	3	4	5

8. I wish I had more self-discipline.	1	2	3	4	5
9. People would say that I have iron self- discipline	1	2	3	4	5
10. Pleasure and fun sometimes keep me from getting work done.	1	2	3	4	5
11. I have trouble concentrating.	1	2	3	4	5
12. I am able to work effectively toward long-term goals	1	2	3	4	5
14. Sometimes I can't stop myself from doing something, even if I know it is wrong.	1	2	3	4	5
15. I often act without thinking through all the alternatives.	1	2	3	4	5

Grit

Participants will rate how much they agree that the following statements seem like them using the Short Grit Scale (Duckworth & Quinn, 2009).

Item	Very Much Like Me	Mostly Like Me	Somewhat Like Me	Not Much Like Me	Not like me at all
1. New ideas and projects sometimes distract me from previous ones.	1	2	3	4	5
2. Setbacks don't discourage me.	1	2	3	4	5
3. I have been obsessed with a certain idea or project for a short time but later lost interest.	1	2	3	4	5
4. I am a hard worker.	1	2	3	4	5
5. I often set a goal but later choose to pursue a different one.	1	2	3	4	5
6. I have difficulty maintaining my focus on projects that take more than a few months to complete.	1	2	3	4	5
7. I finish whatever I begin.	1	2	3	4	5
8. I am diligent.	1	2	3	4	5

Meaningfulness of Effort

Participants will rate how much they agree that the following statements seem like them using the Meaningfulness of Effort Scale (Campbell et al., 2022).

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

1. Pushing myself helps me see the bigger picture.	1	2	3	4	5
2. I often don't understand why I am working so hard.	1	2	3	4	5
3. When I put forth lots of effort, I understand things better.	1	2	3	4	5
4. Life feels orderly or under control when I push myself.	1	2	3	4	5
5. I learn the most about myself when I am trying my hardest.	1	2	3	4	5
6. Things make more sense when I can put my all into them.	1	2	3	4	5
7. What I put a lot of effort into often ends up being meaningless to me.	1	2	3	4	5
8. When I work hard, it rarely makes a difference.	1	2	3	4	5
9. When I push myself, what I'm doing feels important.	1	2	3	4	5
10. When I try my hardest, no one cares.	1	2	3	4	5
11. When I push myself, I feel like I'm part of something bigger than me.	1	2	3	4	5
12. Life would have no purpose if I never had to try	1	2	3	4	5
13. Life would be ideal if I never had to push myself.	1	2	3	4	5
14. Doing my best gives me a clear purpose in life.	1	2	3	4	5
15. When I try my hardest, my life has meaning.	1	2	3	4	5
16. When I exert myself, I feel connected to my ideal life.	1	2	3	4	5
17. I do not find working for others meaningful.	1	2	3	4	5
18. When unexpected work comes up, I feel it is a waste of my time	1	2	3	4	5

APPENDIX E – Study 3 Consent Form

Date:

Study Name: How Planning and Persuasive Messaging Interventions Relate to Experiences of Mental Fatigue in the Context of Physical Activity

Researcher name: The Principal Investigator of this study is Nicholas Santino, a PhD candidate in the department of Kinesiology and Health Science at York University. You can contact Nicholas directly at nsantino@my.yorku.ca

Purpose of the Research: The purpose of this research is to explore to what extent messages influence the planning for PA and PA participation. This research study is to be completed in person, and will be part of Nicholas Santino's doctoral dissertation. Results from this study will be published in an academic journal and presented at academic conferences

What You Will Be Asked to Do in the Research: All participants are responsible for reading the consent form and other documentation in detail, as well as ask questions if they do not understand something about the study or their rights as a research participant. Participants will be required to complete a survey in addition to a simple computer task, and planning exercise. The study will take approximately 45 minutes to complete, plus a two-week follow-up conducted online that will take approximately 15 minutes to complete. Participants will receive academic credit for their Psychology or Kinesiology course.

Risks and Discomforts: We do not foresee any risks or discomfort from your participation in the research.

Benefits of the Research and Benefits to You: As an individual, your participation in the study will benefit you by: (a) academic credit for their Psychology or Kinesiology course, (b) practical experience of academic research in their field of study, and (c) being exposed to physical activity planning, potentially increasing the likelihood that you participate in more physical activity and therefore experience the psychobiological benefits of doing so.
In a broader perspective, your participation in this study will contribute to a novel perspective on physical activity planning. If the hypotheses are found to be true, then we have evidence to support the idea that planning is effortful and mentally fatiguing and therefore we need to shift how we deliver physical activity planning interventions towards the inclusion of additional strategies that minimize perceptions of effort and mitigate feelings of mental fatigue. This is for the ultimate goal of making people more physically active.

Voluntary Participation and Withdrawal: Your participation in the study is completely voluntary and you may choose to stop participating at any time. Your decision not to volunteer, to stop participating, or to refuse to answer particular questions will not influence the nature of

your relationship with York University either now, or in the future. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Confidentiality: Confidentiality of participant data will be ensured through the elimination of identifiable data on any and all working datasets (e.g., name and student number). Data will be stored on a password-protected USB key and will be permanently deleted and the USB will be physically destroyed as of September 2025.
All information you supply during the research will be held in confidence and unless you specifically indicate your consent, your name will not appear in any report or publication of the research. Your online data will be safely stored on a password-protected USB key and only research team members will have access to this information. Confidentiality will be provided to the fullest extent possible by law.

The researcher(s) acknowledge that the host of the online survey may automatically collect participant data without their knowledge (i.e., IP addresses.) Although this information may be provided or made accessible to the researchers, it will not be used or saved without participant's consent on the researchers' system. Further, "Because this project employs e-based collection techniques, data may be subject to access by third parties as a result of various security legislation now in place in many countries and thus the confidentiality and privacy of data cannot be guaranteed during web-based transmission.

Questions About the Research? If you have questions about the research in general or about your role in the study, please feel free to contact me at nsantino@my.yorku.ca or my supervisor, Dr. Rebecca Bassett-Gunter at rgunter@yorku.ca and/or 416-736-2100 Ext. 22072. You may also contact the Program in The School of Kinesiology and Health Science at kahs@yorku.ca and/or 416-736-5807.

This research has received ethics review and approval by the Delegated Ethics Review Committee, which is delegated authority to review research ethics protocols by the Human Participants Review Sub-Committee, York University's Ethics Review Board, and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Director, Research Ethics in the Office of Research Ethics, 5th Floor, Kaneff Tower, York University (telephone 416-736-5914 or e-mail ore@yorku.ca).

Legal Rights and Signatures:

I consent to participate in A Different Perspective on Planning: How Planning and Messaging Interventions Relate to Experiences of Mental Fatigue in the Context of Physical Activity conducted by Dr. Rebecca Bassett-Gunter. I have understood the nature of this project and wish to participate. I am not waiving any of my legal rights by signing this form.

- ☐ I consent to participating (takes participant to demographic survey)
- ☐ I do not wish to participate (takes participant out of survey)

APPENDIX F – Study 3 Materials and Measures

Demographics

1. What is your sex at birth?
    - Male
    - Female
    - Other
    - Do not wish to report

2. What is your age?
    - 18 to 20
    - 21 to 23
    - 23-25
    - 26 or above
    - Do not wish to report

3. What is your current year of university?
    - First year
    - Second year
    - Third year
    - Fourth year
    - Five plus years

4. What is your university major?
    - Psychology
    - Kinesiology
    - Other: _____

A person of colour in Canada is someone who self-identifies as a non-white in colour or non-Caucasian in racial origin, regardless of birthplace or citizenship.

5. Do you identify as a person of colour group?
    - Yes
    - No
    - Do not wish to report

Health Action Process Approach Stage

Over the past month, have you consistently participated in **at least 150 minutes of moderate to vigorous PA per week** (i.e., any activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so, examples include: running,

swimming, cycling, weightlifting exercises, body weight exercises, and resistance band exercises)?

1 = no and I do not intend to (pre intender)

2 = no but I firmly intend to (intender)

3 = yes I have (actor)

Baseline Physical Activity Participation

1. On average over the past month, how many minutes of moderate to vigorous physical activity did you participate in throughout a week (i.e., any physical activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so)?

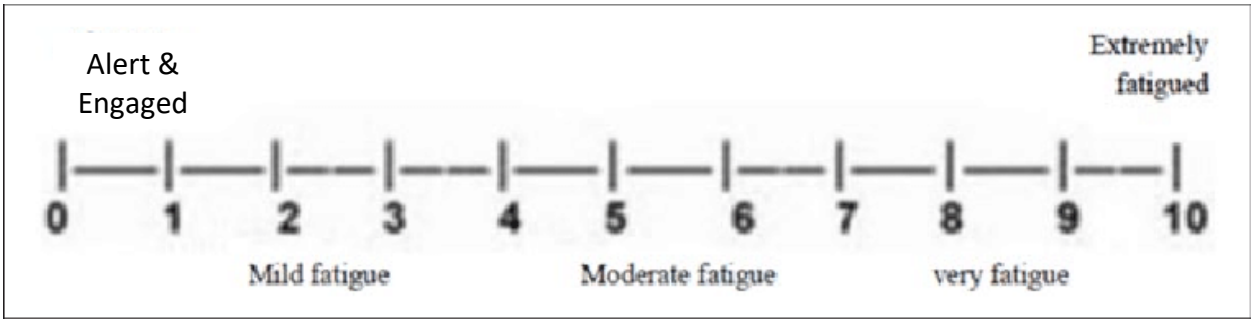
Baseline Planning for Physical Activity Participation

Indicate how much you agree with the following statements:
On average over the past month, I have made detailed physical activity plans regarding....

Item	Completely Disagree	Disagree	Agree	Completely Agree
1. when to exercise	1	2	3	4
2. where to exercise	1	2	3	4
3. how to exercise	1	2	3	4
4. how often to exercise	1	2	3	4
5. what to do if something interferes with my plan to exercise	1	2	3	4
6. how to cope with possible setbacks in my plan	1	2	3	4
7. what to do in difficult situations in order to act according to my intentions in my plan	1	2	3	4
8. which good opportunities for action to take	1	2	3	4
9. when to have to pay extra attention to prevent lapses in following through with my plan	1	2	3	4

Mental Fatigue

On a scale from 0 (i.e., alert and engaged) to 10 (i.e., extremely fatigued), rate how mentally fatigued you feel. There is no right or wrong answer, your personal opinion of how alert versus mentally fatigued you are feeling at this very moment is all that matters.



Psychosocial Variables of the HAPA Model

Risk Perception

If I don't plan and plan well for my physical activity, then I am likely to:

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Not participate in at least 150 minutes of physical activity per week	1	2	3	4	5
2. Not feel motivated and accountable for participating in physical activity	1	2	3	4	5

Outcome Expectancies

If I plan to participate in physical activity for at least 150 minutes a week, then I am likely to:

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Follow through on those plans and obtain the benefits of participating in physical activity	1	2	3	4	5
2. To be more organized and get more out of the physical activity I participate in	1	2	3	4	5

Action Self-Efficacy

For physical activity planning, I am confident that I can:

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Set time aside to really think about when, where, and how I will participate in physical activity	1	2	3	4	5

2. Manage the busy-ness of my schedule and find time to participate in physical activity	1	2	3	4	5

Maintenance Self-Efficacy

I am confident that I can continuously:

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Find the time to schedule and prioritize my physical activity participation	1	2	3	4	5
2. Plan and prepare for the barriers that will prevent me from participating in physical activities (e.g., transportation, injury, finances)	1	2	3	4	5

Recovery Self-Efficacy

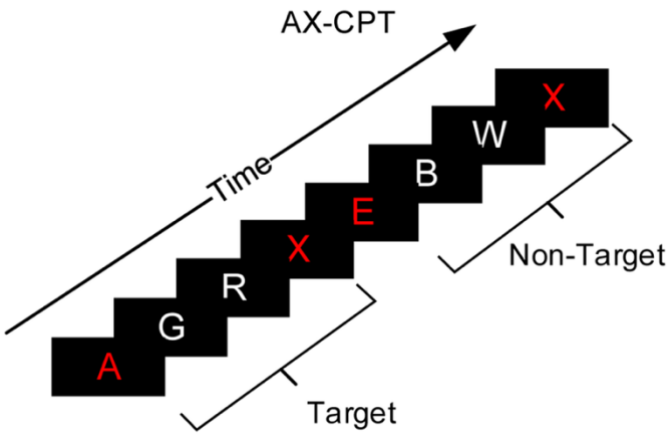
I sincerely believe that I can resume

Item	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Planning for my physical activity, even if my routine is interrupted once or twice	1	2	3	4	5
2. Planning for my physical activity, even if I haven't done so for multiple weeks	1	2	3	4	5

Mentally Fatiguing Task

Please follow the instructions on the screen and complete the task by pressing specific keyboard buttons when the target stimulus appears.

AX-Continuous Performance Task Example:



Action & Planning Intervention

1. *Action Planning:* On the below calendar, create a physical activity plan for this upcoming week. You will not be assessed on the follow through of your plan, that said, we do encourage you do create a plan that you would want to enact over the next week.

Ensure that your plan meets the Canadian Physical Activity Guidelines for Adults described below.

- Moderate to vigorous aerobic physical activities for at least 150 minutes per week (i.e., any activity in which you wouldn't be able to maintain a conversation while participating in it as it is too strenuous to do so)
- Muscle strengthening activities using major muscle groups at least twice a week (e.g., lifting weights, body weight exercises, and resistant band exercises)

An example day is provided in the Calendar below.

Example	**Sun**	**Mon**	**Tues**	**Wed**	**Thurs**	**Fri**	**Sat**
Type: Hot Yoga *Location:* Local Yoga Studio *Time:* 7:30pm *Equipment:* Yoga matt, towel, bag, clothes *Motivation:* Feeling strong and flexible, having functional movement *Incentive:* Watch an episode of a show before bed							

2. *Coping Planning*: Here are examples of different types of barriers to physical activity.

Physical Barriers: Do not have a car to get to the gym
Psychological Barriers: Feel embarrassed at the gym
Physiological Barriers: My knee has been hurting me lately

Social Barriers: I don't have people who want to participate with me
Financial Barriers: I can't afford a gym membership
Priority Barriers: I have to go to school and work so I don't have time

Write down three barriers to physical activity you *may* experience if you *tried* to carry out your physical activity plan over the next week. Use an 'if-then' planning structure to do so. See structure and example below:

If-then Planning Structure:
If *INSERT BARRIER TO PHYSICAL ACTIVITY*, **then** *INSERT SOLUTION TO BARRIER*.

Completed Example:
If *I get nervous about exercising in front of other people at the gym*, **then** *I will go to yoga instead because it feels more welcoming to me*.

Insert Your Three 'If-Then' Planning Strategies:

- _____
- _____
- _____

Manipulation Checks

Plan Quality
Action Planning:
Quality of planning was assessed based on the alignment of the plan relative to Canadian physical activity guidelines. Participants were awarded a score of 1 for including each of the 6 categories (i.e., PA type, location of activity, date and time, equipment needed, motivation, and incentive) in the planning exercise for at least 150 minutes of moderate to vigorous physical activity. A total score of 6 was a perfect score.

Coping Planning:
There were 3 coping plan inputs for the week. A total score for quality of coping planning was therefore calculated by dividing the number of successfully completed coping plans out of 3.

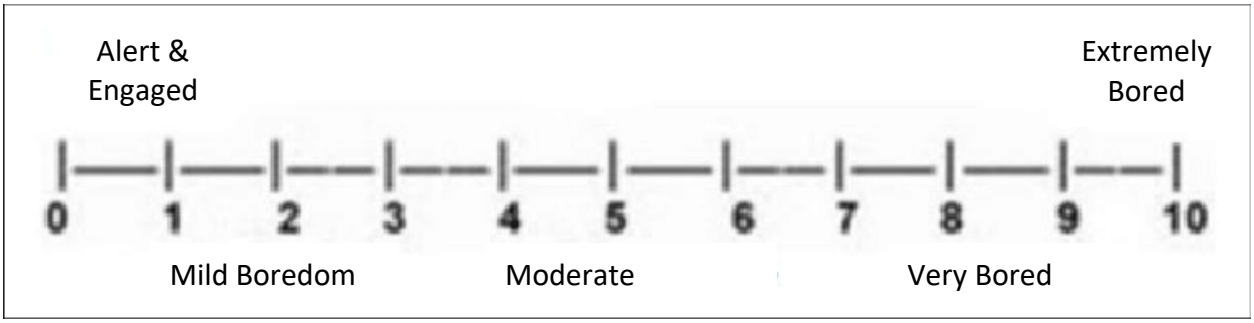
Perception of Effort

Borg Rating of Perceived Exertion (RPE) Scale Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual cognitive load was while completing the activity. Your own feeling of effort and exertion is important, not how it compares to other people's. Choose a below rating that best describes your experience after completing the previous activity.	
Rating	Experience
6	No exertion at all
7	Extremely light (7.5)

8	
9	Very Light
10	
11	Light
12	
13	Somewhat hard
14	
15	Hard (heavy)
16	
17	Very Hard
18	
19	Extremely Hard
20	Maximal Exertion

Boredom

On a scale from 0 (i.e., alert and engaged) to 10 (i.e., extremely bored), rate how bored you feel. There is no right or wrong answer, your personal opinion of how alert versus bored you are feeling at this very moment is all that matters.



Persuasive Messages

Physical Activity Message Scripts

1. Undergraduate students who are meet the physical activity guidelines have better study habits and academic performance than students who do not, so start small and see what happens!
2. By engaging in regular physical activity and meeting the national guidelines, undergraduate students are more likely to feel less stressed and overwhelmed from managing school and life. If you haven't been as physically active as you would like, it is never too late to get started and work towards your goals!
3. Being physically active and meeting the national guidelines makes it easier for university students to cope with stress, especially during academically demanding times.

Planning Message Scripts

1. Many university students find planning helpful because planning gets you thinking about your physical activity NOW, instead of forgetting about it later! Make a plan today to

help yourself work towards the physical activity guidelines and live a happier – healthier life!

2. By making a detailed physical activity plan, university students are more likely to be consistently active, meet the physical activity guidelines, and cope with academic stress much better! Be pro-active, make a plan today...and if you haven't – it is never too late to start.
3. As a university student, planning for your physical activity helps you

- Feel less concerned about fitting physical activity into your schedule
- Create a routine that works with your schedule
- Stay focused on your physical activity goals
- Have a sense of accomplishment - "I did it!" kind of moments

Lots of students have never planned, while others have but currently are not. Whatever your situation, you can get started now. Planning might be easier than you think!