WHY CAN' I STICK TO MY WORKOUT ROUTINE? AN INTEGRATED APPROACH TO SELF-REGULAITON AND PHYSICAL ACTIVITY

A Thesis Submitted to the Committee on Graduate Studies in Partial Fulfilment of the Requirements for the Degree of Master of Science in the Faculty of Arts and Science

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Abstract

Why can't I stick to my workout routine? An integrated approach to self-regulation and physical activity

Eric Samtleben

Previous researchers have linked lower levels of stress and greater ability to mobilize energy toward a goal (self-motivation); confidence in their ability to complete/achieve a particular task or goal (self-efficacy), and ability to willfully control their thoughts, emotions and behaviour (self-control) to regular physical activity (PA). In an effort to provide further insight into the processes underlying regular PA researches have begun to explore the interplay among stress and multiple self-regulatory variables when predicting level of PA (i.e., intensity and duration). In line with this integrated approach the present study aimed to examine the interplay among self-motivation, self-efficacy, and self-control when predicting daily PA. The study was a correlational design with cross-sectional data on trait self-motivation and self-efficacy collected at baseline, and longitudinal data collected on stress, PA, state self-control, self-motivation and self-efficacy over a 2 day period. The results from the regression model (n = 418) revealed a negative indirect effect of stress on participants level of PA through its negative relationship with state multifactor self-regulation. This mediation effect appeared to be moderated by trait SE and SM. In conclusion, these results support the notion of a stress related depletion effect acting on individuals state self-regulatory resources which was associated with lower levels of PA (i.e. intensity and duration). However, the negative effect of stress appeared to be buffered by high levels of trait SE and SM.

Keywords: self-regulation, self-control, self-motivation, self-efficacy, physical activity, exercise

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Introduction

Models of self-regulation vary on what factors underlie self-regulation, but generally, most include one of the following: an individual's ability to mobilize energy toward a goal (self-motivation); confidence in their ability to complete/achieve a particular task or goal (self-efficacy), their ability to willfully control their thoughts, emotions and behaviour (self-control), and perceived environmental demands also known as stress (Bédard-Thom et al., 2020; Englert, 2016; Marcora et al., 2009; McCormick et al., 2019; Shanker, 2013; Taylor et al., 2020). Increasingly, researchers have identified self-regulation as a potential skill that can be enhanced to promote health and well-being (Bandura, 2005; Durand-Bush et al., 2015; Liau et al., 2018; Mitsea, et al., 2021; van Genugten et al., 2017).

One of the primary ways self-regulation can benefit individuals' health and well-being is by helping them to maintain the recommended level of physical activity (PA) for optimal health (i.e.,>150 minutes per week; Oaten & Cheng, 2006; Liau et al., 2018). This is because researchers have associated patterns of inactivity with increases in health ailments (e.g., cancer, cardiovascular disease, psychological distress) and mortality rates (Biswas et al., 2015; Koester et al., 2012; Lippi & Sanchis-Gomar, 2020). In contrast, many studies have demonstrated a positive association between PA and fitness which tends to be associated with improved mental and physical health (e.g., reduced depression and increased cardiovascular functioning), leading to greater longevity (Kandola et al., 2019; Naaktgeboren et al., 2022). Despite the well-known health benefits associated with PA, many individuals still struggle to meet the recommended level of weekly PA (Statistics Canada, 2019; Statistics Canada, 2021; World Health Organization, 2022).

In an effort to address the high rates of inactivity researchers have begun to build on previous literature connecting self-regulatory variables to increased levels of PA (Inzlicht et al., 2021; Taylor et al., 2020). Accordingly, complimentary frameworks based on well established self-regulatory variables (e.g., self-control, self- motivation, and self-efficacy) are being developed and tested to better understand the processes underlying regular PA (Chirico et al., 2020; Pfeffer et al., 2020). The overall goal of the present study was to contribute to the refinement of the relationships among stress, self-control, self-motivation, and self-efficacy when predicting regular PA. Research in this direction will help provide more holistic recommendations for the maintenance of regular PA. Literature regarding stress, self-control, self-efficacy, and self-motivation factors and their relationship with PA will be reviewed in-depth next.

Stress, Self-Control, and Physical Activity

Stress generally refers to an individual's perceived environmental demands (e.g., work, family; Cohen et al., 2016; Cohen et al., 1983). Individuals tend to experience stress across five domains: emotional, cognitive, biological, social, and prosocial (Shanker, 2013). The emotional domain refers to an individual's internal mood and affective state and how this impacts our behaviour (e.g., anger and aggression, happiness and sociability; Fairbrother & Whitley, 2017). The cognitive domain refers to the changes in how an individual's brain processes information under stress (e.g., altered memory encoding and negative attentional bias; Shanker, 2017). The biological domain refers to an individual's physiological reaction to stress, that is, the degree to which their fight/flight/freeze response is triggered (Shanker, 2013). The social domain refers to an individual's interpersonal interaction-based pressures and consequences, such as adhering to social norms or embarrassment after violating social norms (Fairbrother & Whitley, 2017). The prosocial domain refers to the differential impact social pressures can have on various individuals (e.g., someone with social anxiety disorder faces more social pressure than someone without this disorder; Shanker, 2010).

It is important to remember that while individuals tend to experience across these 5 domains their appraisals of which stimuli are stressful can vary from person to person (e.g., some individuals may enjoy physical activity while some may find it unpleasant and stressful; Burns et al., 2017; Lim et al., 2023). Individuals tend to have primary appraisals of events during which they either perceive a stimuli as a threat or non threat (Carpenter, 2016). If perceived as threatening individuals move to the secondary appraisal during which they determine if they possess the necessary coping resources (e.g., cognitive skills, social support) to effectively cope with the challenges the perceived threat presents (Gomes et al., 2016). The perceived degree of coping resources (secondary appraisal) then influences the individuals stress response to the perceived threatening stimuli (primary appraisal; Carpenter, 2016; Gomes et al., 2017). After the stressful situation has been resolved the individual then reappraises the stressfulness event based on their experience (i.e., was it more or less stressful than anticipated?), which influences their stress response when faced with the same stimuli in the future (Lim et al., 2023).

Self-control broadly refers to individuals' ability to control their cognitions, emotions, and behaviour willfully (Englert et al., 2020; Hagger et al., 2009). It consists of two interconnected factors, trait and state self-control (Englert et al., 2020). Trait self-control refers to the overall size of an individual’s self-control capacity, and state self-control refers to the level of self-control resources available to an individual at any given moment (Baumeister et al., 2007). In addition, self-control tends to be considered domain general as the training hypothesis asserts that self-control can be trained within one domain before these skills are applied within other domains (e.g., using exercise to enhance focus in school; Berkman et al., 2013; Hagger et al., 2009).

The shifting and cost-gain hypotheses assert that when an individual becomes fatigued momentary lapses in self-control become more frequent (Heatherton & Wagner, 2011; Vohs & Baumeister, 2004). Increased frequency of momentary self-control lapses can be connected to the increasing implicit cost of continuing regulatory effort becoming greater than the distal reward promised for continuing regulatory effort, resulting in a shift in attention to more proximal rewarding stimuli (e.g., watching T.V. over exercising after a long day of work; Heatherton & Wagner, 2011; Marcora et al., 2009). However, the recovery hypothesis asserts that when an individual is in a state of fatigue, they can recover their state-self-control recourses by engaging in a relaxing activity such as sleep, meditation, or watching TV (Hagger et al., 2009). Often, the muscle metaphor is used to capture the whole nature of self-control; because, similar to a muscle, its size and strength can be increased, it can be generalized to multiple tasks, and it will fatigue after extended use, but can recover its strength after a period of rest (Boat & Cooper, 2019; Baumeister et al., 2007; Hagger et al., 2009).

Previous researchers have demonstrated increased levels of stress impair individuals' ability to employ their self-control resources to regulate their behaviour in the desired manner (Englert et al., 2020; Giboin & Wolf, 2019; Hagger et al., 2016; Martin-Ginis & Bray, 2010). For example, Englert and Rummel (2016) examined the relationships among stress, state self-control, and adherence to a prescribed seven-day PA routine within a sample of inactive (<300 min activity per week) Scandinavian university students. The results from their path analysis demonstrated that students were less likely to engage in PA when experiencing more significant stress. Similarly, using moderated mediation analysis, Pfeffer et al. (2020) demonstrated that the gap between individuals' PA intentions and observed PA was mediated by action and coping planning and conditional on stress and self-control. This means that higher levels of self-control buffer the effect of stress when individuals' have high exercise intentions and a strong plan for implementation and coping with challenges. The above research indicates that stress negatively contributes to PA through its negative association with state self-control resources, making it less likely that individuals will follow through with their PA intentions.

Past researchers have demonstrated that greater stress impairs self-regulatory abilities through its positive association with fatigue (Coutts& Reaburn, 2008; Hamlin et al., 2019; Ruiz-Fernandez et al., 2020). For example, Jalilian et al. (2019) examined stress and its relationship to fatigue within a sample of nurses who worked in educational settings. Using correlation analysis, they demonstrated that greater levels of perceived stress were related to more significant fatigue. Similarly, Thorsteinsson et al. (2019) examined the relationships among stress, sleep quality, and fatigue within a non-clinical sample of participants recruited online. Using path analysis, they demonstrated that stress was negatively associated with sleep quality which was positively associated with fatigue. Specifically within the domain of PA, Kwag et al. (2011) examined the relationships among stress, PA, and mental health (i.e., fatigue, depression, and loneliness) among older adults. Using structural equation modeling, they showed that stress positively contributed to fatigue, negatively impacting participants' level of

PA. Taken together these results highlight the interconnectedness of individuals' level of stress, fatigue and failure to employ their self-control resources to regulate their behaviour.

Self-Efficacy and Physical Activity

Self-efficacy has been defined as an individual's confidence in their ability to achieve a specific outcome (e.g., PA-self-efficacy does not automatically transfer into academic self-efficacy; Bandura, 1988; Bandura, 1986; McCormick et al., 2019). Traditionally, self-efficacy is influenced by four factors mastery experience, vicarious experience, verbal persuasion from self and others, and physiological arousal (Bandura, 1977; Warner et al., 2014). The first factor, mastery experience, refers to an individual's experience with the target behaviour that informs their current perceived self-efficacy (Muretta et al., 2005). The second-factor vicarious experience refers to observational learning, that is, observation of a more experienced other or a fellow learner engaging in the target behaviour (Warner et al., 2011).

The third factor, verbal persuasion from self or others reflects how the individual responds to verbal motivation to persist with PA and how the valence of their self-talk impacts their PA behaviour (Hendricks, 2016). The fourth factor, physiological arousal, refers to the physiological reactions and individual experiences in anticipation of a task and how they interpret these (Muretta et al., 2005); for example, triggering the fight or flight response before PA can be interpreted as excitement or nervousness depending on the degree of arousal (Austin, 2022; Jones & Uphill, 2011). Due to physiological arousal component, self-efficacy can also be impacted by physical fatigue as the individual will experience less physiological arousal when fatigued (Anens et al., 2015; Graham et al., 2017). Through this lens, high self-efficacy would result from successful experience, observational learning, positive internal and external encouragement, and the ideal level of physiological arousal.

Past research has consistently demonstrated a positive association between increased levels of self-efficacy for PA and more frequent bouts of moderate to intense PA (Samson & Solmon, 2011; Warner et al., 2011, 2014; Yu et al., 2022). For example, Juwita & Damayanti (2022) examined the relationship between self-efficacy for PA and the level of PA among elderly individuals. Using correlation analysis, they determined that individuals with greater levels of self-efficacy were likelier to report engaging in more PA. Additionally, Tayama et al. (2012) examined the relationship between the effectiveness of a single-week pedometer intervention designed to increase PA among female university students. Their ANOVA showed that the intervention was more effective for participants with higher levels of SE, indicating individuals with more PA- self-efficacy engaged in more PA. Similarly, Dzielska et al. (2020) demonstrated that more significant changes in self-efficacy scores throughout a healthy eating and PA intervention predicted greater improvements in these behaviours within a sample of overweight adolescents. Overall, the above research indicates that higher self-efficacy can potentially increase an individual's level of PA.

Two of the primary mechanisms underlying the positive relationship between self-efficacy and physical activity are action and coping planning from the health action process approach (Carraro & Gaudreau, 2013; Zhang et al., 2019). Action planning refers to the individuals plan to implement a specific behaviour (Parschau et al., 2014). For example an individual seeking to exercise regularly may follow a workout plan/video, schedule time during their day for PA, and deciding on where they will engage in PA (Hattar et al., 2016), Coping planning refers to the individuals to plan to cope with challenges associated with enacting the target behaviour(Schwarzer, 2016; Zhang et al., 2019). For example, the same individual seeking to exercise regularly may hire a professional for support or exercise with a partner for accountability (Boutevillain et al., 2017; Spiteri et al., 2019).

Previous research has demonstrated that individuals with more confidence (i.e., self-efficacy) in their action and coping plans are more likely to follow through with their physical activity intentions (Pfeffer & Strobach, 2019; Tang et al., 2019; Sniehotta et al., 2005). For example, over a 1 year period Di Maio et al., (2020) followed up five times with participants from a randomized control trial testing the effectiveness of a action planning physical activity intervention. Using multilevel modeling they demonstrated that individuals with higher action planning self-efficacy were more likely to follow through with their plans for regular PA. In a similar fashion, Araujo-Soares et al., (2009) measured physical activity and coping and action planning at three time points over five months. Results from their hierarchical regression analyses determined there was a positive association between increased confidence in action and coping plans. Lastly, Luszcynska et al., (2010) demonstrated a moderation effect of self-efficacy where the benefit of action and coping planning was more salient for individuals with higher self-efficacy. Taken together, the research above highlights the importance of self-efficacy for enacting planned behaviour (e.g., PA).

Self-Motivation and Physical Activity

Concerning self-motivation, there are two critical dimensions to consider, that is, trait (drive) and state (arousal) motivation (Brehm & Self, 1989; Deci & Ryan, 2000; Richter et al.,2016). State motivation or arousal can be represented by the individual’s motivational intensity from moment to moment. This is a reasonably simple construct as it mainly refers to the overall amount of effort an individual is willing to invest to achieve a desired outcome (i.e., potential motivation) and the degree to which the individual can mobilize the necessary energy for the target behaviour (i.e., motivational arousal; Brehm & Self, 1989). The distinction between potential motivation and motivational arousal exists because an individual's ability to mobilize energy can be influenced by environmental/contextual factors (Richter et al., 2016). For example, an individual at risk for cardiovascular issues may be required to engage in aerobic PA as part of their treatment (Moreira et al., 2020; Murray et al., 2023). The context of the message can influence their potential motivation in that, gain framed messages emphasizing the possible benefits associated with regular PA are likely to lead to greater potential motivation compared to loss framed messages emphasizing the consequences related to inactivity (Gallagher & Updegraff, 2011; Li et al., 2014a). Environmental factors such as stress can influence the individuals' motivational arousal as its fatigue inducing effects can decrease the amount of energy available for a specific PA decreasing the likelihood of enacting PA (Stults-Kolehmainen et al., 2023). Thus, an individual's state self-motivation consists of two interconnected dimensions (i.e., potential motivation and motivational arousal) which are subject to contextual (e.g., message framing) and environmental factors (e.g., stress).

Self-determination theory best describes an individual's trait self-motivation; within this theory, the nature of an individual's motivation ranges from external to internal (Stone et al., 2009). At the external level of motivation, an individual's behaviour is entirely motivated by rewards and punishers (e.g., indulgent treat after PA, avoiding criticism; Ryan & Deci, 2000). At the internal end of the motivational continuum, an individual's behaviour is entirely motivated by internal factors as it is enjoyable, holds personal importance to them, and brings value or joy to their life (e.g., engaging in PA for health benefits or for enjoyment; Stevens et al., 2020).

As individuals progress from external to internal motivation for behavioural regulation, they pass through two sub-stages. First, introjected regulation is where an individual's behaviour begins to be motivated by internal rewards and punishers (e.g., guilt for missing PA; Zhong & Wang, 2019). Second, identified regulation is when an individual has begun integrating a specific behaviour (e.g., PA) as part of their identity, meaning the individual has begun to consciously value this behaviour as important (Stone et al., 2009). Lastly, fulfillment of our three basic psychological needs autonomy (i.e., greater control over daily life), competence, that is, confidence in daily tasks and environmental interactions, and relatedness (i.e., interpersonal connections/interaction) can aid in the development of internal motivation (Deci & Ryan, 2000; Deci & Vansteenkiste, 2003). This implies that within the context of regular PA the presence of a certified instructor to boost confidence, congenial peer group, and flexibility around timing can be used to fulfill an individual's basic needs to promote internal motivation for PA (Brown et al., 2016; Kalajas-Tilga et al. 2020).

Regarding the connection between state and trait self-motivation, previous research has demonstrated a small to medium positive relationship (Zamarippia et al., 2018; Standage et al., 2008; Noels et al., 1999). This implies that individuals with greater intrinsic motivation are likely to have a greater motivational potential and arousal. In relation to PA, past research has consistently demonstrated a small to medium positive association between increased levels of self-motivation for PA and more frequent bouts of moderate to intense PA (Mitchell et al., 2020; Ntoumanis et al., 2021; Owen et al., 2014). For example, Mullan et al. (2021) examined the relationship between PA intentions, self-motivation, and PA and healthy eating within a convenience sample of adults recruited online. Using stepwise regression, they demonstrated that greater levels of PA intention were related to greater levels of PA. However, this effect was much more substantial for those with high levels of internal motivation for PA. Additionally, Kalajas-Tilga et al. (2020) examine the relationship between need fulfillment, internal motivation, PA duration, and intensity within a sample of adolescents. Using structural equation modeling, they determined that greater fulfillment of all three needs was associated with greater internal motivation for PA, which was associated with greater PA.

Similarly, Attig and Franke (2019) demonstrated that individuals with greater levels of internal motivation for PA were less affected by the absences of their physical activity trackers than those with greater external motivation for PA. This differential effect then led to lower levels of PA among those with greater external motivation (i.e., self-monitoring with the tracker) compared to those with greater internal motivation. The above research indicates that greater levels of self-motivation for PA can potentially increase individuals' PA.

The Present Study

Taken together the above research makes it clear that self-control, self-motivation, self-efficacy, and stress are reliable predictors of individuals' levels of PA (Englert & Rummel, 2016b; Juwita & Damayanti, 2022; Kwag et al., 2017; Mullan et al., 2021). In an effort to build on these positive results recent efforts are being made to refine models of self-regulation by adopting a complimentary framework to the study of self-regulation and regular PA (de Bruin et al., 2020; Inzlicht et al., 2021; Taylor et al., 2020; Vink et al., 2020). Research adopting this complimentary framework tends to include multiple well established self-regulatory variables (e.g., self-control, behavioural intentions, stress) with the aim of testing the interplay among them when predicting a specific outcome (e.g. adherence to PA; Brown et al., 2016; Graham et al., 2017; Harris & Bray, 2022; Pfeffer et al. 2020). For example, Chirico et al., (2020) conducted a cross-sectional analysis examining the psychosocial mechanisms underlying physical activity behaviour during the COVID-19 pandemic within a sample of Italian adults. Results from their analysis demonstrated that greater intrinsic motivation and lower levels of anxiety were indirectly associated with greater intention to engage in PA through perceived behavioural control/self-efficacy, subjective norm, and attitude. Greater intention was then associated with greater levels of PA.

In line with this integrated approach the overall goal of the present study was to further refine the relationships among stress, self-control, self-efficacy, and self-motivation when predicting PA behaviour. Based on past research demonstrating the depletion effect of stress on individuals' self-regulatory resources and the negative impact of stress on regular PA (Englert & Rummel 2016; Harris et al., 2022; Kwag et al., 2011; Pfeffer et al., 2020); it was hypothesized that 1) stress would negatively impact individuals' level of PA directly and indirectly through its negative relationship with state multifactor self-regulation (i.e., state self-control, state self-efficacy, and state self-motivation). Given that previous researchers have demonstrated the depletion effect of stress and its impact on PA can be independently influenced by self-efficacy and self-motivation (Brown et al., 2016; Graham et al., 2014; Graham et al., 2017) it was hypothesized that 2) the negative relationship between stress and state multifactor self-regulation would be buffered by both trait self-efficacy and trait self-motivation. Furthermore, previous researchers have demonstrated increased levels of self-motivation and self-efficacy tend be associated with more regular PA (Kalajas-Tigla et al., 2020; Mullan et al., 2021; Pfeffer & Strobach, 2019; Tayama et al., 2012); based on this it was hypothesized that 3) the positive relationship between state multifactor self-regulation and individuals' level of PA would be enhanced by both trait self-efficacy and trait self-motivation. Lastly, given the potential for self-efficacy and self-motivation to buffer the depletion effect and contribute to more regular PA (Brown et al., 2016; Graham et al., 2014; Graham et al., 2017) it was hypothesized that 4) the negative indirect effect of stress would be buffered by both trait self-efficacy and trait self-motivation.

Methods

Design

The present study used a correlational design was used where cross sectional data assessing trait self-motivation and trait self-efficacy was collected at intake. Following completion of the intake measures participants completed the items assessing state self-control, self-motivation, and self-efficacy over a two day period using ecological momentary assessment (EMA) methodology. EMA methodology was ideal for the present study as it is often employed to measure state-like variables (Schondube et al., 2017; Testa et al., 2020). This was desirable within the present study as state self-control, self-motivation, and self-efficacy can vary throughout the day in response to stress and fatigue; meaning EMA had the potential to more accurately measure these variables (Remmerswaal et al., 2019; Testa et al., 2020; Yoshiuchi et al., 2008). This is because it uses technology (e.g., email, phones, tablets) to obtain self-report data from individuals as they go about their day (Doherty et al., 2016; Schondube et al., 2017; Yang et al., 2019).

Participants

Convenience sampling was used as participants were recruited online via Facebook and Reddit social media platforms. Facebook groups and sub Reddits (online forums dedicated to specific subjects on the website www.reddit.com) containing populations of Ontario adults made up the bulk of the participants as recruitment methods were targeted this population by posting recruitment messages within Ontario based online forums (e.g., facebook groups, sub-reddits). Examples of Ontario-specific Facebook groups and sub-Reddits include: *'r/Peterborough,' 'r/YorkRegion,' 'r/Ottawa,'* '*Events Ottawa,' 'Things to do in Barrie,'* and '*Peterborough Ontario.'* In addition, snowball sampling was used as participants were able to refer others to the study for extra raffle entries. Prior to data collection and the final analysis a monte carlo simulation power analysis was performed using the power.boot function from the bmem package (Zhang & Wang, 2022). By varying the expected effect sizes from small to medium it was determined the ideal sample size for detecting multiple interaction effects with 80% power was in the range of 400 to 500.

Overall 711 participants responded to the intake survey providing informed consent and an email to participate in the study. Of these 711 participants, 627 responded to the items within the question set emails sent over the 2 day EMA period (see Figure 1). Participants who responded to the question sets but did not provide data regarding their PA habits were removed from the 627 participants resulting in a final sample of 582. In the final sample the average age was 33.80 years (SD = 9.05), with the majority being female (see Table 1). Most participants lived with another adult. However, small minorities reported living alone or with two other adults (see Table 1). Participants' household income, measured in Canadian dollars, was average; however, this could vary quite a bit (see Table 1). Lastly, the bulk of participants reported having zero, one, or two children (see Table 1).

Table 1.

Demographic descriptive statistics

Variable	Mean(SD)	Frequency (%)
AGE (n= 577)	33.80(9.06)	-
INCOME (n= 477)	62850(54056)	-
ADULTS_NUM		
1	-	99(17)
2		344(60)
3		100(17)
4		30(5)
5		1(1)
MINORS_NUM		
0	-	146(25)
1		247(43)
2		162(28)
3		14(2)
4		10(1)
5		1(1)
SEX		
Female	-	336(58)
Male		240(41)
Non-binary		3(1)

Note. *This table contains the means and standard deviations for continuous demographic variables and frequencies for categorical demographic variables. AGE = participants age in years; INCOME = participants household income in Canadian dollars; ADULTS_NUM = number of adults living with the participant; MINORS_NUM = number of minors residing with the participant; SEX = gender.*

Procedures

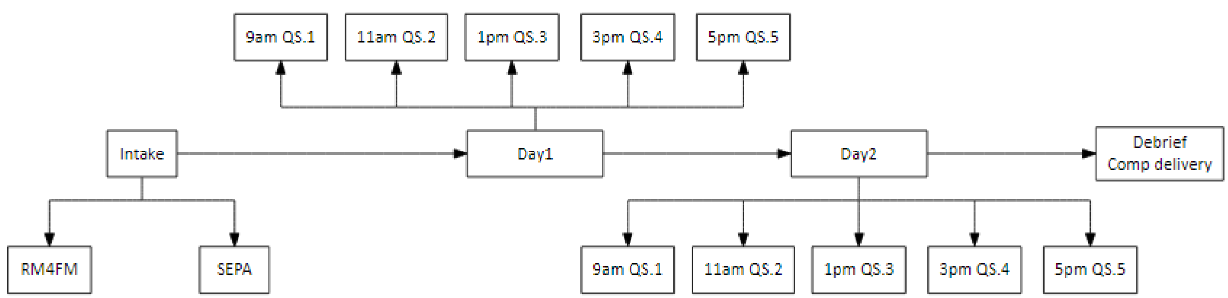
Interested participants were recruited via social media posts containing a recruitment link that would send them to the informed consent form (see Appendix D). If the participant chose '*I do not consent,'* they were redirected to a thank you message; if they chose *'I consent,'* they were redirected to the baseline measures assessing demographics, trait self-motivation (i.e., intrinsic versus extrinsic motivation) and self-efficacy (see Figure 1). After answering all baseline items, participants were prompted to enter their email for delivery of a randomly generated participant number that was used to match their responses. Given that snowball sampling was used, participants could also enter the email of the person who referred them at this stage.

One business day following the completion of the baseline measures, the participants' two-day EMA period began. In line with EMA methodology, participants received automated emails throughout the day prompting them to respond to the study's questionnaire. These emails contained Qualtrics links to sets of 4 to 5 questions sent at 2-hour intervals (see Figure 1; Qulatrics, Provo, UT). After no greater than one business day following the completion of the EMA period, participants received an email at 9 am containing a Qualtrics link to a debrief package (Qulatrics, Provo, UT). It also contained an open-ended question assessing the impact of the EMA measures on their behaviour (see Appendix E). The debrief package contained more information about the relationships being assessed (i.e., the interactions among stress, SC, SE, and SM) and scholarly resources if participants wished to learn more.

Upon completion of the study requirements, participants were provided with compensation in the form of $10 for greater than 95% complete data and $5 for greater than 75% complete data (see Figure 1). All participants with greater than 75% complete data were entered into a raffle to win 1 of 3 $100 Amazon gift cards. Participants received one extra entry per participant referral and two extra entrees if the referred participant provided complete data. Finally, it was emphasized in the informed consent form that compensation is related to successfully responding to the questionnaire items, not the amount of physical activity participants engaged in throughout the study. Prior to the commencement of this project, all methods used were approved by the Research Ethics Board at Trent University, project number 28023.

Figure 1.

Flow chart of study procedures



Note. *This figure depicts the flow of the study procedures. RM4FM = trait self-motivation measured by the Motivation for Exercising/Working-Out questionnaire; SEPA = trait self-efficacy measured by self-efficacy for physical activity scale; QS.1 = question set 1 contained 2 items assessing stress, 1 item assessing state SE, and 1 item assessing state SC; QS.2 = question set 2 contained 1 item assessing state SC, and 3 items assessing perceived stress; QS.3 = questions set 3 contained 2 state SC items and 2 stress items; QS.4 = question set 4 had 1 item assessing state SC, and 3 items assessing perceived stress; QS.5 = Question set 5 contained 1 item assessing state SM, 4 items assessing rate of perceived exertion, duration of PA, time of PA, and type of PA.*

Baseline Measures

Demographics

Brief demographic information of interest was collected regarding participants' age, gender, and socioeconomic status. Data was collected on these variables to obtain an understanding of the characteristics of the participants within the sample.

Trait Self-Motivation

The 12-item RM4-FM Motivation for Exercising/Working-Out questionnaire was administered at baseline to measure participants' trait self-motivation for PA in line with self-determination theory (Deci & Ryan, 2004). The RM4-FM measures motivation along the intrinsic-extrinsic continuum and provides four subscales of the motivation continuum (i.e., external regulation, introjected regulation, identified regulation, and intrinsic regulation). Example items include "*I engage in physical activity or would like to because I have a strong value for being active and healthy*" and "*I engage in physical activity or would like to because I simply enjoy physical activity".* This questionnaire uses a likert scale ranging from 1 '*not at all true'* to 7 *'very true'.* See Appendix B for the complete list of RM4FM items.

Trait Self-Efficacy

The 18-item Self-efficacy for physical activity scale (SEPA) developed by Warner et al. (2014) was administered at baseline to measure trait self-efficacy. The SEPA was used as it provides six subscales associated with the four dimensions of the four-factor model of self-efficacy (i.e., past/mastery experiences, vicarious experiences, verbal persuasion, and physiological experiences). Due to the similarities between self-efficacy and self-motivation, there is great potential for overlap among these constructs when included in the same study

(Williams & Rhodes, 2016). Thus, the wording of questions six to ten was altered by changing the word '*motivation*' to '*confidence'.* This change was made to better reflect the core concept of self-efficacy, which is confidence, not motivation.

Unfortunately, item 12, *'I motivate myself to be physically active on a regular basis,'* was dropped as it was too challenging to reword while keeping the original structure of the question intact. Moreover, its corresponding subscale, '*self-persuasion,'* still contained three items. This was deemed sufficient within the scope of the current study as the subscales are secondary to the overall objective of measuring self-efficacy within the context of PA. Regarding the questionnaire items, participants were required to respond to each statement using a likert scale ranging from 1, '*strongly agree'* to 4, '*strongly disagree'*. However, this scale was altered to a 7pt scale ranging from 1, '*not at all true'* to 7, *'very true'* for uniformity within the study. See Appendix B for the complete list of SEPA items.

Ecological Momentary Assessment Measures

State Self-Efficacy and Self-Motivation

State self-efficacy and self-motivation were each assessed by 1 item specifically designed for the present study. For state self-motivation, participants were required to respond to the following statement, *'I feel/felt energized to engage in physical activity today'* using a likert scale ranging from 1, *'not at all true'* to 7, *'very true'*. Using the same scale, participants were required to respond to the following statement, '*I feel/felt confident in my ability to engage in physical activity today'* to measure state self-efficacy. Single items were deemed sufficient to measure state self-efficacy and self-motivation as adding more questions to the EMA measures would have run the risk of inducing response fatigue and participant dropout.

State Self-Control

The 5-item adaptation of Ciarocco et al. (2007) state self-control capacity scale, validated by Linder et al. (2019), was selected to measure participants' daily self-control levels. Participants responded to items on a Likert scale ranging from 1 '*not true*' to 7 '*very true'.* This questionnaire was chosen as it is short and straightforward, meaning it was less likely to induce response fatigue and participant dropout, making it the ideal choice. See Appendix C for the complete list of state self-control items.

Perceived Stress

The 10-item Perceived Stress Scale (PSS; Cohen, 1994) was used as a measure of stress as it is one of the most commonly employed measures of stress across several environments (Lee, 2012; Cohen, 1983). Participants were required to respond to 10 items on a Likert scale ranging from 0 '*never*' to 4 '*very often'*. However, the response scale was changed to a 7pt likert scale ranging from 1 '*not true'* to 7 '*very true'* for uniformity within the study. Furthermore, the items were reworded to first-person language for uniformity and to reflect their current state in line with EMA methodology. For example, item 8 was changed from *'In the month, how often have you felt that you were on top of things'* to *'I feel I am on top of things'*. See Appendix C for the complete list of PSS items.

Physical Activity

The primary exercise behaviours of interest were physical activity duration, intensity, and time of day. To measure these behaviours, participants were required to report the number of minutes of physical activity that day, physical activity time of day (i.e., morning/afternoon/evening), and the perceived intensity level. The perceived intensity level was measured by the Borg et al. (1998) Rate of Perceived Exertion (RPE) Scale, ranging from 1 (minimum intensity) to 10 (maximum intensity). This scale was ideal as it is commonly used to measure RPE within research examining workout intensity (Bray et al., 2015; Marcora et al., 2009; Martin-Ginis and Bray 2010; Wagstaff, 2014); and is delivered in a format that is familiar to a large portion of individuals who have prior experience with exercise/sport. See Appendix C for the complete list of PA items.

Statistical Methods

All data analysis was done in R studio. After loading the raw data file (N=582) into R studio participants responses were analyzed for careless responding using the responsePatterns package (Rihacek & Gottfried, 2021). The rp.patterns function examines participants' responses for patterns indicative of careless responding (e.g., straight line or back and forth responding) falling within a minimum and maximum pattern length values. Pattern length was set with a minimum of 2 and a maximum of 29 as 29 was the greatest number of sequential items participants were exposed to at a single time. The number of repetitions of each pattern was summed and weighted, with smaller patterns receiving a smaller weight, before a standardized problem score was calculated for each participant by the rp.pattern function algorithm. Standardized problem scores range from 0 to 1 with higher scores indicating a greater likelihood of careless responding by that participant. Using the rp.select function the top 10% of problem scores were selected for further inspection. Of these top 10% the top 18 had a problem score ≥ .50. Their responses were plotted to examine for patterns of careless responding such as straight line responding or back and forth responding. Inspection of these plots revealed some instances of straight line and back and forth responding, however, none were sever enough to warrant exclusion from the study (see Appendix A)

After examining for careless responding, items 12, 13, and 14 of the self-efficacy for physical activity scale; items 1, 3, and 4 of the state self-efficacy scale; and items 4, 5, and 8 of the perceived stress scale were reverse scored where 7=1, 6=2, 5=3, 4=4, 3=5, 2=6, 1=7 using the mutate and recode functions from the dplyr package (Wickham et al., 2022). After the items were reversed scored confirmatory factor analysis (CFA) using maximum likelihood with robust standard errors was run using the package lavaan (Rosseel, 2012). This was done to confirm the psychometric properties of each variable scale and subsequent total used in the final analysis. Path diagrams of each scales factor structure were then produced using the graph_sem function from the tidySEM package (van Lissa, 2022). Please note only complete cases were used within the CFA.

Total scores were calculated based on the factor structure from the CFA using the mutate function from the dplyr package (Wickham et al., 2022). The SEPA was scored by calculating a 17-item average resulting in the trait self-efficacy total which was then mean centered. The RM4FM was scored by a calculating an average for each subscale of the 11-item 3-factor RM4FM (i.e., external, identified, and intrinsic). To stay as true as possible to the original scoring system where a weighted total was calculated with the external/introjected subscale weighted negatively and the identified/intrinsic subscales weighted positively (Deci & Ryan, 2004) each subscale was weighted (i.e., external as -1, identified as .5, and intrinsic as .5) and summed to calculate a relative autonomy index . Note that the 1- item 3-factor RM4FM was used as the CFA revealed it to have improved psychometric properties compared to the 4-factor RM4FM.

The 10 item perceived stress scale was calculated as a 2-day average where day 1 and day 2 averages were calculated and then averaged. The 2-day perceived stress scale average was then mean centered. The 5-item state self-control scale was combine with the two single items measuring state self-efficacy and state self-motivation as this combination showed improved psychometric properties vs the 5-item state self-control scale and was more theoretically robust (see Factor Analysis). The resulting 7 item state multifactor self-regulation total was calculated as a 2-day average where day 1 and day 2 averages were calculated and then averaged. The 2-day state multifactor self-regulation average was then mean centered.

Given that some participants may have exercised for less time but at a higher intensity or vice versa, the outcome variable rate of perceived exertion load was calculated as the product of minutes of physical activity and rate of perceived exertion. The rate of perceived exertion load variable more accurately captures participants' level of exercise as individuals who exercise for shorter periods but at higher intensities and those who exercise for longer periods at lower intensities both receive higher scores (e.g., 20min*10rpe=200 and 100min*2rpe=200). The final rate of perceived exertion load total was represents a 2 day average where averages for day 1 and day 2 were calculated and then averaged (Movella, 2010). This outcome variable was chosen as it provides a better representation of participants PA behaviours than either minutes or RPE alone.

Time of day exercise was performed was transformed to be represented numerically where morning was 1, afternoon was 2, evening was 3, and 0 was no PA. This numeric representation was then used to calculate a 2-day average representing day 1 and day 2. The number of adults' cohabitating and number of minors living in the residence were represented on numeric scales ranging from 0 to 5. Sex and physical activity type were recoded to have numeric categories. The following numeric codes were used: sex had female as 1, male as 2, and 3rd gender as 3; physical activity type had aerobic as 1, strength as 2, sport as 3, built in as 4, and none as 5. Please note only complete cases were used when computing all totals.

After cleaning the data and calculating totals as described a final data file was saved to be used for calculating descriptive statistics (i.e., mean, sd) and correlations, testing normality, and the final path analysis. Descriptive statistics were calculated using the skim function from the skimr package (Waring et al., 2022), correlations and confidence intervals using the cor.test function, normality using the stat.desc and qqPlot functions from the pastecs and car packages (Fox & Weisberg, 2019; Grosjean & Ibanez, 2018). The final path analysis was done using the 'Process' macro by Hayes (2022) for R studio. This macro allows the user to fit various moderation, mediation, and moderated mediation models using ordinary least squares regression to estimate model parameters. When fitting a model using process the necessary interactions terms are calculated based on the model number which corresponds to a prespecfied model. The present study used model number 75 which specifies a W and Z moderator acting on the IV-mediator and mediator-DV paths. Given the interaction terms were entered into the model for the user there was no need to manually create them before conducting the path analysis.

In addition, all data points necessary for probing and visualizing each interaction were calculated by process and provided for the user. Of specific interest were the relationships between stress and state multifactor self-regulation, and state multifactor self-regulation and rate of perceived exertion load conditional on high, medium, and low values of trait self-motivation and self-efficacy. The provided data was then plotted using the plot function and a path diagram was created using the grViz form the DiagrammeR package (Iannone, 2023). Plots included in the path analysis section represent each significant conditional effect where trait self-efficacy and self-motivation were the moderators.

Results

The results will be reported in the following order. First, descriptive statistics on all measures PA variables are given. Second, the results from factor analysis and Cronbachs alpha confirming the psychometric properties of each questionnaire are presented. Third, descriptive statistics, including bivariate correlations, are given for all model variables. Lastly, the results from the moderated mediation path analysis are presented, beginning with the hypothesized relationships, followed by the three way interaction effects, and finally, the conditional indirect effects.

Physical Activity Descriptive Statistics

The participants within the present sample appear to be very active across both days; however, the intensity and duration varied considerably (see Table 2). Concerning the type of exercise, most participants reported engaging in some form of aerobic exercise such as running, biking, or swimming. Small minorities reported engaging in resistance training, including weights or calisthenics; sports such as basketball, tennis, or Frisbee; and building PA into their daily routine through active transport, or being active at work (see Table 2). Lastly, there appeared to be a relatively even distribution of PA occurrences throughout the day (see Table 2)

Table 2.

Descriptive statistics for moderate to vigorous physical activity measures

Variable	Mean(SD)		Frequency(%)	
	Day 1	Day 2	Day 1	Day 2
MIN	64.54(38.73) n= 582	67.04(41.07) n= 541		
RPE	4.56(2.03) n= 579	4.45(2.07) n= 538		
Type of PA				
Aerobic			351(63)	321(60)
Resistance			67(12)	57(11)
Sport			78(14)	89(17)
Built-in			36(7)	49(9)
None			20(4)	14(3)
Time of day of PA				
Morning			191(33)	161(30)
Afternoon			203(36)	184(35)
Evening			151(26)	162(30)
No PA			29(5)	26(5)

Note. *This table contains the means and standard deviations for continuous PA variables and frequencies for categorical PA variables on days 1 and 2. MIN = minutes of physical activity; RPE = rate of perceived exertion.*

Factor Analysis

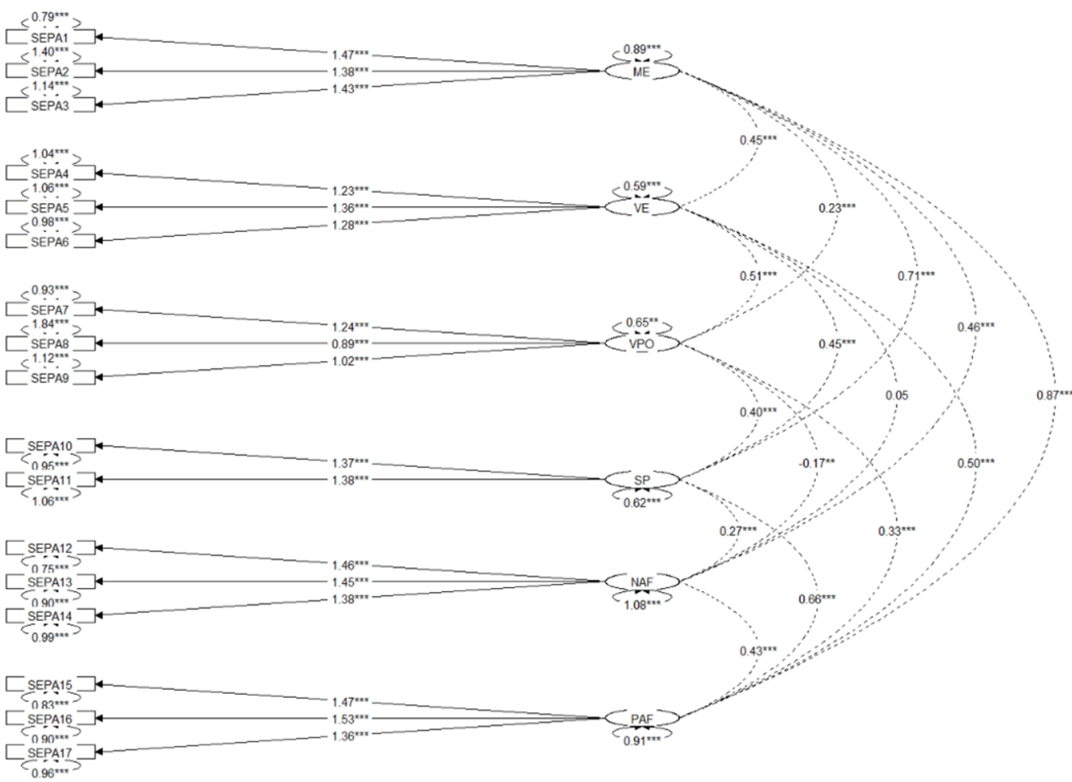
Baseline Measures

Factor analysis was used to confirm the psychometric properties of each baseline measure (i.e., the RM4FM and SEPA). General guidelines for model fit recommend that the Confirmatory Factor Index (CFI) be ≥.95 for good fit and ≥.90 for moderate fit, Root Mean Square Error Approximation (RMSEA) be ≤ .06 for good fit and ≤ .10 for moderate fit, and

Standardized Root Mean Square Residuals (SRMR) be ≤ .05 for good fit and ≤ .08 for moderate fit (Iacobucci, 2010; Kenny, 2015; Kumar & Upadhaya, 2017; Shi et al., 2020). Regarding the SEPA (n=524), analysis confirmed the 6 factor structure with good to moderate fit (CFI = .94, RMSEA =.06, SRMR = .05), good reliability α =.89, .95CI = [.88 to .90], and each item significantly loading onto its respective factor (see Figure 2). The results from this analysis suggest the SEPA possesses strong psychometric properties.

Figure 2.

Factor structure of the SEPA



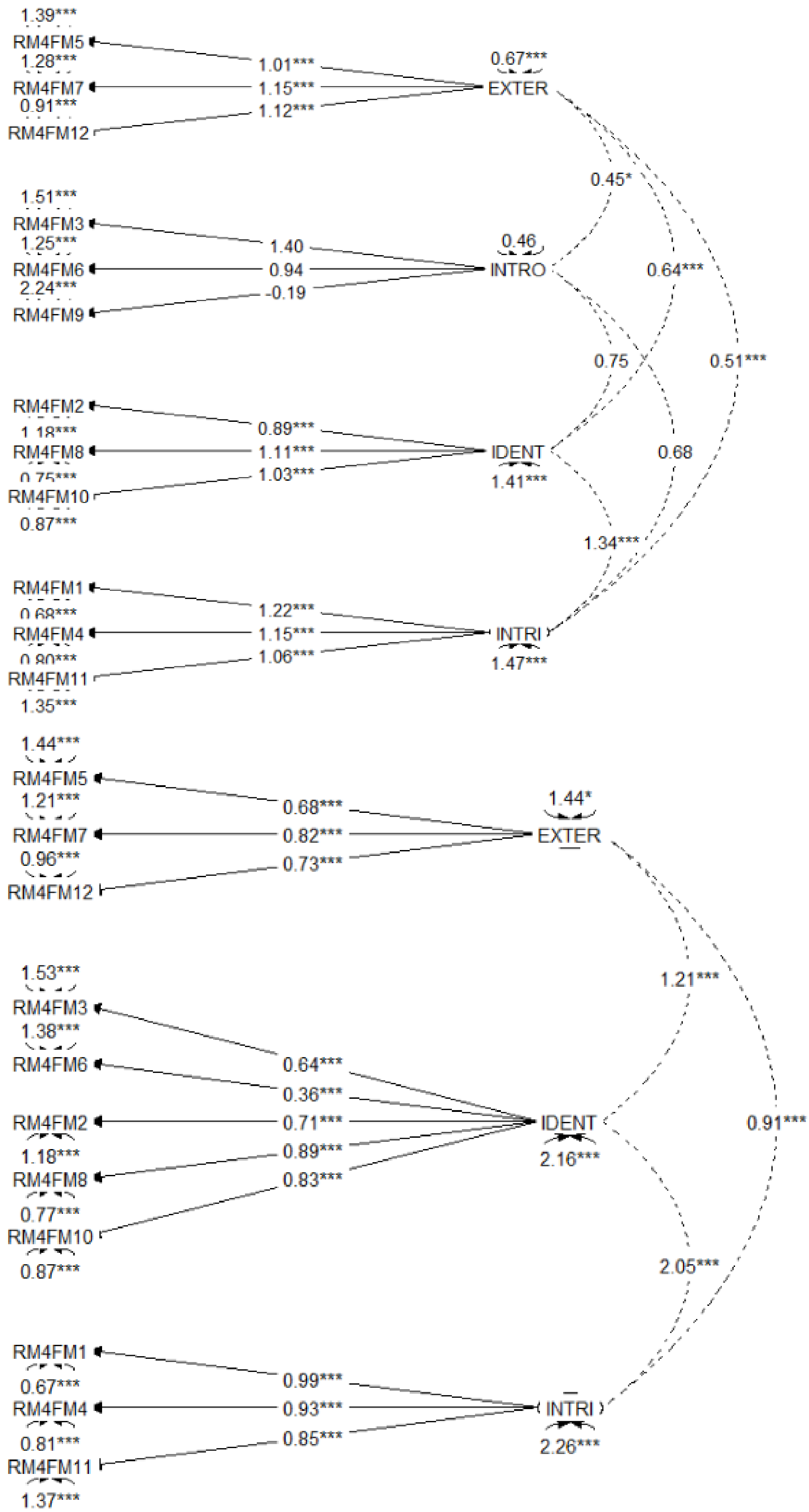
Note. **** represents significance at p<.001. This figure contains the unstandardized beta weights for each item, the variances for each items and factor, and the covariance's among each factor. ME = mastery experience; VE = vicarious experience; VPO = verbal persuasion from* *others; SP = self-persuasion; NAF = negative affect; PAF = positive affect; SEPA1:17 = self-efficacy for physical activity scale items 1 through 17. See Table 3 for .95ci's for each path coefficient.*

Regarding the RM4FM (n = 540), initial analysis revealed a moderate to poor fit (CFI = .87, RMSEA = .12, SRMR = .08), good reliability α =.85, .95CI = [.84 to .86], and all items significantly loaded onto their respective factors except for the introjected subscale items 3,6, and 9 (see Figure 3 top). Correlations among the items and factors revealed negative relationships between RM4FM9 *"because I feel pressured to be physically active"* and the rest of the items. Accordingly, it was dropped from the model. The remaining items 3 and 6 were examined for covariance and similarities with the other three factors. RM4FM3 and RM4FM6 were most strongly correlated with the identified subscale ($r_{RM4FM3\text{-}identifed}$ =.57, p<.001, $r_{RM4FM6\text{-}identifed}$ = .46, p<.001). In addition, the introjected and identified subscales shared a strong positive correlation r = .93, p<.001. Examination of the items supported this observed overlap between the introjected and identified subscales. For example, the introjected subscale item 3 *"Because I would feel bad about myself if I didn't"* was very similar to identified subscale item 8 *"Because it is personally important to me to be physically active"*. Given the observed covariance and similarities, the introjected subscale was combined with the identified subscale.

This change improved the model fit of the RM4FM (n =545) from moderate-poor to good-moderate (CFI = .93, RMSEA = .08, SRMR = .05) with a slight improvement in reliability α =.88, .95CI = [.87 to .89]. Furthermore, items 1 through 11 all significantly loaded onto their respective factors (see Figure 3 bottom). The results from this analysis suggest a 3 factor model of self-motivation consisting of external, identified, and intrinsic motivations may be preferable to a 4 factor model.

Figure 3.

Factor structure of the RM4FM



Note. **** represents significance at p<.001. This figure contains the unstandardized factor loadings, variance, and covariances for the factors and items of the RM4FM Motivation for Physical Activity and Exercise Scale.EXT = external motivation; INTRO = introjected motivation; IDEN = identified motivation; INTRI = intrinsic motivation; RM4FM1:RM4FM12 = Motivation for Physical Activity and Exercise Scale Questions 1 through 12.See Table 3.95ci's for each path coefficient.*

Table3.

.95CI's for SEPA and RM4FM item path coefficients

SEPA item	.95ci	RM4FM item	.95ci
SEPA1	1.24 to 1.69	RM4FM1	1.09 to 1.35
			0.75 to 1.23
SEPA2	1.18 to 1.58	RM4FM2	0.78 to 0.99
			0.62 to 0.80
SEPA3	1.19 to 1.66	RM4FM3	-0.03 to 2.84
			0.55 to 0.73
SEPA4	0.90 to 1.56	RM4FM4	1.02 to 1.28
			0.70 to 1.15
SEPA5	1.03 to 1.69	RM4FM5	0.76 to 1.28
SEPA6	0.97 to 1.59	RM4FM6	-0.36 to 2.24
			0.26 to 0.47
SEPA7	0.85 to 1.63	RM4FM7	1.05 to 1.25
			0.43 to 1.22
SEPA8	0.44 to 1.34	RM4FM8	1.08 to 1.21
			0.81 to 0.98
SEPA9	0.66 to 1.38	RM4FM9	-1.02 to 0.65

			-
SEPA10	1.13 to 1.62	RM4FM10	0.94 to 1.12
			0.073 to 0.92
SEPA11	1.10 to 1.66	RM4FM11	0.93 to 7.19
			0.63 to 1.06
SEPA12	1.36 to 1.56	RM4FM12	0.81 to 1.43
			0.38 to 1.09
SEPA14	1.28 to 1.48		
SEPA15	1.21 to 1.73		
SEPA16	1.25 to 1.81		
SEPA17	1.11 to 1.62		

Note. *This table contains the unstandardized .95ci's for each path coefficient from the SEPA and RM4FM. Please note regarding the RM4FM on top is the .95ci/p value from the 4 factor 12 item model on the left in Figure 3, while on the bottom is the .95ci/p value from the 3 factor 11 item model on the right in Figure 3. SEPA1:17 = self-efficacy for physical activity scale items 1 through 17. RM4FM1: RM4FM12 = Motivation for Physical Activity and Exercise Scale Questions 1 through 12*

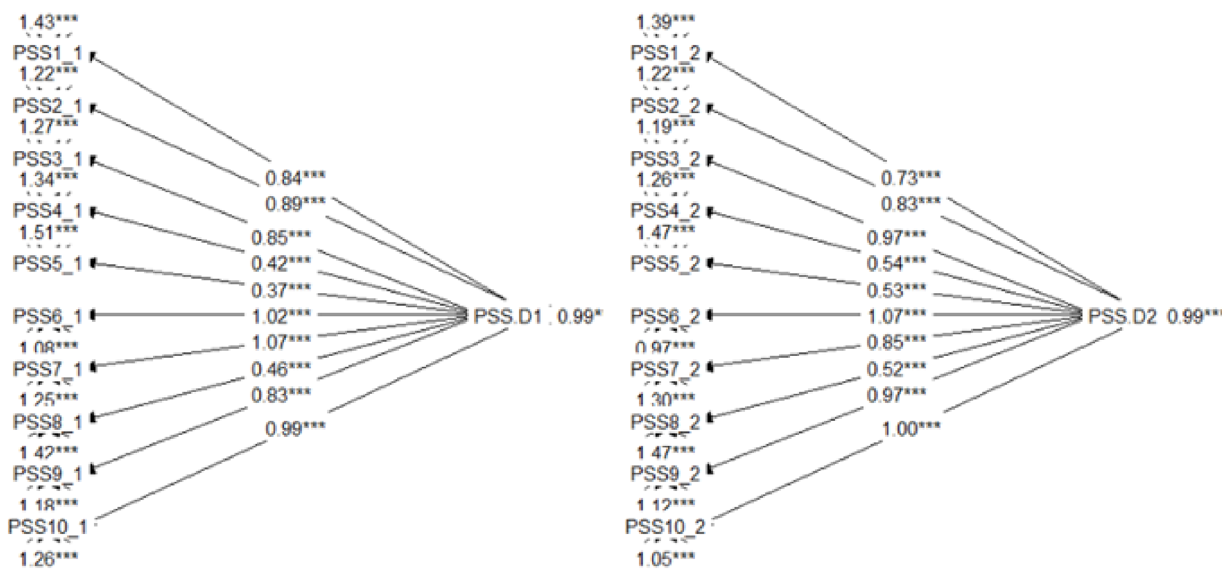
Ecological Momentary Assessment Measures

Similar to the baseline measures, factor analysis was used to confirm the psychometric properties of each EMA measure. Regarding the perceived stress scale, analysis revealed good reliability and moderate to poor fit for both day 1 (α = .81, .95CI = [.78 to .84], CFI = .88, RMSEA = .08, SRMR = .07, n = 550) and day 2 (α = .83, .95CI = [.81 to .86], CFI = .82, RMSEA = .10, SRMR = .07, n = 503). Furthermore, each item significantly loaded onto the single stress factor (see

Figure 4). The results from this analysis suggest the perceived stress scale used within the present study context possesses adequate yet weaker psychometric properties.

Figure 4.

Factor structure of the PSS



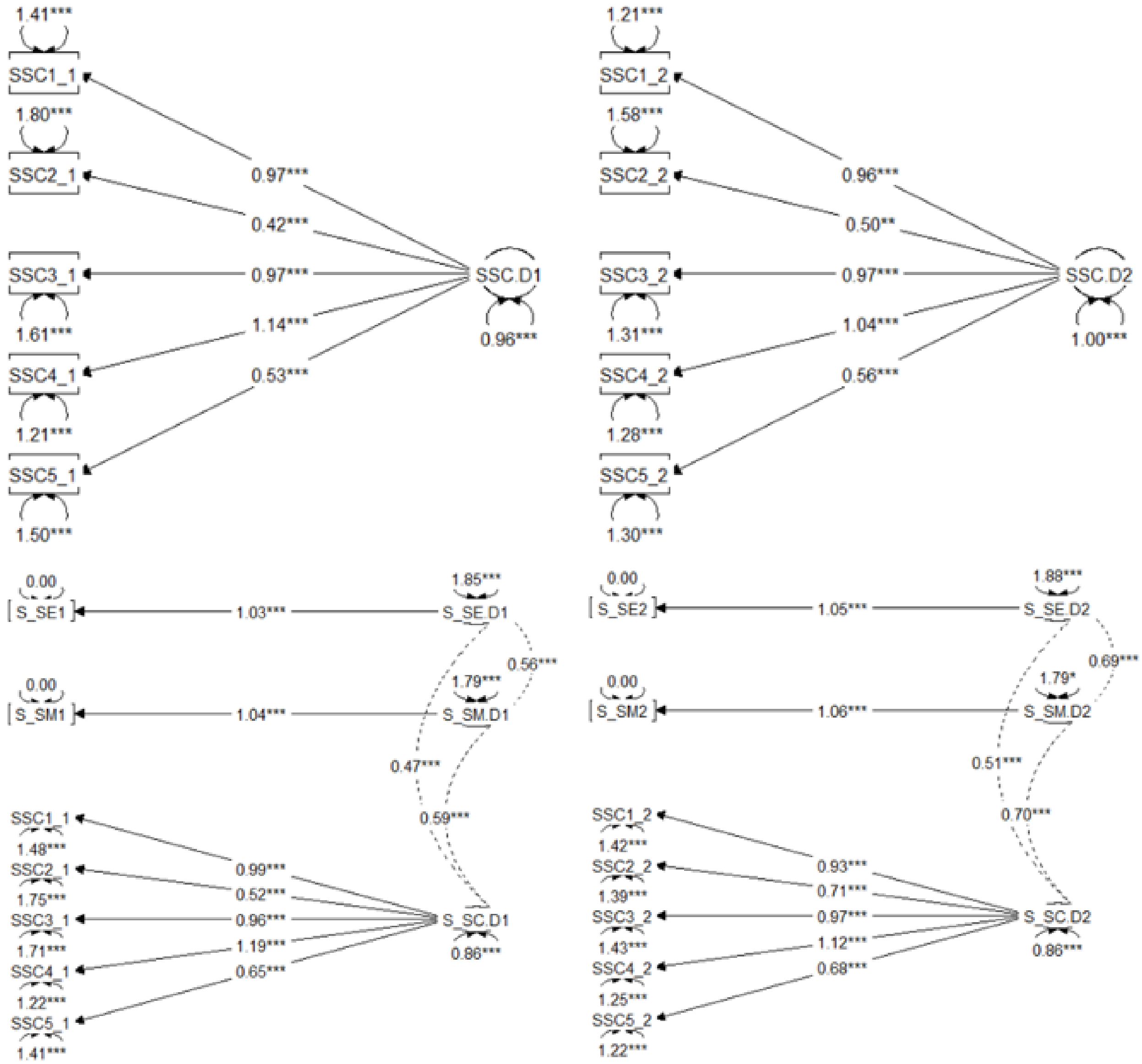
Note. **** represents significance at p<.001. This figure contains the unstandardized factor loadings, variance, and covariances for the factors and items of the perceived stress scale on day 1 (left) and day 2(right). PSS1:10_1 = day 1 responses to perceived stress scale items 1 through 10; PSS.D1 = perceived stress on day1; PSS1:10_2 = day 2 responses to perceived stress scale items 1 through 10; PSS.D2 = perceived stress on day2. See Table 4 for .95ci's for each path coefficient.*

The 5 item state self-control scale demonstrated low reliability α = .66, .95CI = [.60 to .70] and moderate to poor fit on day 1 (CFI = .87, RMSEA = .12, SRMR = .07, n = 559), while on day 2 the reliability slightly improved α = .69, .95CI = [.64 to .74] and the model fit decreased to poor (CFI = .77, RMSEA = .24, SRMR = .09, n= 507). Despite the weak psychometric properties of the state self-control scale within the current context all items significantly loaded onto the single state self-control factor across both days (see Figure 5 top).

In an attempt to improve the psychometric properties of the state self control scale and create a more theoretically robust measure of self-regulation the individual items measuring state self-motivation and state self-efficacy were added to create a preliminary 3 factor 7 item state multifactor self-regulation scale. Results revealed a modest increase in reliability on day 1 $\alpha = .71$, .95CI = [.66 to .75] and day 2 $\alpha = .75$, .95CI = [.71 to .79]. Additionally, model fit indices showed slight improvement as they increased to moderate on day 1 (CFI = .90, RMSEA = .09, SRMR = .06, n= 553) and poor to moderate on day 2 (CFI = .84, RMSEA = .13, SRMR = .07, n=492) with all items significantly loading onto their factors (see Figure 5 bottom). Thus, it appears as if the addition of the state self-motivation and self-efficacy items improved the psychometric properties of the state self-control scale resulting a more theoretically robust measure of self-regulation.

Figure 5.

Factor structure of the state self-control and multifactor self-regulation scales



Note. **** represents significance at p<.001. This figure contains the unstandardized factor loadings, variance, and covariances for the factors and items of the state self-control scale on day 1 (top left) and day 2(top right) and state multifactor self-regulation scale on day 1(bottom left) and day 2(bottom right) . SSC1:5_1 = day 1 responses to state self-control items 1 through 5; SSC.D1 = state self-control on day 1; SSC1:5_2 = day 2 responses to state self-control items 1* *through 5; SSC.D2 = state self-control on day 2; S_SM1 = day 1 response to state self-motivation items 1; S_SM.D1 = state self-motivation on day 1; S_SM2 = day 2 response to state self-motivation items 1; S_SM.D2 = state self-motivation on day 2; S_SE1 = day 1 response to state self-efficacy items 1; S_SE.D1 = state self-efficacy on day 1; S_SE2 = day 2 response to state self-efficacy item; S_SE.D2 = state self-efficacy on day 2. See Table 4 for .95ci's for each path coefficient.*

Table 4.

.95CI's for PSS, 5 item SSC, and 7 item MSR item path coefficients

Day 1 items	.95ci	Day 2 items	.95ci
PSS1_1	0.57 to 1.11	**PSS1_2**	0.62 to 0.84
PSS2_1	0.56 to 1.22	**PSS2_2**	0.73 to 0.92
PSS3_1	0.55 to 1.15	**PSS3_2**	0.84 to 1.09
PSS4_1	0.34 to 0.51	**PSS4_2**	0.42 to 0.67
PSS5_1	0.26 to 0.48	**PSS5_2**	0.40 to 0.67
PSS6_1	0.63 to 1.41	**PSS6_2**	0.97 to 1.16
PSS7_1	0.67 to 1.47	**PSS7_2**	0.74 to 0.97
PSS8_1	0.36 to 0.56	**PSS8_2**	0.34 to 0.66
PSS9_1	0.53 to 1.14	**PSS9_2**	0.87 to 1.07
PSS10_1	0.63 to 1.36	**PSS10_2**	0.88 to 1.12
SSC1_1	0.85 to 1.10	**SSC1_2**	0.87 to 1.05
	079 to 1.18		0.68 to 1.18
SSC2_1	0.27 to 0.57	**SSC2_2**	0.13 to 0.86
	0.38 to 0.66		0.55 to 0.87
SSC3_1	0.76 to 1.17	**SSC3_2**	0.87 to 1.07
	0.80 to 1.11		0.74 to 1.20
SSC4_1	0.98 to 1.29	**SSC4_2**	0.59 to 1.49

	1.06 to 1.32		1.03 to 1.20
SSC5_1	0.42 to 0.64	**SSC5_2**	0.26 to 0.86
	0.49 to 0.80		0.55 to 0.81
S_SE1	0.75 to 1.32	**S_SE2**	0.75 to 1.35
S_SM1	0.99 to 1.10	**S_SM2**	0.65 to 1.45

Note. *This table contains the unstandardized .95ci's for each path coefficient from the perceived stress scale, state self-control scale, and state multifactor self-regulation scale on day 1 and day 2. Please note regarding the SSC items on top is the .95ci/p value from the single factor 5 item model on the top of Figure 5, while on the bottom is the .95ci/p value from the 3 factor 7 item model on the bottom of Figure 5. PSS1:10_1 = day 1 responses to perceived stress scale items 1 through 10; PSS.D1 = perceived stress on day1; PSS1:10_2 = day 2 responses to perceived stress scale items 1 through 10; PSS.D2 = perceived stress on day2. SSC1:5_1 = day 1 responses to state self-control items 1 through 5; SSC.D1 = state self-control on day 1; SSC1:5_2 = day 2 responses to state self-control items 1 through 5; SSC.D2 = state self-control on day 2; S_SM1 = day 1 response to state self-motivation items 1; S_SM.D1 = state self-motivation on day 1; S_SM2 = day 2 response to state self-motivation items 1; S_SM.D2 = state self-motivation on day 2; S_SE1 = day 1 response to state self-efficacy items 1; S_SE.D1 = state self-efficacy on day 1; S_SE2 = day 2 response to state self-efficacy item; S_SE.D2 = state self-efficacy on day 2.*

Model Descriptive Statistics

Participants' activity levels were reflected in their perceived exertion load consisting of minutes of PA*rate of perceived exertion, again this reflected an active sample with quite a wide variation (see Table 5). Regarding participants' self-regulatory abilities, they reported moderate levels of trait self-motivation indicating a mix of internal and external motivators for engaging in physical activity (see Table 5). Participants reported moderate levels of trait physical activity self-efficacy indicating they were reasonably confident in their physical abilities at baseline (see Table 5). Participants reported moderate levels of state multifactor self-regulation indicating they felt relatively in control of their behaviour, motivated to engage in PA, and confident in their ability to do so (see Table 5). Lastly, participants reported moderate levels of perceived stress indicating they were neither overstressed nor under stressed (see Table 5).

Table 5.

Descriptive statistics of model variables

Variable	Mean	Std. Dev	Min	Max	Skew.2se	Kurt.2se	Valid N
RPE.L	334	247	0	1575	6.54	5.68	537
S_MSR	4.33	0.84	2.14	6.93	3.71	0.32	477
STRESS	3.66	0.83	1.3	6.6	-3.68	-0.11	490
T_SE	4.34	0.96	2.06	6.35	-0.92	-1.32	524
T_SM	-.13	1.19	-4.07	3.6	-2.68	3.50	545

Note. *This table contains the means, standard deviations, min and max values, standardized skew, standardized kurtosis, and number of participants for each model variable. RPE.L = participants 2 day average rate of perceived exertion load; S_MSR = participants 2 day average state multifactor self-regulation; STRESS = participants 2 day average stress; T_SE = participants trait self-efficacy for PA; T_SM = participants trait self-motivation for PA. Please note that QQ plots supplementing the standardized skew and kurtosis statistics can be found in Appendix A.*

Initial bivariate r's between the model variables revealed small positive relationships between rate of perceived exertion load and number of adults cohabitating, trait self-motivation, and trait self-efficacy (see Table 6). This means that participants who achieved a higher rate of perceived exertion load likely worked out in the evening, lived with more than 1 adult, and possessed greater levels of trait self-efficacy and more internal motivation for PA. Small negative relationships between the number of adults living together and state multifactor self-regulation and trait self-efficacy were observed, while number of adults cohabitating had a small to medium positive relationship with stress and time of day physical activity was performed (see Table 6). This indicates that individuals who live with more than one adult are likely to experience more stress, and engage in exercise in the evening, while also experiencing lower state multifactor self-regulation and trait self-efficacy.

Small to medium negative relationships were observed between time-of-day exercise was performed and state multifactor self-regulation and trait self-efficacy (see Table 6), indicating individuals exercising in the evening possessed lower levels of state multifactor self-regulation and trait self-efficacy. Small to large negative relationships were observed between stress and all self-regulatory variables (i.e., state multifactor self-regulation, trait self-efficacy, and trait self-motivation; see Table 6). It appears that individuals who experience more stress possess lower levels of state multifactor self-regulation, trait self-efficacy, and more external motivation. Lastly, moderate relationships were observed between state multifactor self-regulation, trait self-efficacy, and trait self-motivation (see Table 6). This indicates that individuals with higher levels of one self-regulatory variable are also likely to possess higher levels of the others.

Table 6.

Bivariate correlations among model variables

Variable Name	RPE.L	S_MSR	STRESS	TOD	T_SE	T_SM
ADULTS_NUM	r(534) = .12, p=.007 [.03 to .20]	r(547) = -.23, [-.32 to -.15]	r(487) = .29, [.20 to .37]	rho(526) = .19, [.17 to .27]	r(521) = -.15, [-.24 to -.07]	r(542) = -.004, p =.90 [-.09 to .08]
RPE.L		r(473) = .05, p =.25 [-.04 to .14]	r(478) = .02, p =.67 [-.07 to .11]	rho(523) = .39, [.31 to .46]	r(482) = .14, [.05 to .23]	r(502) = .21, [.13 to .29]
S_MSR			r(463) = -.87, [-.89 to -.84]	rho(470) = -.08, p = .05 [-.17 to .00]	r(439) = .50 [.43 to .58]	r(456) = .28 [.20 to .37]
STRESS				rho(473) = .13, p = .006 [.04 to .21]	r(448) = -.49, [-.56 to -.42]	r(465) = -.23, [-.31 to -.14]
TOD					rho(477) = -.03, p=.46 [-.12 to .06]	rho(497) = .12, p =.009 [.03 to .20]
T_SE						r(503) = .41 [.33 to .48]

Note. *This table contains the bivariate correlations and in brackets .95CI's among all variables included in the final model. Please note that unless an exact p value is given correlations are significant at p<.001. RPE.L = participants 2 day average rate of perceived exertion load; S_MSR = participants 2 day average state multifactor self-regulation; STRESS = participants 2 day average stress; TOD = participants 2 day average time of day for engaging in PA; T_SE = participants trait self-efficacy for PA; T_SM = participants trait self-motivation for PA.*

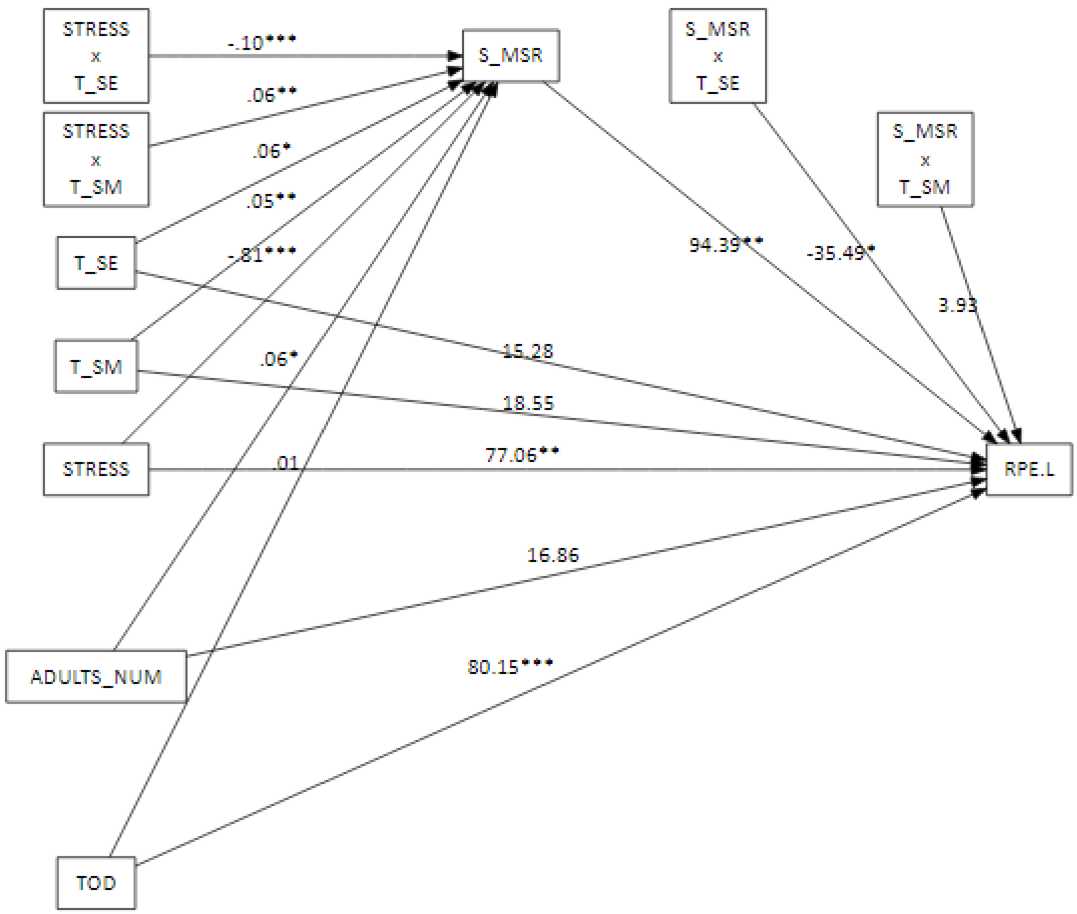
Path Analysis

Path analysis using ordinary least squares regression was used to test the hypothesized relationships. Before proceeding with any structural analyses, the normality of each model variable was examined using skew.2se, kurt.2se, and qq-plots. The majority of model variables were either skewed or kurtotic or both, with the exception of trait self-efficacy (see Table 1 and Appendix A).Thus, bootstrapped CI's were calculated around all model parameters to correct for any effect of the non-normality within the model variables (Hancock & Liu, 2012; West et al., 1995).

The current model (n = 418) had a R2 for state multifactor self-regulation of.79 indicating the model accounted for 79% of variance in participants state multifactor self-regulation. The R2 for rate of perceived exertion load was .15 indicating the model accounted for 15% of variance in participants' rate of perceived exertion load. Based on the results from the regression-based path analysis displayed in Figure 6 there appeared to be a positive direct effect of stress on rate of perceived exertion load (see Figure 6). However, the indirect effect of stress on participants' rate of perceived exertion load was negative b = -201.33, p=.003, .95CI = [-335.12to -67.54]. Furthermore, the negative indirect effect of stress on participants' rate of perceived exertion load appeared to be conditional on participants' trait self-motivation and trait self-efficacy b = -181.13, p= .002, .95CI = [-297.42 to -64.85]. Lastly, this effect appears to be independent of time-of-day exercise was performed and the number of adults cohabitating, although individuals cohabitating with more than one adult tended to have higher levels of state multifactor self-regulation, and those exercising later in the evening were more likely to have a higher rate of perceived exertion load (see Figure 6).

Figure 6.

Path diagram of hypothesized relationships



Note. **** indicates significance at p<.001; ** indicates significance at p< .01; and * indicates significance at p<.05*. *This figure contains the unstandardized path coefficients for each on the model variables. RPE.L = participants 2 day average rate of perceived exertion load; S_MSR = participants mean centered 2 day average state multifactor self-regulation; STRESS = participants mean centered 2 day average stress; TOD = participants 2 day average time of day for engaging in PA; T_SE = participants mean centered trait self-efficacy for PA; T_SM = participants trait self-motivation for PA; ADULTS_NUM = number of adults cohabitating; STRESS* *x T_SM = stress and trait self-motivation interaction term; STRESS x T_SE = stress and trait self-efficacy interaction term; S_MSR x T_SM = state multifactor self-regulation and trait self-motivation interaction term; S_MSR x T_SE= state multifactor self-regulation and trait self-efficacy interaction term. See Table 5 for 95ci's for each path coefficient.*

Interaction Effects

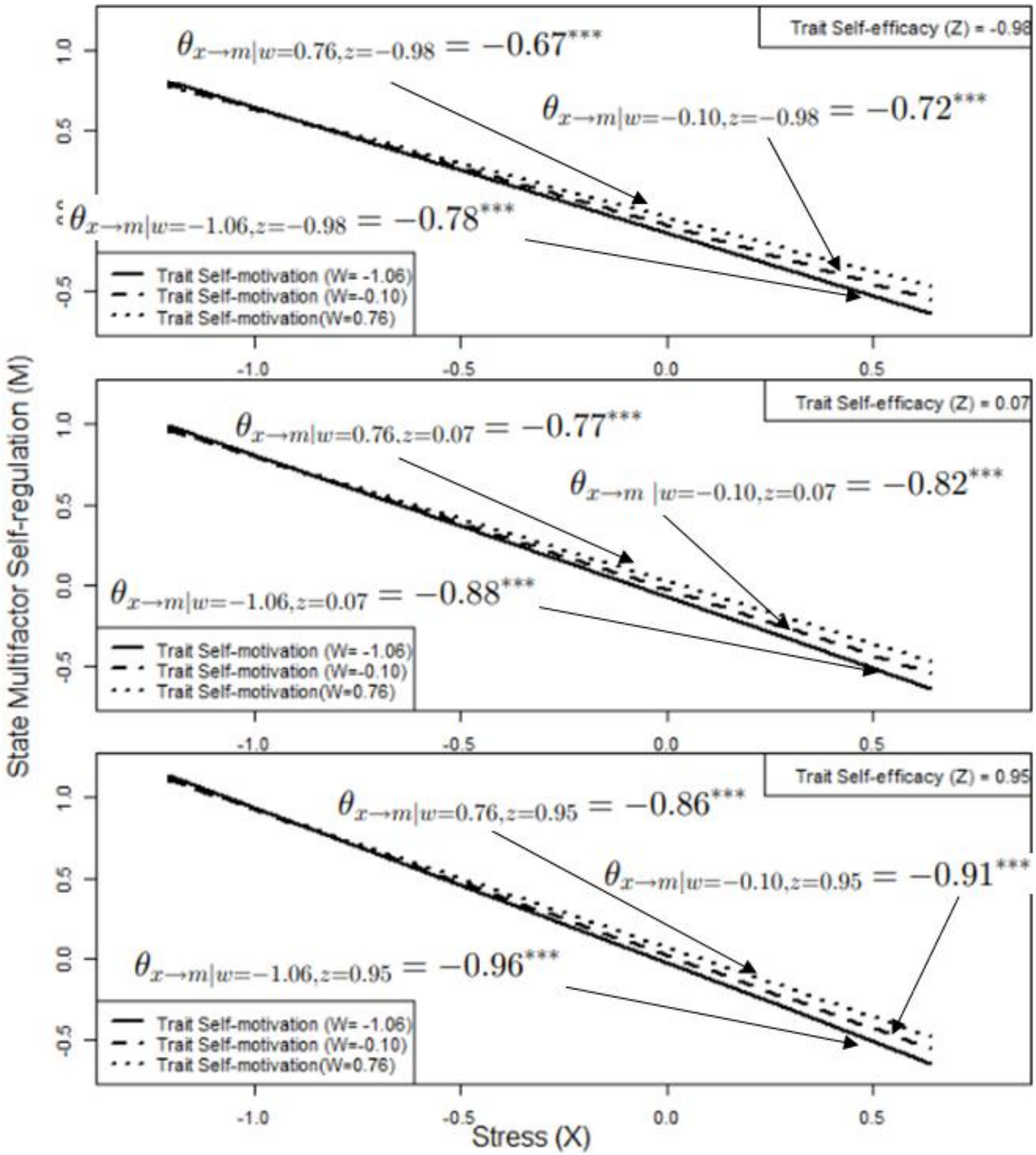
To explore the conditional effects each interaction was visualized and probed using the pick a point method. The values used correspond to the $16^{th}/50^{th}/84^{th}$ percentiles of the focal predictor (i.e., stress), mediator (i.e., state multifactor self-regulation), and moderators (i.e., trait self-efficacy and motivation) as they correspond to the mean +/- 1 SD but are more resistant to skewed distributions**.** Based on the visualization and probe of the negative relationship between stress and state multifactor self-regulation conditional on trait self-motivation and self-efficacy it appears that as stress increases state multifactor self-regulation decreases. As expected, the degree of this decrease seems to be least severe for those with greater levels of internal motivation (see Figure 7). However, opposite of expectations self-efficacy appeared to enhance the negative relationship between stress and state multifactor self-regulation (see Figure 7). This was likely because individuals with greater self-efficacy had greater levels of state multifactor self-regulation when under lower levels of stress leaving more room to decrease as stress increased.

The visualization and probe of the relationship between multifactor self-regulation and rate of perceived exertion load revealed that as state multifactor self-regulation increases so did rate of perceived exertion load. The degree of this increase was least salient for those with high trait self-efficacy, suggesting rate of perceived exertion load was least affected by low state multifactor self-regulation among individuals with high trait self-efficacy (see Figure 8). Although the interaction term between state multifactor self-regulation and trait self-motivation was nonsignificant (see Figure 6) a general trend of higher rate of perceived exertion load among individuals with higher trait self-motivation was observed (see Figure 8).

Taken together we can see that when individuals possessed high levels of trait self-motivation the negative impact of stress on state multifactor was reduced. However, when they possessed high levels of trait self-efficacy the negative impact of stress was enhanced due to their higher baseline state multifactor self-regulation (see Figure 7). Despite the enhancement effect, individuals with high trait self-efficacy rate of perceived exertion load was less affected by lower state multifactor self regulation compared to individuals with low trait self-efficacy leading to more consistent levels of exercise over time (see Figure 8). This pattern of relationships contributed the attenuation of the negative indirect effect of stress on rate of perceived exertion load based on varying levels of trait self-motivation and trait self-efficacy. Specifically, the negative indirect effect of stress on rate of perceived exertion load was buffered by trait self-motivation when trait self-efficacy was low, and as trait self-efficacy increased the indirect effect of stress appeared to continue to get weaker, however, the role of trait self-motivation became less important (see Figure 9).

Figure 7.

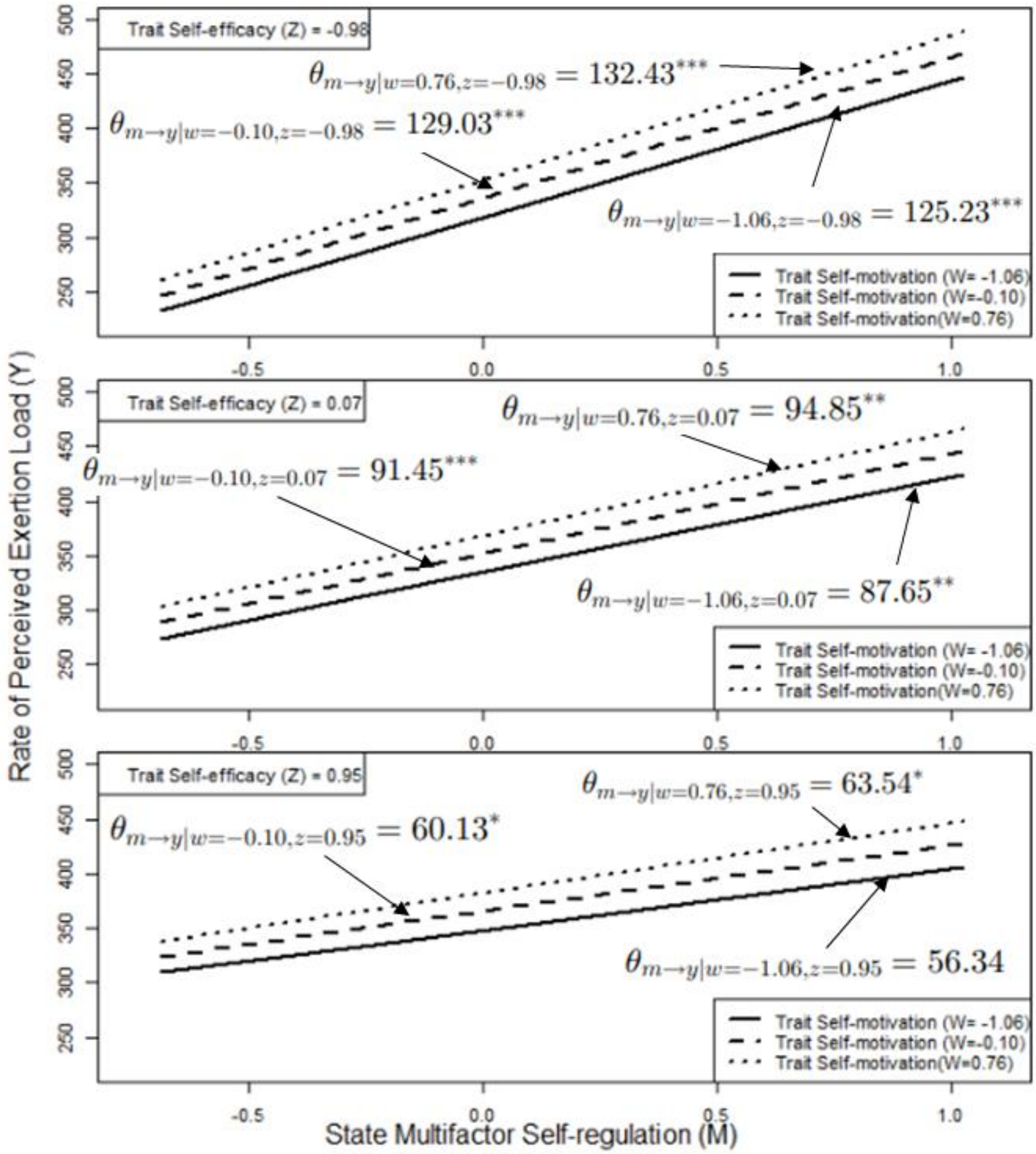
Stress, trait self-motivation and self-efficacy interaction



Note. **** indicates significance at p<.001. This figure contains the effect of stress (X) on state multifactor self-regulation (M) conditional on high/medium/low values of both trait self-efficacy (Z) and trait self-motivation (W).* $\theta_{x\to m|w}$ *= -1.06, z=-0.98 represents the effect of stress on state* *multifactor self-regulation at low trait self-motivation and low trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= -0.10, z=-0.98 represents the effect of stress on state multifactor self-regulation at medium trait self-motivation and low trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= 0.76, z=-0.98 represents the effect of stress on state multifactor self-regulation at high trait self-motivation and low trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= -1.06, z=0.07 represents the effect of stress on state multifactor self-regulation at low trait self-motivation and medium trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= -0.10, z=0.07 represents the effect of stress on state multifactor self-regulation at medium trait self-motivation and medium trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= 0.76, z=0.07 represents the effect of stress on state multifactor self-regulation at high trait self-motivation and medium trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= -1.06, z=0.95 represents the effect of stress on state multifactor self-regulation at low trait self-motivation and high trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= -0.10, z=0.95 represents the effect of stress on state multifactor self-regulation at medium trait self-motivation and high trait self-efficacy;* $\theta_{x \rightarrow m|w}$ *= 0.76, z=0.95 represents the effect of stress on state multifactor self-regulation at high trait self-motivation and high trait self-efficacy. See Table 7 for 95ci's for each path coefficient.*

Figure 8.

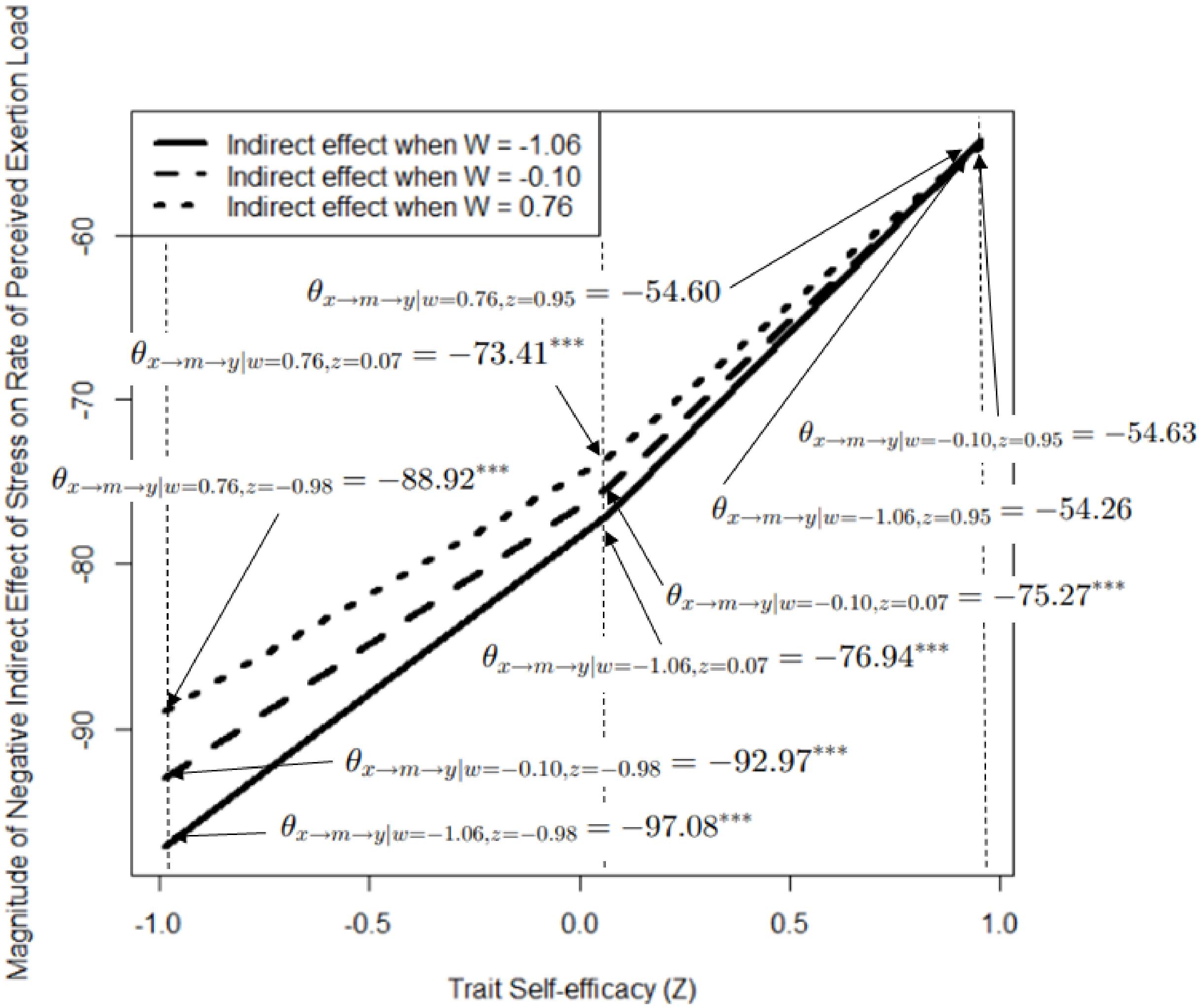
State multifactor self-regulation, trait self-motivation and self-efficacy interaction



Note. **** indicates significance at p<.001; ** indicates significance at p< .01; and * indicates significance at p<.05. This figure contains the effect of multifactor state self-regulation (M) on* *rate of perceived exertion load (Y) conditional on high/medium/low values of both trait self-efficacy (Z) and trait self-motivation (W).* $\theta_{m\rightarrow y|w}$ *= -1.06, z=-0.98 represents the effect of state multifactor self-regulation on rate of perceived exertion load at low trait self-motivation and low trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= -0.10, z=-0.98 represents the effect of state multifactor self-regulation on rate of perceived exertion load at medium trait self-motivation and low trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= 0.76, z=-0.98 represents the effect of state multifactor self-regulation on rate of perceived exertion load at high trait self-motivation and low trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= -1.06, z=0.07 represents the effect of state multifactor self-regulation on rate of perceived exertion load at low trait self-motivation and medium trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= -0.10, z=0.07 represents the effect of state multifactor self-regulation on rate of perceived exertion load at medium trait self-motivation and medium trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= 0.76, z=0.07 represents the effect of state multifactor self-regulation on rate of perceived exertion load at high trait self-motivation and medium trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= -1.06, z=0.95 represents the effect of state multifactor self-regulation on rate of perceived exertion load at low trait self-motivation and high trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= -0.10, z=0.95 represents the effect of state multifactor self-regulation on rate of perceived exertion load at medium trait self-motivation and high trait self-efficacy;* $\theta_{m\rightarrow y|w}$ *= 0.76, z=0.95 represents the effect of state multifactor self-regulation on rate of perceived exertion load at high trait self-motivation and high trait self-efficacy. See Table 7 for 95ci's for each path coefficient.*

Figure 9.

Conditional indirect effect visualization and probe



Note. **** indicates significance at p<.001*. *This figure contains the magnitude of the negative indirect effect of stress (X) on participants' rate of perceived exertion load (Y) through state multifactor self-regulation (M) conditional on high/medium/low values of both trait self-efficacy (Z) and trait self-motivation (W).* $\theta_{x\to m\to y|w}$ *= -1.06, z=-0.98 represents the indirect effect of stress at low trait self-motivation and low trait self-efficacy;* $\theta_{x\to m\to y|w}$ *= -0.10, z=-0.98 represents the indirect effect of stress at medium trait self-motivation and low trait self-efficacy;* $\theta_{x\to m\to y|w}$ *= 0.76, z=-0.98 represents the indirect effect of stress at high trait self-motivation and low trait* *self-efficacy;* $\theta_{x \rightarrow m \rightarrow y|w}$ *= -1.06, z=0.07 represents the indirect effect of stress at low trait self-motivation and medium trait self-efficacy;* $\theta_{x \rightarrow m \rightarrow y|w}$ *= -0.10, z=0.07 represents the indirect effect of stress at medium trait self-motivation and medium trait self-efficacy;* $\theta_{x \rightarrow m \rightarrow y|w}$ *= 0.76, z=0.07 represents the indirect effect of stress at high trait self-motivation and medium trait self-efficacy;* $\theta_{x \rightarrow m \rightarrow y|w}$ *= -1.06, z=0.95 represents the indirect effect of stress at low trait self-motivation and high trait self-efficacy;* $\theta_{x \rightarrow m \rightarrow y|w}$ *= -0.10, z=0.95 represents the indirect effect of stress at medium trait self-motivation and high trait self-efficacy;* $\theta_{x \rightarrow m \rightarrow y|w}$ *= 0.76, z=0.95 represents the indirect effect of stress at high trait self-motivation and high trait self-efficacy. See Table 7 for 95ci's for each path coefficient*

Table 7.

.95CI for all model parameters and probes

Parameter	.95CI	Parameter	.95CI
STRESS	-0.32 to -0.01	$\theta_{m \rightarrow y|w=-1.06,z=-0-.98}$	59.42 to 191.04
	20.44 to 133.69		
T_SM	0.02 to 0.09	$\theta_{m \rightarrow y|w=-0.10,z=-0.98}$	60.12 to 197.94
	-2.63 to 39.72		
STRESS x T_SM	0.02 to 0.10	$\theta_{m \rightarrow y|w=-0.76,z=-0.98}$	54.11 to 210.75
T_SE	0.01 to 0.10	$\theta_{m \rightarrow y|w=-1.06,z=0.07}$	28.83 to 146.48
	-12.89 to 43.45		
STRESS x T_SE	-0.15 to -0.05	$\theta_{m \rightarrow y|w=-0.10,z=0.07}$	35.78 to 147.12
S_MSR	20.44 to 133.69	$\theta_{m \rightarrow y|w=0.76,z=0.07}$	33.32 to 156.38
S_MSR x T_SM	-21.28 to 29.14	$\theta_{m \rightarrow y|w=-1.06,z=0.95}$	-10.75 to 123.43
S_MSR x T_SE	-67.61 to -3.37	$\theta_{m \rightarrow y|w=-0.10,z=0.95}$	1.04 to 119.22
ADULTS_NUM	0.01 to 0.11	$\theta_{m \rightarrow y|w=-0.76,z=0.95}$	3.56 to 123.51
	-13.72 to 47.42		
TOD	-0.05 to 0.06	$\theta_{x \rightarrow m \rightarrow y|w=-1.06,z=-0-.98}$	-148.64 to -45.61
	48.45 to 111.85		
$\theta_{x \rightarrow m|w=-1.06,z=-0-.98}$	-0.87 to -0.69	$\theta_{x \rightarrow m \rightarrow y|w=-0.10,z=-0.98}$	-151.32 to -32.49
$\theta_{x \rightarrow m|w=-0.10,z=-0.98}$	-0.81 to -0.63	$\theta_{x \rightarrow m \rightarrow y|w=-0.76,z=-0.98}$	-157.05 to -17.99

$\theta_{x \to m \mid w=-0.76,z=-0.98}$	-0.77 to -0.57	$\theta_{x \to m \to y \mid w=-1.06,z=0.07}$	-130.30 to -23.42
$\theta_{x \to m \mid w=-0.10,z=0.07}$	-0.95 to -0.81	$\theta_{x \to m \to y \mid w=-0.10,z=0.07}$	-125.72 to -23.78
$\theta_{x \to m \mid w=-0.76,z=0.07}$	-0.88 to -0.77	$\theta_{x \to m \to y \mid w=-0.76,z=0.07}$	-131.53 to -12.64
$\theta_{x \to m \mid w=-1.06,z=0.07}$	-0.84 to -0.71	$\theta_{x \to m \to y \mid w=-1.06,z=0.95}$	-127.96 to 15.31
$\theta_{x \to m \mid w=-1.06,z=0.95}$	-1.05 to -0.88	$\theta_{x \to m \to y \mid w=-0.10,z=0.95}$	-110.15 to 1.31
$\theta_{x \to m \mid w=-0.10,z=0.95}$	-0.97 to -0.85	$\theta_{x \to m \to y \mid w=-0.76,z=0.95}$	-109.54 to 2.29
$\theta_{x \to m \mid w=-0.76,z=0.95}$	-0.92 to -0.80	-	-

Note. *This table contains the .95CI's for all model parameters including each probe. Note that .95CI's are unstandardized and when two .95CI's are present for one variable the top value was for the path to state multifactor self-regulation while the bottom value was for the path to rate of perceived exertion load. See Figures 7, 8, and 9 for parameter definitions.*

Discussion

The results partial support hypothesis 1 as counter to predictions the direct effect of stress on PA was positive, however, in line with predictions, there was an indirect effect of stress on PA through state multifactor self-regulation. In addition, they provide partial support for hypothesis 2 as the negative association between stress and state multifactor self-regulation was buffered by trait self-motivation; however, trait self-efficacy seemed to enhance this relationship. Furthermore, the results only partially support hypothesis 3 as the positive relationship between state multifactor self-regulation was only significantly enhanced by trait self-efficacy. Finally, the present results provide support for hypothesis 4 as the negative indirect effect of stress on participants' level of PA was buffered by both trait self-motivation and trait self-efficacy. These results suggest a depletion effect of stress on state multifactor self-regulation which then reduces the amount of time and/or effort participants were willing to invest in their physical activity. They contribute to further understanding of the processes underlying regular PA by demonstrating that higher levels of internal motivation can buffer the depletion effect and greater levels of trait self-efficacy can increase the likelihood of enacting PA leading to more regular PA over time.

These conclusions are supported by past meta-analytic research demonstrating a small to medium effect size for the negative impact of ego depletion or mental fatigue on task performance, including PA effort (Balzquez et al., 2017; Dang, 2018; Giboin & Wolf, 2019; Hagger et al., 2010, 2016). The bulk of the effect sizes included within these meta-analyses have demonstrated the ego depletion effect using the two-task paradigm (Lin et al., 2020). Using this paradigm, researchers have established that greater exertion of self-control on a cognitive task (i.e., the stoop task) induces mental fatigue. Increased fatigue then caused decreased task self-efficacy which impaired resistance exercise performance (i.e., bench press, leg extensions, and isometric hand grip; Graham & Bray 2015; Graham et al., 2017). Additionally, researchers have used longitudinal correlational data to infer a depletion effect based on the fatigue inducing characteristics of stress and its negative effect on individuals' state self-control resources which reduced their adherence to a 7- day PA program (Englert and Rummel, 2016).

It should be noted that the existence of the depletion effect was called into question by updated meta-analytic techniques correcting for publication bias (Carter et al., 2015, Carter & McCullough 2014). However, further testing of the bias corrected meta-analytic techniques revealed them to be overly conservative when controlling for the effect of publication bias (Inzlicht et al., 2015). Re-examination of the literature using further refined meta-analytic techniques that controlled for publication bias and small study effects supported the existence of the ego depletion effect, although, it seemed to be trending toward small in magnitude (Blazquez et al., 2017; Giboin & Wolf, 2019;Hagger et al., 2016). Thus, it is reasonable to infer the negative indirect effect of stress on rate of perceived exertion load was due to the depletion effect participants experienced in their daily lives. These results further support the existence of a depletion effect associated with stress induced fatigue.

As noted above the depletion effect of stress tends to result in a state of mental fatigue (Englert and Rummel, 2016; Graham & Bray 2015; Graham et al., 2017). In relation to PA, researchers have identified that when in a state of mental fatigue individuals are less willing to invest energy in a physical activity session which results in less effort during the session (Brown & Bray 2019a; Harris et al., 2022). It appears that mental fatigue operates through perceived effort required to complete the workout and perceived cost vs gain valuations by increasing perceived effort, increasing cost and thus making PA less likely (Harris & Bray, 2021). However, researchers have demonstrated that the negative impact of mental fatigue on PA effort was conditional on objective performance feedback in the form of a HR monitor (Brown & Bray 2019b).

It has also been demonstrated that the effect of mental fatigue can be blunted by delivering statements designed to prime autonomous motivation such as providing individuals praise for their participation or emphasizing that they only need to give their best effort (Brown et al., 2016; Graham et al., 2014). In comparison, controlled motivation in the form of a monetary incentive appears to only motivate participants to enact exercise when fatigue is low (Harris & Bray 2022). The present results extend this work on stress, depletion of self-regulatory resources and fatigue by demonstrating a possible stress related depletion effect acting on individuals' more volatile momentary state self-regulatory resources which seems to be buffered by individuals' more stable trait self-efficacy and trait self-motivation. Future research should continue to build on these results by exploring this possibility within a laboratory setting using experimental design to possibly establish causal arguments for the combine effect of trait self-efficacy and self-motivation when moderating the depletion effect.

Practical implications of this research suggest that individuals with lower trait self-efficacy and more external motivation for PA are at greater risk for abandoning their PA routine when experiencing high stress and associated low multifactor self-regulation. Based on these findings, practitioners seeking to help individuals maintain regular PA should be aware that clients with low confidence in their ability to enact exercise regularly and who do not experience any personal enjoyment from PA are more likely to forgo their PA during highly stressful periods. Thus, practitioners should be sure to identify these individuals and make extra efforts to help increase their trait self-efficacy and develop more internal motivation to combat the depletion effect and increase long term PA adherence.

Individuals with low trait self-efficacy and relying more on external motivation can be identified through a screening process where they complete items assessing their trait self-motivation and self-efficacy, followed by an interview centred on exploring the individuals past experiences with PA and possible motivations for PA (O'Halloran et al., 2014; Olson & McAuley, 2015). Once individuals with low trait self-efficacy and more reliant on external motivation have been identified practitioners should aim to create a mastery climate to cultivate more internal motivation and increase trait self-efficacy (Erturan et al., 2020; Moreno et al., 2010). One of the first steps toward creating a mastery climate requires the development of personally meaningful achievement goals based on the individual's current PA ability level and desired outcomes (Hardwoord et al., 2015). Once achievement goals have been set practitioners should emphasise the importance of focusing on incremental progress toward the end goal and use of a progress tracker for objective performance feedback. The emphasis on mastery through incremental progress and performance tracking can serve to increase individuals' trait self-efficacy and internal motivation for PA (Nuss et al., 2021; Pekmezi et al. 2009). Lastly, the creation of a flexible schedule or skill matched exercise group can help cultivate trait self-efficacy and internal motivation by satisfying psychological needs for relatedness and autonomy, and providing vicarious learning experiences and positive social support (Li et al., 2014b; Pekmezi et al. 2009; Samson & Solomon, 2011).

Regarding the unexpected positive direct effect of stress on participants' level of PA there are two likely explanations. First, individuals who engage in more PA may be experiencing more stress and fatigue related to the maintenance of regular PA (e.g., role conflict, time pressures, exercise related injuries; Malm et al., 2019; Stults-Kolehmainen & Sinha , 2014). The positive association between stress and PA would arise because the challenges associated with regular PA would serve to increase the individuals stress levels. Alternatively, individuals who are more stressed may be engaging in more PA as a means of stress relief as it is commonly recommended for this purpose (Pascoe et al., 2020; Schultchen et al., 2019; Teychenne et al., 2020). For example, Van Der Zwan et al., (2015) demonstrated over the course of a 5 week intervention that as little at 10 to 20 min of exercise per day can as effective as mindfulness meditation and biofeedback techniques for stress reduction. However, it should be noted the beneficial effects of PA on mental health may be conditional on low chronic stress (Strahler et al., 2016). Given the present sample was relatively active, representative of average Ontario adults who likely have multiple roles and responsibilities to balance (e.g., family, work), and had moderate levels of stress it seems reasonable that for some participants the positive association may represent PA being used as a means of stress reduction while for other participants it may represent the stress associated with the maintenance of regular PA. Given this study was not set up to establish causality it cannot be said which interpretation would be more accurate. Future research should seek to explore the positive relationship between stress and PA to better understand the underlying processes.

Strengths and Limitations

A primary limitation of the present study was the correlational nature as it cannot establish causality among the observed relationships. This approach did, however, allow for a larger sample size increasing statistical power for detecting multiple interactions with small to medium effect sizes (Hayes, 2022; Majeed et al., 2020). Furthermore, data on participants' state self-regulation and physical activity behaviour was collected over a 2-day period allowing for greater insight into the degree and direction of the effect over time (Caruana et al., 2015). The EMA methodology also reduced common method bias as the items measuring each variable were broken up throughout each day reducing the likelihood of spurious association within their responses (Kock et al., 2021).

Given recruitment was done primarily through Ontario based online forums the results primarily apply to the adult population of Ontario and other similar regions (e.g., other Canadians, Americans, or Europeans). The sample primarily contained participants with average income; however, this could vary quite a bit indicating these results apply to a range of socioeconomic statuses. Lastly, regarding gender, the sample contained predominantly males and females with the frequencies slightly favouring the latter. Non-binary individuals did not have a strong representation meaning these results may not generalize to this sub group nor was data regarding participants ethnicity collected. This means it cannot be said with certainty if the present results can be generalized to various ethnicities and non-binary individuals. Future researchers should seek to include measures of ethnicity and actively recruit members of the LGBTQ+ community through LGBTQ+ friendly organizations.

Despite using well established measures model fit appeared to range from poor to good. However, the reliability was sufficient at ≥.70 (Schober et al., 2021) for all measures and all items significantly loaded onto their factors. Future research should seek to improve the properties of the scale measuring state multifactor self-regulation by adding more items such as *"seeing others engage in physical activity will give/gave me the confidence to do it myself"* state self-efficacy, or *"I am/was motivated to engage in physical activity today because when I miss a day I feel as if I let myself down"*.

Another limitation of the present study was the self-report nature of the data, which can be subject to various response biases (Bauhoff, 2011). Within the present study, there was the possibility of recall bias regarding self-regulatory states and over reporting of PA due to self-selection bias. It appears a small degree of both biases may be present in the current data set as individuals primarily responded to the EMA items at the end of the day and reported relatively high daily minutes of physical activity.

Targeted recruitment aiming to reach traditionally inactive populations and the use of a wearable physical activity tracker can help reduce self-selection bias and PA over reporting. Targeted recruitment can be achieved by seeking out participants through organizations aiming to promote active lifestyle among historically inactive individuals (Smit et al., 2021). Wearable's have the potential to achieve this by collecting more objective data regarding participants' level and intensity of physical activity based on physiological metrics such heart rate, distance travelled, or duration of workout (McCarthy et al., 2021). Furthermore, wearable's can calculate more objective stress scores based on daily activity level, heart rate variability, and sleep (Umair et al., 2021; Zhuo et al., 2020). Using a context aware EMA application where participants are prompted to respond based on times which are convenient for them can help to increase responding at the desired time (Aminikhanghahi et al., 2019). Lastly, gamification where participants receive small rewards for each response may motivate participants to respond as they receive the items (Kargarandehkordi & Washington, 2023).

Conclusion

In conclusion, the present results further support the notion of a depletion of self-regulatory resources associated with increased stress and related to lower rate of perceived exertion load. They extend previous research by providing preliminary support for a buffering effect of both trait self-efficacy and trait self-motivation. Any conclusions drawn from this study are limited by the correlational nature of the data, the possible presence of self-selection and recall bias, and mixed model fit. However, they are lent strength by the high-powered longitudinal nature of the study and the strong reliability of the scales. Future research should seek to expand on the present results by using an experimental design to establish causality, refining the EMA methodology and scales, and using wearable activity tracking devices for more accurate PA and stress data.

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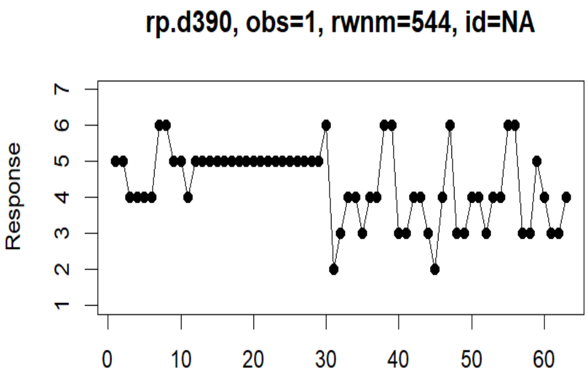
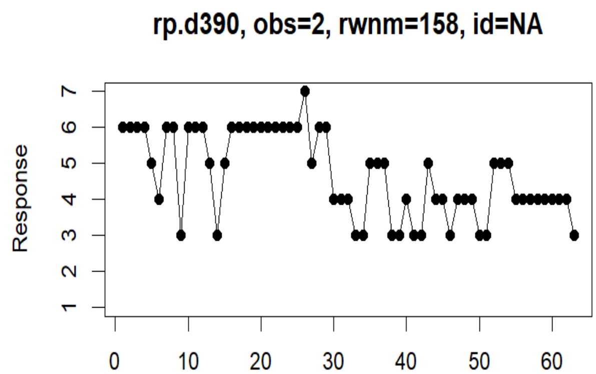
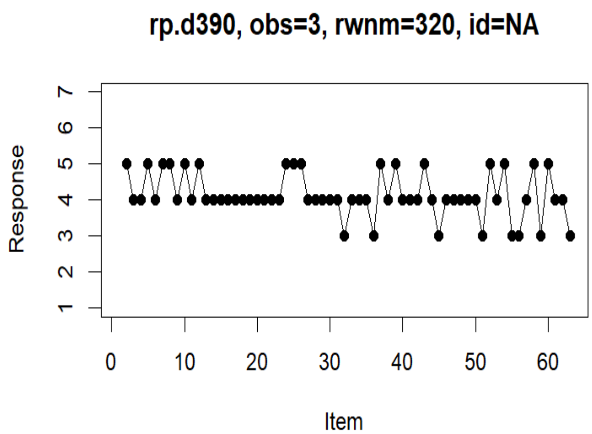
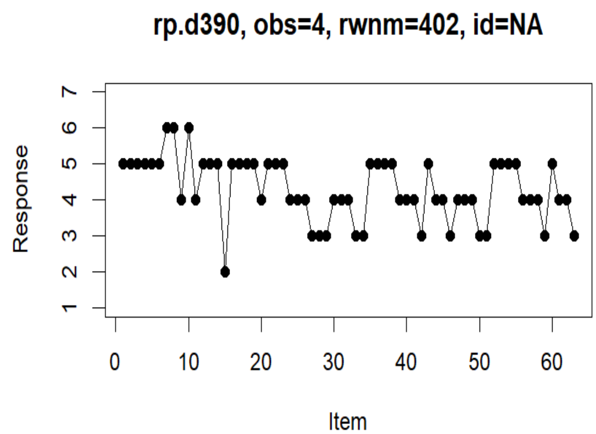
Appendices

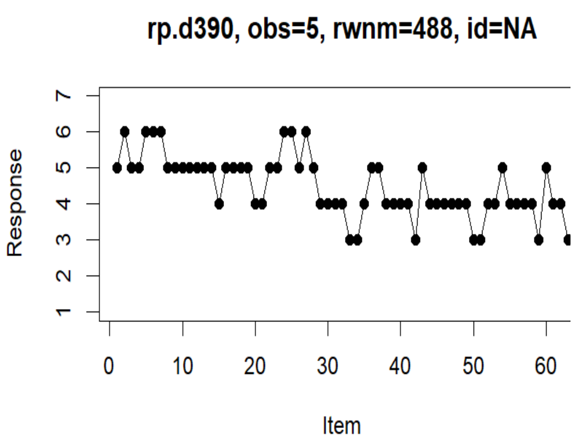
Appendix A Careless Responding and QQ Plots

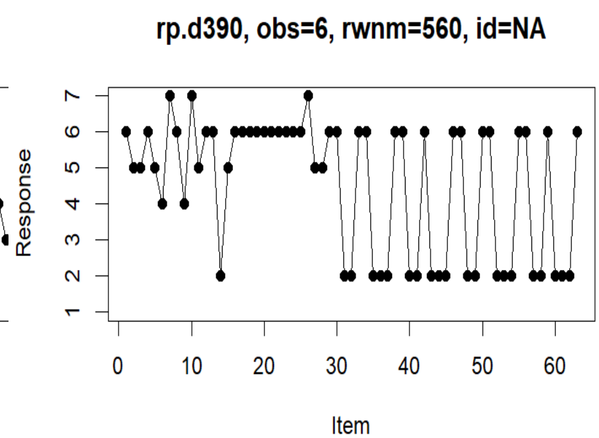












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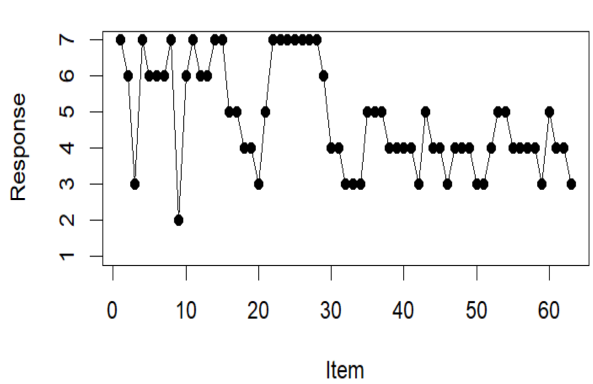

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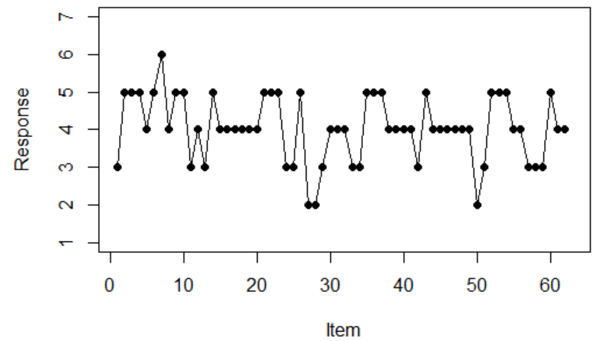

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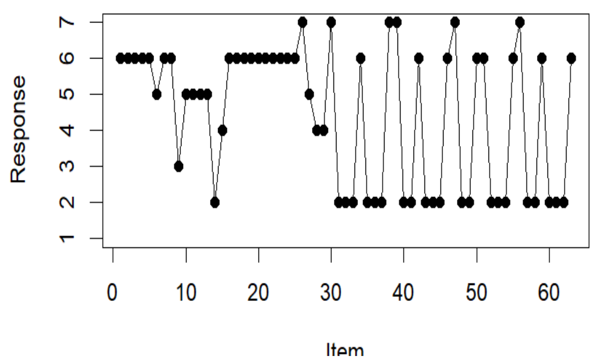

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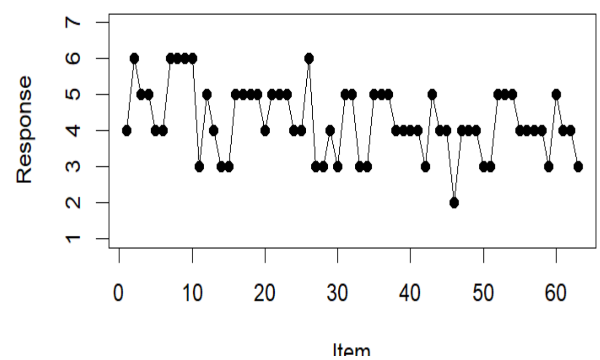

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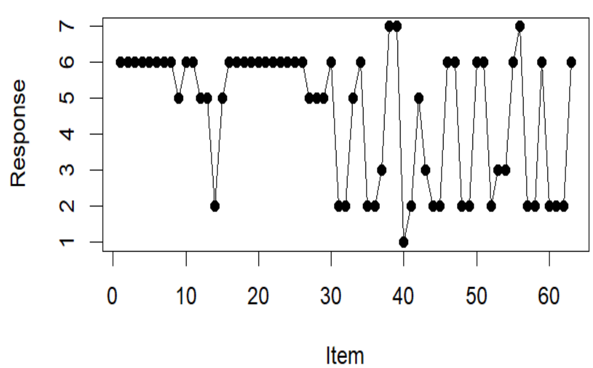

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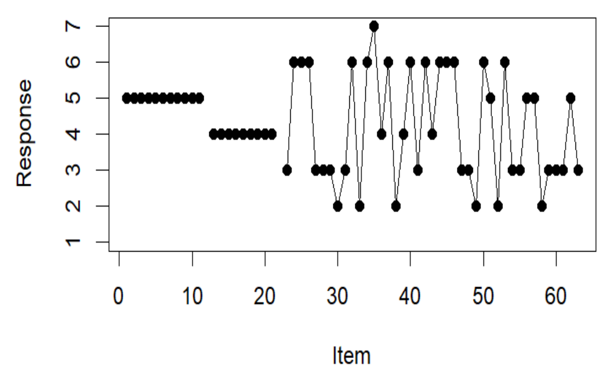

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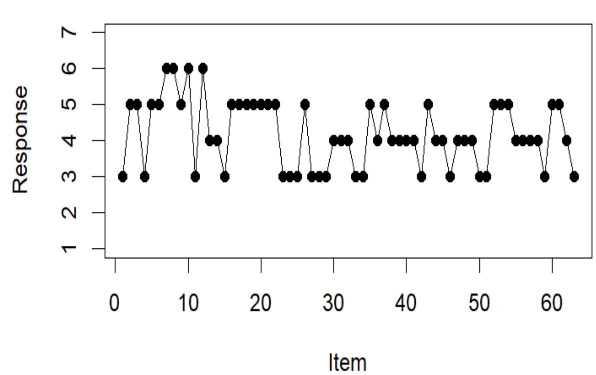

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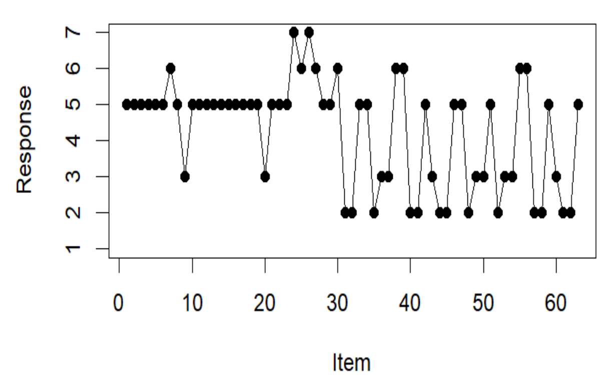

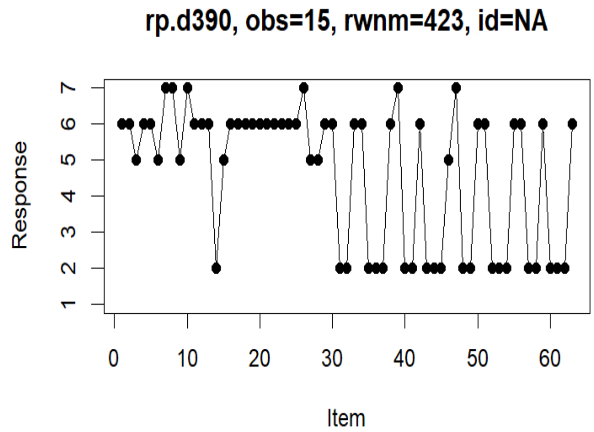
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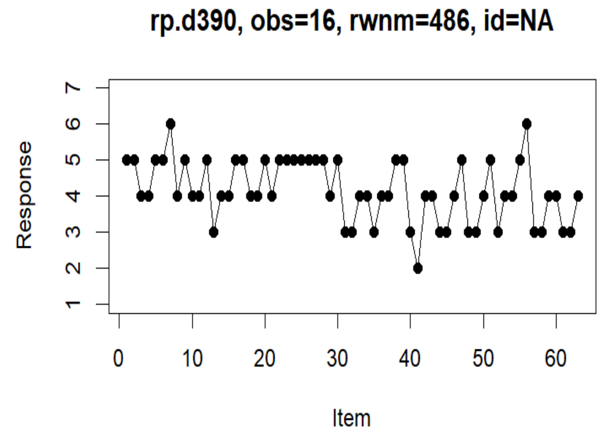
Item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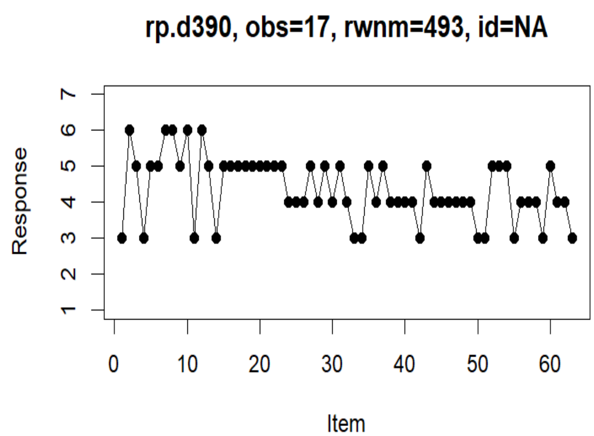
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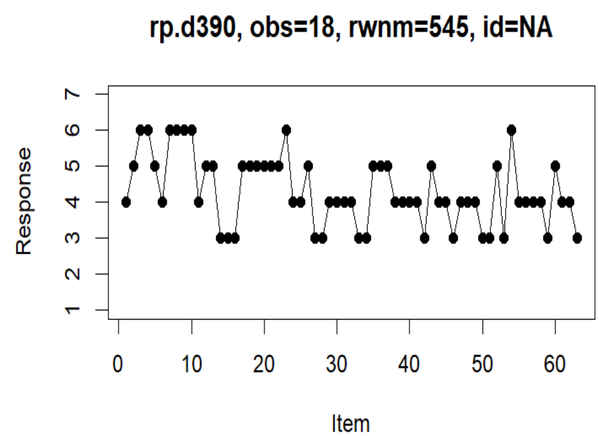
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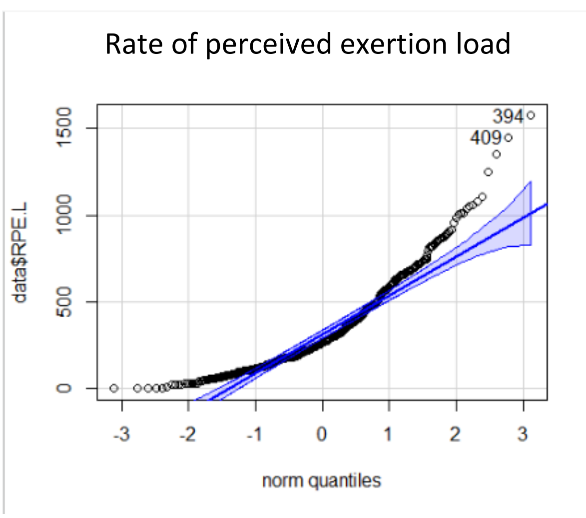
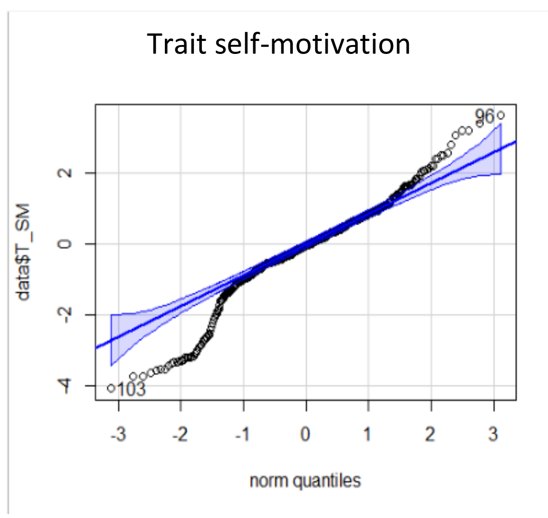
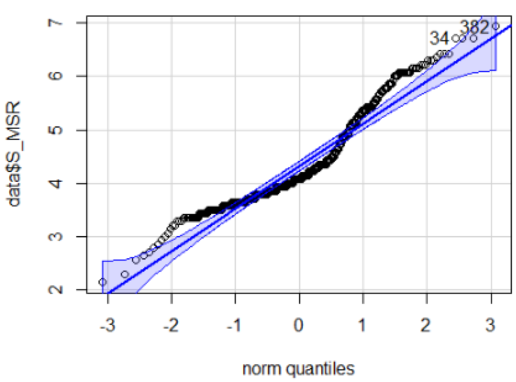
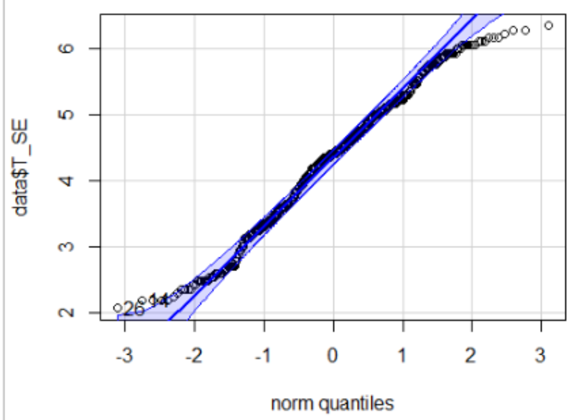

Rate of perceived exertion load
data$RPE.L
norm quantiles
394
409


Trait self-motivation
data$T_SM
norm quantiles
96
103

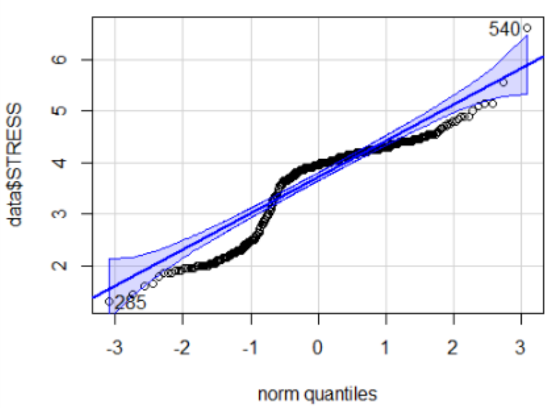
State multifactor self-regulation



Trait self-efficacy



Stress



Appendix B Baseline Measures

Demographics

1. What is your age?
2. What is your gender?
    a. Male
    b. Female
    c. Non-binary/third gender
    d. Prefer not to answer
3. Estimated annual household income?
4. How many adults reside in the household?
5. How many minors reside in the house hold?

RM 4-FM: Motivation for physical activity

Using the rating scale below please indicate how true each of the following reasons is for why you engage in physical activity or would like to engage in physical activity.

Rating Scale:

1(not true at all) 2 3 4 (somewhat true) 5 6 7 (very true)

I engage in physical activity (or would like to) ...

1. Because I simply enjoy physical activity
    a. 1-2-3-4-5-6-7
2. Because physical activity is important and beneficial for my health and life style
    a. 1-2-3-4-5-6-7
3. Because I would feel bad about myself if I didn’t
    a. 1-2-3-4-5-6-7
4. Because it’s fun and interesting
    a. 1-2-3-4-5-6-7
5. Because others like me better when I am in shape

   a. 1-2-3-4-5-6-7

6. Because I’d be afraid of falling too far out of shape if didn’t
   a. 1-2-3-4-5-6-7
7. Because it helps my lungs
   a. 1-2-3-4-5-6-7
8. Because it is personally important to me to be physically active
   a. 1-2-3-4-5-6-7
9. Because I feel pressured to be physically active
   a. 1-2-3-4-5-6-7
10. Because I have a strong value for being active and healthy
    a. 1-2-3-4-5-6-7
11. Because I find pleasure in discovering and mastering new training techniques
    a. 1-2-3-4-5-6-7
12. Because I want others to see me as physically fit
    a. 1-2-3-4-5-6-7

Scoring:

Sum and divide by total items to score the subscales, items include:

- *External regulation 5, 7, 12*
- *Introjected regulation 3, 6, 9*
- *Identified regulation 2, 8, 10*
- *Intrinsic motivation 1, 4, 11*

Calculating relative autonomy index:

*(External regulation * -2) +(Introjected regulation * -1) + (Identified regulation * 1) + (Intrinsic motivation * 2)*

Self-efficacy for physical activity scale

Please respond to each statement by rating your level of agreement, the rating scale below.

Rating Scale:

1(not true at all) 2 3 4 (somewhat true) 5 6 7 (very true)

1. ME1: I have mostly been successful in being physically active on a regular basis.
   a. 1-2-3-4-5-6-7
2. ME2: Even if it turned out challenging at times, I have managed to remain active.
   a. 1-2-3-4-5-6-7
3. ME3: It was never difficult for me to be physically active on a regular basis.
   a. 1-2-3-4-5-6-7
4. VE1: I model myself on people who are more active than I am.
   a. 1-2-3-4-5-6-7
5. VE2: I feel more confident in being physically active if I can model myself on somebody else.
   a. 1-2-3-4-5-6-7
6. VE3: I feel confident being active if I see people my age being active.
   a. 1-2-3-4-5-6-7
7. VPO1: Support from others gives me the confidence to be physically active.
   a. 1-2-3-4-5-6-7
8. VPO2: Whenever I lack the confidence to be physically active, verbal support from others can persuade me to be active.
   a. 1-2-3-4-5-6-7
9. VPO3: The people who are important to me give me confidence to resume physical activities when I have quit doing them.
   a. 1-2-3-4-5-6-7
10. SP1: Whenever I lack the confidence to engage in physical activity, I tell myself that I can do it.
    a. 1-2-3-4-5-6-7
11. SP2: I tell myself I can manage to be physically active on a regular basis.

   a. 1-2-3-4-5-6-7

12. NA1: Just before I start physical activities, I feel worn out.
    a. 1-2-3-4-5-6-7
13. NA2: Just before I start physical activities, I feel tired.
    a. 1-2-3-4-5-6-7
14. NA3: Just before I start physical activities, I feel tense.
    a. 1-2-3-4-5-6-7
15. PA1: Just before I start physical activities, I feel energetic.
    a. 1-2-3-4-5-6-7
16. PA2: Just before I start physical activities, I feel thrilled in anticipation.
    a. 1-2-3-4-5-6-7
17. PA3: Just before I start physical activities, I feel strong
    a. 1-2-3-4-5-6-7

Note: PA = positive affective, NA = negative affect, SP = self persuasion, VPO = verbal persuasion by others, VE = vicarious experiences, ME = Mastery experiences

Scoring – sum items and divide by total items

Reverse Score 12,13,14

Appendix C Ecological Momentary Assessment Measures

State Self-control

Please reply spontaneously to the following statements about how you feel at the moment using the rating scale below.

Rating Scale:

1(not true at all) 2 3 4 (somewhat true) 5 6 7 (very true)

1. I feel drained 1 – 2 - 3 – 4 – 5 – 6 – 7
2. I feel calm and rational 1 – 2 - 3 – 4 – 5 – 6 - 7
3. I feel lazy 1 – 2 - 3 – 4 – 5 – 6 - 7
4. I feel like my willpower is gone 1 – 2 - 3 – 4 – 5 – 6 – 7
5. I feel sharp and focused 1 – 2 - 3 – 4 – 5 – 6 - 7

Scoring – sum items and divide by total items

Reverse Score 1, 3, 4

Perceived Stress Scale

Please reply spontaneously to the following statements about how you feel at the moment using the rating scale below.

Rating Scale:

1(not true at all) 2 3 4 (somewhat true) 5 6 7 (very true)

1. I am often upset by unexpected events? 1-2-3-4-5-6-7
2. I feel I am unable to control the important things in my life?1-2-3-4-5-6-7
3. I feel nervous and “stressed”?1-2-3-4-5-6-7
4. I feel confident about my ability to handle my personal problems?1-2-3-4-5-6-7
5. I feel things that things are going my way? 1-2-3-4-5-6-7
6. I am having difficulty coping with all the things that I have to do? 1-2-3-4-5-6-7
7. I am having difficulty controlling the irritations in my life?1-2-3-4-5-6-7

8. I feel I am on top of things?1-2-3-4-5-6-7
9. I am often angered by things that are outside of my control? 1-2-3-4-5-6-7
10. I feel difficulties are piling up so high that I cannot overcome them?1-2-3-4-5-6-7

Scoring – sum items and divide by total items

Reverse Score 4, 5, and 8

Self-efficacy and Motivational Intensity

Please reply spontaneously to the following statements about how you feel at the moment using the rating scale below.

Rating Scale:

1(not true at all) 2 3 4 (somewhat true) 5 6 7 (very true)

1. I feel/felt energized to engage in physical activity today
2. I feel/felt confident in my ability to engage in physical activity today.

Scoring – sum and average

Physical Activity Items

1. In minuets, how long was my physical activity session today?
2. What was my perceived exertion during today's physical activity session on a scale from 1 to 10 where:
   a. 1 = very light activity doesn't even feel like exercising
   b. 2-3 = light activity you could keep going for hours, easy to breath and have a conversation
   c. 4-6 = moderate activity breathing heavily but you can have a conversation
   d. 7-8 = somewhat difficult activity, your short of breath, you can speak but only one sentence at a time
   e. 9 = very difficult activity, you can barely breath and can only say a few words at a time

    f. 10 = maximum effort, completely out of breath can't talk

3. What time of day was my physical activity session?
    a. Morning
    b. Afternoon
    c. Evening
    d. Did not engage in physical activity
4. What form of physical activity did I engage in?

Scoring – questions 1 and 2 will have averages calculated, question 3 is nominal, and 4 is open ended

Appendix D Informed Consent and Recruitment Materials

Social Media Post

Greetings,

I would like to invite you to participate in a research project going on at Trent University in Ontario, Canada. The aim of the project is to assess how stress, self-control, self-motivation, and physical activity confidence influence your physical activity habits. Participation will span 3 days and we are looking for participants from all walks of life and of all fitness levels so a diverse group of individuals will be represented within our sample. Participation is simple; first you will complete a 34 item baseline questionnaire taking approximately 15 to 20 minutes. The morning after completing your baseline questionnaire we will email you links to sets of 4 to 5 questions at 2 hour intervals beginning at 9am and ending at 5pm. The sets of 4 to 5 questions will take 2 to 3 minutes to answer and all you have to do is go about your day normally as you respond to the questions we send. We will compensate you for your time by providing you with the chance to earn some cash and win prizes. If you are interested at this point please follow the link below.

https://trentu.qualtrics.com/jfe/form/SV_dgaqyxn2xz7bWOG

Please note all procedures and materials used in this study have been approved by the Trent University Research Ethics Board. Should you have any ethical concerns please contact Jamie Muckle at jmuckle@trentu.ca

Project Number: 28023

Informed Consent Form

Primary Investigator: Mr. Eric Samtleben Email: ericsamtleben@trentu.ca

Supervisor: Dr. Brenda Smith-Chant Email: bresmith@trentu.ca

The primary objective of this study is to examine how stress, self-control, self-motivation, and physical activity confidence influence physical activity habits. It is expected that this study will further our understanding of the factors associated with the creation of healthy physical activity habits. Insights gained from the present study have the potential to benefit members of the general population by helping them to maximize the health benefits associated with an active lifestyle.

Upon providing consent you will proceed to the initial baseline survey containing 34 questions which will take approximately 15 to 20 minutes to complete. Before completing the survey you will be required to enter your email as it is required in order for the primary investigator Mr. Samtleben to contact you throughout the duration of the study. After successful submission of your baseline responses, you will be emailed your participant number which will be used to track your participation and deidentify your responses following completion of your participation period. Over the next two days while you go about your day as normal you will be emailed links to sets of 4 questions and one set of 5 assessing your current state and daily physical activity habits each of which will take approximately 2 to 3 minutes to complete. Question sets will be emailed to you at 9 am, 11am, 1pm, and 3pm; with the final set sent at 5 pm. Please note that while you are free to skip over any questions you feel uncomfortable answering it is asked that you respond to those you are comfortable answering even if you do not engage in physical activity that day as we are interested in your everyday behaviour. In addition, please allow the primary investigator up to 1 business to begin sending you questions; if you do not begin receiving questions 1 business day after completing the baseline questionnaire please contact the primary investigator at the email listed above. Lastly, should you have any questions about the study procedures you are able to contact the primary investigator Mr. Samtleben at the email included above; should you have any ethical questions please contact Jamie Muckle at the email address included at the end of this document.

Compensation includes; $10 per person for greater than 95% response rate, $5 per person for greater than 75% response rate, and for all participants with greater than 75% response rate entry into a raffle for 1 of 3 $100 Amazon gift cards. Furthermore, you will receive one extra raffle entry for each participant you refer and two extra entrees if the referred participant provides complete data. Please note that compensation is directly tied to your response rate (i.e. the proportion of questions you answer) not the level of physical activity you engage in. The researchers are committed to the highest level of security when handling your data. All data will be stored on the secure, encrypted, password-protected Trent University servers.

Only the primary investigator Mr. Samtleben and his supervisor Dr. Smith-Chant will have access to your data and any identifying information. Furthermore, to protect your privacy all your responses will be deidentified through the use of randomly generated numeric codes that will be entered when submitting them. Any identifying or personal information collected (e.g. contact information, names, etc.) will be kept in a separate data file from your responses and destroyed upon completion of the study and raffle. This research is being conducted by Mr. Samtleben as a master’s thesis and for future academic research. Mr. Samtleben intends to publish these findings and present them at academic conferences; however, they will not be commercialized as they are purely scientific in nature. Any future use of your data for academic/scientific purposes (i.e. presentations, publications, teaching, etc.) will be done so with a secure deidentified final data file through which your identity will be concealed.

As Mr. Samtleben is an active fitness coach and athlete he will not use this survey for any advertising or commercial purposes. This research poses minimal risk for participants meaning you will be exposed to no greater physical and/or psychological risk than you would face in your everyday life. Examples of these risks include but are not limited to muscle strains, joint irritations, becoming upset, etc. Should you experience any physical and/or psychological issues throughout the course of the study please contact your doctor. If any questions make you uncomfortable you are free to skip over them, and you are able to withdraw at any point and have any of your previous responses destroyed. If you wish to withdraw please contact the primary investigator at the email listed above stating you wish to withdraw and specifying whether or not you would like your data destroyed.

This form is not a legal waiver, is available to download and all methods and procedures for this study have been approved by the Trent University Research Ethics Board. If at this point, you wish to participate, please provide consent by selecting "I consent" below. The researchers have no other information to disclose about this study.

Thank you for your time! For more information, contact the Certifications and Regulatory Compliance Officer - Jamie Muckle at: jmuckle@trentu.ca

Project Number: 28023

Appendix E Automated Emails and Debrief Package

Automated EMA Emails

Greetings,

Below is a link to the 1st question set. Please note you will be required to enter your participant number before responding to the survey questions.

https://trentu.qualtrics.com/jfe/form/SV_e9voCZ2mvmnqcPc

Thank-you for your responses!

Greetings,

Below is a link to the 2nd question set. Please note you will be required to enter your participant number before responding to the survey questions.

https://trentu.qualtrics.com/jfe/form/SV_aWVWm5RblPHopv0

Thank-you for your responses

Greetings,

Below is a link to the 3rd question set. Please note you will be required to enter your participant number before responding to the survey questions.

https://trentu.qualtrics.com/jfe/form/SV_e9tXprnK4g2OeTs

Thank-you for your responses!

Greetings,

Below is a link to the 4th question set. Please note you will be required to enter your participant number before responding to the survey questions.

https://trentu.qualtrics.com/jfe/form/SV_0rltRis5sxJpbro

Thank-you for your responses!

Greetings,

Below is a link to the 5th question set. Please note you will be required to enter your participant number before responding to the survey questions.

https://trentu.qualtrics.com/jfe/form/SV_0cyV6g4oY7BIYlw

Thank-you for your responses!

Automated Debrief Email

Congratulations on completing the study successfully your compensation will be awarded shortly. In the meantime, please be patient and allow the researcher up to 3 business days to calculate your response rate and level of compensation. Below is a link to a debriefing package containing more information about the study.

https://trentu.qualtrics.com/jfe/form/SV_b91xPfHXhIPRdK6

Thank-you for your participation!!

Debriefing Package

1. Did the daily questions influence your behaviour at all? If so please explain below?

The researchers wish to inform you more about the relationships being assessed. The primary relationships of interest are the impact of self-efficacy – a individuals confidence in their ability, self-motivation – an individuals desire to achieve a goal, self-control – and individuals ability to inhibit impulses, and stress on self selected physical activity frequency and intensity. It is thought that increased levels of stress present in ones life are linked to lower rates of and less intense physical activity as it drains an individual's self control resources. However, it is suspected that this effect may depend on and individuals self motivation and self efficacy; meaning individuals with higher levels of self-efficacy and self motivation are less prone to the effects of stress on self control and subsequent physical activity frequency and intensity. Please note you are still able to withdraw your participation and request your data be destroyed at any point.

If you are interested in learning more about these relationships please follow up with the resources below.

Boucher, H. C., & Kofos, M. N. (2012). The idea of money counteracts ego depletion effects. *Journal of Experimental Social Psychology*, *48*(4), 804-810.

Englert, C., & Rummel, J. (2016)a. I want to keep on exercising but I don't: The negative impact of momentary lacks of self-control on exercise adherence. Psych*ology of Sport and Exercise* , *2*6 , *24*-31.

Graham, J. D., Martin Ginis, K. A., & Bray, S. R. (2017). Exertion of self-control increases fatigue, reduces task self-efficacy, and impairs performance of resistance exercise. *Sport, Exercise, and Performance Psychology*, *6*(1), 70