DOES BOREDOM LEAD TO EGO-DEPLETION?

EXAMINING THE ASSOCIATION BETWEEN STATE BOREDOM AND EGO-DEPLETION

A Thesis Submitted to the Committee on Graduate Studies

In partial Fulfilment of the Requirements for the Degree of Master

Science in the Faculty of Arts and Science

TRENT UNIVERSITY

Peterborough, Ontario, Canada

Psychology M.Sc. Graduate Program

January 2023

ABSTRACT

Does boredom lead to ego-depletion?
Examining the association between state boredom and ego-depletion

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Ego-depletion refers to the observation that using self-control at Time 1 (T1) in the sequential-task paradigm leads to worse self-control at Time 2 (T2; Baumeister et al., 1998). Self-control is often manipulated by varying the difficulty of the task used at T1. Recently, Wolff and colleagues (2020) suggested that failures to replicate the ego-depletion phenomenon may arise because simple tasks may be boring, therefore requiring self-control to maintain attention on the task. Three experiments (Experiment 1, *N*=60; Experiment 2, *N*=61; Experiment 3, *N*=59) are reported that examined whether boredom at T1 predicted self-control at T2. A simple Go/No-Go task was used at T1. The ratio of Go to No-Go trials was changed across experiments to explore how the properties of the boring task impacted the association between boredom and self-control. When responding was frequent, increased boredom at T1 was associated with *fewer* anagrams correctly solved (Experiment 1 and 3), and *more* self-reported fatigue at T2 (Experiment 1), consistent with boredom leading to ego-depletion. However, when responding was infrequent (Experiment 2), increased boredom at T1 was associated with *more* correctly solved anagrams at T2, suggesting that the properties of a boring task change the psychological outcome that task has on self-control.

Keywords: boredom, self-control, ego-depletion, executive function, attention

Acknowledgements

I would like to show my gratitude to my supervisor, Professor Michael Chan-Reynolds for his skilled insight and constant support on this research, and the many other projects we conducted throughout my time in the laboratory. I would also like to thank Professor John Eastwood who provided theoretical knowledge and greatly assisted in the interpretation of the present research's findings. Finally, I would like to show my gratitude for Jenna Bolzon and Zac Sharpardanis, previous research assistants in the laboratory, for aiding in data collection.

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Introduction

Self-control is involved in any instance where an individual exerts deliberate and conscious effort to change, or to avoid changing, their behaviour (Hagger et al., 2010). Individuals frequently encounter situations that require self-control (e.g., resisting a second helping of a tempting dessert). Lower self-control ability has been associated with poor spending behaviours (Allom et al., 2018), lower physical health (Moffit et al., 2011), trouble with personal relationships (Tangney et al., 2004), as well as with having less overall life satisfaction (Zheng et al., 2019). Despite the importance of self-control for factors that affect well-being, self-control is often deemed to be effortful and aversive (Wolff et al., 2019) and failures to exert self-control are common irrespective of best intentions.

A critical finding from experimental research is that prior acts of self-control can lead to diminished performance on later self-control tasks (Muraven et al., 1998). This diminished self-control performance after a previous act of self-control is referred to as ego-depletion; a term that blends the empirical phenomenon with an account of why the phenomenon occurs (Baumeister et al., 1998; Baumeister et al., 2000). The ego-depletion phenomenon is typically studied using the sequential-task paradigm (for a review see Lee et al., 2016), but not exclusively (see Francis et al., 2018; Lin et al., 2020). In this paradigm, participants perform two consecutive tasks. A self-control task at Time 1 (T1) is used to induce ego-depletion and another self-control task at Time 2 (T2) is used to measure ego-depletion. Participants in the depletion condition perform a task at T1 that requires the use of (more) self-control, whereas participants in the control condition perform a task at T1 that requires minimal (or less) self-control. All participants then complete the same task at T2, which requires the use of self-control and is usually unrelated to the first task (Baumeister et al., 1998; Hagger et al., 2016). Worse performance at T2 in the depletion condition relative to the control condition is indicative of ego-depletion.

One of the initial demonstrations of ego-depletion by Baumeister and colleagues (1998) provides a prototypical illustration of the sequential-task paradigm. At T1 an emotion-regulation task was used. All participants watched an emotion-provoking video. In the depletion condition, participants were instructed to control the impulse to emotionally react to the video, whereas those in the control condition were allowed to let their emotions show freely. At T2 a solvable anagram task was used. It was hypothesized that persistence at this task would require self-control because participants were told they could quit at any time after completing as few or many anagrams as they wanted. Consistent with self-control use at T1 affecting later self-control performance at T2, those in the depletion condition correctly solved significantly fewer anagrams relative to the control condition.

The ego-depletion effect has been shown to affect numerous abilities that are believed to require self-control, including controlling attention, impulses, emotions, cognitive and social processing, and decision-making (Cunningham & Baumeister, 2016; Hagger et al., 2010). For example, ego-depletion has been observed as increases in risky-driving behaviour (Fischer et al., 2012; Freeman & Muraven, 2010), aggression (Stucke & Baumeister, 2006; Vohs et al., 2011; Wang et al., 2017) and impulsivity (Osgoode & Muraven, 2016). As well, ego-depletion has been observed as poorer evaluations of risk through increases in mental passivity (Vonasch et al., 2017), increased racial stereotyping

(Govorun & Payne, 2008), and worse performance on executive functioning tasks such as the operation span task (Schmeichel & Baumeister, 2010) and the Stroop task (Bray et al., 2008).

Theoretical Accounts of Self-Control and Ego-Depletion

Early psychological research on self-control examined models of self-regulation that characterized self-regulation as a function of self-awareness and general attitudes (Koestner et al., 1992), as well as beliefs and intentions (Ajzen, 1985; for a review on previous theories see Baumeister et al., 1994). According to these models, self-control could be conceptualized as either a skill (i.e., learned ability) or a knowledge structure (i.e., schema; Muraven et al., 1998). Later theories on self-control, however, introduced the possibility that self-control may act similar to a limited commodity (Baumeister & Heatherton, 1996).

Currently, the dominant account of the ego-depletion effect is the limited *strength model of self-control*, which attributes decreases in performance to a depletion in available self-control resources (Muraven et al., 1998; Baumeister et al., 1998; Baumeister et al., 2000; Baumeister & Vohs, 2007). The resource used by self-control is argued to be domain-general, in that all acts of volition deplete the same limited capacity (Baumeister et al., 2007). A critical feature of the strength model is that self-control capacity is restored over time, similar to a muscle that is fatigued after exertion and takes time to recover (Muraven et al., 1998). This is in contrast to capacity in most cognitive models, which is restored upon cessation of an activity (Kahneman, 1973; Pashler, 2000). Therefore, using self-control on one task (e.g., control the impulse to laugh when something is funny) results in diminished resources available to control behaviour on a subsequent self-control task (e.g., persisting on an anagram solving task; Vohs & Heatherton, 2000).

Importantly, Baumeister and colleagues (Baumiester & Vohs, 2016; Baumeister et al., 2000; Vohs & Heatheron, 2000) define self-control as the active effort by the self to control automatic or prepotent responses. Self-control is therefore a deliberate action to inhibit or alter predominant tendencies. In line with the muscle metaphor, subjective reports of effort are used to indicate the active expenditure of self-control (Hagger et al., 2010) and self-reported fatigue is hypothesized to indicate that self-control is in a state of depletion (André et al., 2019).

Alternative accounts to the strength model argue that the ego-depletion phenomenon can be explained without involving a limited capacity mechanism. Two of these accounts are (1) Inzlicht and colleagues *process model of depletion* and (2) Kurzban and colleagues *opportunity cost model of subjective effort*. Both of these accounts are considered to be *cost/benefit models of self-control* in that they forego the involvement of resources and attempt to explain why self-control is exerted via the calculation of costs and benefits of persisting on the present activity. Therefore, self-control failures are argued to be due to the adaptive withdrawal of motivation from current tasks toward those that serve more enjoyment or gratification.

According Inzlicht and colleagues' *process model of depletion*, initial acts of self-control shift individual's motivation from continued self-control exertion to more gratifying behaviour (Inzlicht & Schmeichel, 2012, Inzlicht et al., 2014). According to this model, given that self-control is experienced as effortful, over time the costs associated with continued exertion increase while the benefit of withdrawal from the task or to act on impulse also increases, subsequently offering greater incentive to disengage self-control. This shift in motivation is accompanied by a corresponding shift in attention away from stimuli that signals the need for control, toward stimuli that signal reward. Therefore, according to the process model of depletion, ego-depletion occurs, not because self-control resources are depleted, but because the benefit of not exerting self-control at T2 after already exerting self-control at T1 is greater than continued self-control exertion. For example, controlling emotions during an evocative video at T1 is effortful. As a result, the benefit of exerting further control on a later anagram task at T2 is reduced and the benefit of, and focus on, acting on impulse (i.e., quitting the task) is increased, resulting in reduced self-control performance at T2.

The *opportunity cost model of subjective effort* proposed by Kurzban and colleagues (Kurzban, 2016; Kurzban et al., 2013) asserts that self-control failures are due to increasing opportunity costs associated with persisting. According to this model, computational mechanisms, such as those involved in executive functioning, can only be deployed on a finite number of actions at any given time. This problem of simultaneity leads to the benefits and costs associated with ending the present task to alternatively perform another task being calculated, which represent the opportunity costs of persisting. Opportunity costs are theorized to accumulate and therefore increase with time-on-task. In the sequential-task paradigm, both the self-control task at T1 (e.g., controlling emotions) and the task at T2 (e.g., solvable anagrams) are considered to utilize the same computational mechanisms and are argued to hold similar expected utility by virtue of being in the same context. Therefore, using self-control at T1 is argued to lead to decrements in self-control performance at T2 in the sequential-task paradigm because the costs of persisting in the present context increasingly outweigh the potential benefits, resulting in withdrawal from the second self-control task.

Fatigue according to these cost/benefit models is considered to represent an adaptive function used to prevent fixation on costly activities. This is opposed to the strength model which views fatigue as signalling depletion. The sense of effort is considered to represent the deployment of mechanisms involved in executive functioning. In this way, cost/benefits models differ from the strength model in that they propose that all tasks that engage executive functioning should lead to performance decrements, rather than just those that require the deliberate inhibition of a prepotent responses.

Testing the Strength Model of Self-Control

A substantial amount of research has examined the strength model of self-control. The central premise of the strength model, namely the notion of a limited capacity system that takes time to be replenished, has been a source of much controversy. The criticism of this premise has taken two forms, (1) the identification of moderating variables that call into question whether self-control failures are due to depleted resources and (2) the difficulty in identifying a physiological analogue of the resource being depleted by self-control exertion. These criticisms will be discussed below.

First, the strength model of self-control in its original form does not specify a mechanism by which self-control capacity can be affected by moderating factors (Loschelder & Friese, 2016; Inzlicht et al., 2019). Further, the strength model of self-control does not provide a detailed description of the relationship between resource depletion and performance. Consequently, it is often assumed that the extent of depletion should be dose-dependent so that prior self-control should always result in a relative decrement in subsequent performance. However, researchers have identified situations where exerting self-control does not always lead to decrements in later self-control. For instance, a participant's implicit theory about whether self-control acts as a limited or unlimited resource has been shown to moderate the effect of ego-depletion (Job et al., 2010). Job et al. (2010) found that participants who did not believe that self-control was a limited capacity showed no later decrements in self-control performance after previously completing a self-control task. However, participants who believed that self-control was a limited capacity, produced the typical ego-depletion effect, suggesting that implicit beliefs concerning the nature of self-control can moderate whether ego-depletion is observed. If performance decrements are solely due to previous self-control exertion, then individual beliefs about the nature of self-control should have no bearing on performance because self-control should operate similarly across individuals.

Also problematic for the strength model is the observation that small incentives to participants can eliminate the ego-depletion effect (Luethi et al., 2016; Muraven et al., 2008; Muraven & Slessareva, 2003). Muraven and Slessareva (2003) found that depleted participants showed no decrements in later self-control performance at T2 when they believed their performance on the task could help others. However, depleted participants who were not provided any instructions regarding the benefit of their performance produced the typical ego-depletion effect. This suggests that factors such as mood and motivation can mitigate later self-control failure. If the performance deficits were entirely due to the loss of self-control resources, then incentives should not improve performance as there would be no resources available for mobilization.

Research has identified further moderators of the ego-depletion effect, including self-monitoring performance on self-control tasks (Wan & Sternthal, 2008), self-affirmation (Schmeichel & Vohs, 2009), and positive affect (Tice et al., 2007). The existence of moderators suggests that the strength model of self-control in its original form may lack sufficient explanatory power.

The second criticism concerning the strength model is the lack of evidence identifying a physiological analogue of the resource depleted by self-control (Inzlicht & Friese, 2019). The most notable attempt at identifying the physical resource has suggested that glucose, being the primary energy source in the brain, may be the physiological analogue of the resource implicated by self-control (Baumeister et al., 2007; Galliot et al., 2007). However, later research exploring the association between glucose and ego-depletion have raised concerns regarding the conceptual (Kurzban, 2010) and observed (Ainsworth et al., 2016) likelihood of glucose being the direct correlate of ego-depletion. Inzlicht and colleagues (Inzlicht & Friese, 2019; Inzlicht et al., 2014) subsequently suggest that self-control may appear, but may not actually be, a limited resource if no direct resource can be observed.

While glucose may not be the direct correlate of depletion, research examining the neurological basis of self-control has pointed to the involvement of the anterior cingulate cortex, medial prefrontal cortex, and striatum in the execution of self-control (André et al., 2019; Tang et al., 2015). Moreover, André et al. (2019) argues that the depletion effects observed after previous self-control exertion, are not due to the depletion of some intrinsic biological fuel, but rather may be due to progressive electrophysiological changes in the signal communicated between the brain regions involved in self-control.

Alternative cost/benefit models, which forego the involvement of resources, can account for the evidence that incentives and positive affect can alleviate the effects of depletion. However, Baumeister and Vohs (2018) have argued that cost/benefit models cannot account for the diverse range of depletion phenomena and instead focus mainly on situations where self-control is involved in persistence. For example, it is difficult to explain the finding that depletion can result in increased intrusive anxiety and worry (Englert & Bertrams, 2012), if self-control failures are due to shifts in motivation from current effortful tasks to activities that bring gratification. Further, a role for motivation does not exclude a role for resources. Instead, motivation may play a key role in whether self-control resources are mobilized for use. According to the conservation hypothesis, ego-depletion is not due to a strict incapacity for further self-control exertion (Baumeister & Vohs, 2018; Alquist et al., 2020). Instead, initial acts of self-control lead to an attempt to conserve remaining self-control resources, resulting in performance decrements at T2. Incentives and positive affect can therefore alleviate the effects of depletion because an individual is sufficiently motivated to continue mobilizing self-control resources rather than conserving what remains. It follows that as self-control use persists, however, depletion should eventually be observed regardless of motivation. Indeed, Vohs et al. (2013) found that motivation moderated the effects of depletion only when participants were mildly depleted (i.e., performing one self-control task at T1). At more severe levels of depletion (i.e., performing two self-control tasks at T1) motivation failed to alleviate subsequent self-control performance decrements. Further support for the conservation hypothesis comes from Alquist et al. (2020) who found that participants who were uncertain whether they were going to perform a later self-control task, performed worse on a current, unrelated self-control task relative to controls. This evidence is consistent with the notion that individuals will conserve self-control resources in anticipation of potential later use and suggests that the involvement of motivation is fully compatible with the strength model of self-control.

Here I will use the strength model of self control to derive predictions. I will use the strength model to derive predictions because it is sufficient to explain the majority of findings in the ego-depletion literature. The strength model is easy to understand, and the account makes straight-forward predictions in the context of the present studies. Finally, motivational factors are not explicitly manipulated in any of the studies.

A Brief Review of the Ego-Depletion Phenomenon

In the initial demonstrations of ego-depletion, Baumeister and colleagues (1998) conducted a series of experiments designed to assess whether self-control relies on a limited resource using the sequential-task paradigm. They hypothesized that if using self-control draws on a domain-general, but limited pool of resources, then participants who use self-control at T1, should show worse performance on a self-control task at T2 relative to those who did not use self-control on the first task at T1. A variety of self-control tasks were used at T1 that operationalized self-control as the inhibition of some prepotent response (e.g., impulses, habits). These tasks included resisting temptation (Experiment 1), decision making (Experiment 2), controlling emotions (Experiment 3), and controlling habits (Experiment 4). Therefore, while a wide variety of self-control tasks were used, they were each similar in that they required participants to control, inhibit, or modify a dominant or automatic behaviour. The tasks used at T2 were intentionally unrelated to the tasks at T1 to examine whether the limited resource used by self-control is domain-general. These tasks included persisting on unsolvable puzzles (Experiment 1 and 2), solvable anagrams (Experiment 3), and decision making (Experiment 4). Ego-depletion was inferred from task specific performance changes (e.g., changes in accuracy, task persistence) as well as self-reported fatigue and desire to quit measured after the task at T2. Here, I review these specific experiments in detail because they provided both a methodological and empirical foundation for many of the subsequent studies on ego-depletion. In particular, variations of these methods for inducing ego-depletion will recure throughout my thesis.

In Experiment 1, self-control at T1 was manipulated using a tempting cookie task. Participants were either instructed to inhibit the impulse to eat from a plate of cookies in front of them (depletion condition) or were allowed to eat as many cookies as they liked (control condition). At T2, self-control was measured using an unsolvable puzzle task where participants were asked to trace geometric figures without lifting the pencil or crossing a previously drawn line. Consistent with self-control at T1 leading to worse self-control at T2, participants in the depletion condition who had to initially resist the temptation to eat the cookies, were found to spend less time on the task at T2, made fewer attempts on the unsolvable puzzles before quitting, reported greater fatigue, and had a greater desire to quit the experiment relative to the control condition.

In Experiment 2, self-control at T1 was manipulated using a decision-task. Participants in the depletion condition had to decide which of two speeches they would present. Participants in the control condition were assigned a speech to present. At T2, self-control was measured using the same unsolvable puzzle task used in Experiment 1. Consistent with self-control at T1 leading to worse self-control at T2, participants in the depletion condition made fewer attempts on the puzzle task and quit the task sooner relative to the control condition.

In Experiment 3, self-control at T1 was manipulated using an emotion-regulation task. During this task, participants watched an evocative movie clip. In the depletion condition participants were required to control any impulse they had to emotionally react while watching the video, whereas in the control condition they were instructed to let their emotions show freely. At T2, self-control was measured using a solvable anagram task where participants were asked to unscramble letter strings to form English words. It was hypothesized that persistence on this task would require self-control because participants were given the option to complete as few or as many anagrams as they would like and were allowed to quit the task at anytime. Consistent with self-control at T1 leading to worse self-control at T2, participants in the depletion condition correctly solved significantly fewer anagrams at T2 relative to control.

In Experiment 4, self-control at T1 was manipulated using an "e"-cancellation task. For this task, participants were given a photocopy of an excerpt from a statistics textbook and were instructed to cross out the "e's" on the page of text. After first establishing a habit of following these simple instructions, participants in the depletion condition were given new, harder instructions that required the inhibition of the newly established habit of crossing out all of the "e's" (e.g., cross out the "e" only if they are not next to, or one letter away from, another vowel). In the control condition participants continued following the established instructions. An additional difference between conditions was also the legibility of the photocopy. While the depletion condition was given a photocopy that was difficult to read, those in the control condition were given a photocopy that was easy to read. At T2, self-control was measured using persistence at watching a boring video. Participants were either told they could stop watching the video by pressing the button whenever they wanted to quit (active-quit), while the other half were told to continue holding a button as long as they wanted to watch the video and to release the button when they wanted to stop (passive-quit). Consistent with using self-control at T1 leading to worse self-control at T2, participants in the depletion condition indicated increased passivity at T2 relative to the control condition. Indeed, the depletion condition spent longer watching the video when stopping required an active, relative to passive response. This contrasts with the control condition which showed no difference in duration when stopping required either an active or passive response.

Since the initial demonstrations (Baumeister et al., 1998; Muraven et al., 1998), the ego-depletion effect has been replicated over 600 times across various laboratories (for a review see Baumeister et al., 2007). These replications have used a diverse set of self-control tasks that evoke ego-depletion at T1 and measure ego-depletion at T2 to examine the breadth of the ego-depletion phenomenon in the sequential-task paradigm. Some demonstrations of ego-depletion have even utilized tasks that are considered more socially relevant. For instance, Muraven et al. (2002) found that male participants who performed a thought suppression task at T1 (e.g., do not think about the white bear) subsequently consumed more alcohol before an expected driving test at T2 than participants who initially solved arithmetic problems. Further, Vohs and Heatherton (2000) found that chronic dieters consumed more ice cream at T2 after having to control their emotions during an emotion regulation task at T1 relative to dieters who were allowed to let their emotions flow freely during the task at T2. As well, in Englert et al. (2015), basketball players who initially performed a transcription task at T1 that got them to write out a story but omit certain letters while writing, reported getting more distracted performing free throws by stressful background noise relative to controls who initially wrote out a story without any writing stipulations. These studies along with a large body of independent replications support the consistency of the ego-depletion effect (Hagger et al., 2010).

Adventures in Replication

Since the early 2010's there has been an increased focus in scientific research on replicability. This recent concern was spurred by evidence of academic fraud (Bhattacharjee, 2013), questionable research practices (Ioannidis, 2005; Simmons et al., 2011), and several large-scale failures to replicate established phenomena (Open Science Collaboration, 2012, 2015). Together these findings suggested that a large portion of scientific findings may be false. The replication crisis has particularly affected Psychology and has resulted in a wide-spread re-examination of the robustness of many prominent psychological phenomena to establish the integrity of these effects (for a review see; Maxwell et al., 2015).

The ego-depletion phenomenon has been the focus of multiple systematic replication efforts (Dang et al., 2021; Hagger et al., 2016; Vohs et al., 2021) and multiple meta-analyses (Carter & McCullough, 2014; Carter et al., 2015; Dang, 2018; Hagger et al., 2010). The findings of these investigations have generated substantial debate in the ego-depletion literature, with some researchers questioning whether the effect exists at all

(Carter et al., 2015; Inzlicht et al., 2019) and others questioning what it means to replicate (e.g., Baumeister et al., 2018; Dang & Hagger, 2019).

While an initial meta-analysis indicated the effect of ego-depletion to be quite robust (*d*=.62; Hagger et al., 2010), subsequent meta-analyses from Carter and colleagues suggested evidence of publication bias and other small study effects (Carter & McCullough, 2013; Carter et al., 2015), that when controlled for, indicated the effect of ego-depletion to be non-existent (Carter et al., 2015). Small-study effects are when studies with small sample sizes often produce inflated effect sizes (Egger et al., 1997), which can be overrepresented in meta-analyses due to publication bias (i.e., when counterfactual and statistically nonsignificant findings are less likely to be published; Carter et al., 2015).

To deal with evidence of publication bias, Carter et al. (2015), included a large proportion of unpublished demonstrations of ego-depletion (42%) in their analyses and utilized new bias-correction techniques in addition to standard meta-analysis to estimate the “true” effect of ego-depletion. These new techniques included the Precision Effect Test (PET) and Precision Effect Estimate with Standard Error (PEESE), which use weighted-least squares regression models to correct for the influence of small-study effects (Stanley & Doucouliagos, 2014). Despite finding a statistically significant effect of ego-depletion when utilizing standard meta-analytic techniques (Hedge’s *g*=.43), the authors concluded the effect of ego-depletion to be small and not meaningfully different than zero based on results from the PET and PEESE models.

Although efforts to correct for small-study effects in ego-depletion are important, some researchers have criticized Carter et al.’s (2015) conclusion given their methodology. First, Carter et al. (2015) did not estimate effect sizes based on depleting self-control tasks, but rather on frequently used dependent measures, which may conceal ineffective manipulations of ego-depletion (Dang, 2018). Second, Baumeister and Cunningham (2016) have criticized Carter et al. (2015) for excluding many studies with strong, replicated methodology and instead including many unpublished studies that may lack methodological rigour. Third, researchers have criticized the use of PET and PEESE as the basis of their conclusion that ego-depletion is non-existent (Baumeister & Cunningham, 2016; Dang, 2018; Inzlicht et al., 2015). Currently, there is a lack of consensus among statisticians concerning whether PET and PEESE can reliability capture small-study effects (Inzlicht et al., 2015). Moreover, PET and PEESE require a large number of studies with low heterogeneity in effect sizes to produce strong estimates (Stanley & Doucouliagos, 2014). These conditions were not met in Carter et al. (2015). In fact, low heterogeneity in effect sizes is a condition infrequently met in psychology (Inzlicht et al., 2015) and therefore calls into question whether these techniques are adequate to assess the robustness of psychological phenomenon in general. Altogether, these criticisms suggest that Carter et al.'s (2015) conclusion that ego-depletion is non-existent may be over-stated.

Large-scale replication attempts have also generated substantial debate concerning the replicability of ego-depletion. The most well-known replication attempt is Hagger et al. (2016) who across 23 laboratories, with a combined sample of 2,141 participants, failed to find evidence of ego-depletion. In their study, Hagger et al. (2016) used a variation of the sequential-task paradigm that was standardized across all participating laboratories. It required participants to perform a computerized version of the “e”-crossing task at T1 that was initially reported by Baumeister et al. (1998). Participants in the depletion condition were instructed to press a button on a keyboard every time a word with an “e” appeared on the screen that met certain criteria concerning when to withhold responding (e.g., respond unless the “e” follows another vowel). Participants in the control condition were able to respond to every word with an “e” without having any conditions to withhold responding. Self-control was measured at T2 using the Multi-Source Interference Task. In this task, participants were shown a series of number strings that contained one unique number (e.g., 233 or 131). Participants were instructed to respond on a keyboard regarding the spatial location of the unique number and to not respond to the number’s identity. Results indicated the overall effect of ego-depletion to be small and non-significant, which supports Carter et al.’s (2015) conclusion that ego-depletion may not be as robust as initially presumed.

Researchers have raised some methodological concerns regarding the Hagger et al. (2016) replication attempt (Baumeister & Vohs, 2016; Dang, 2016). The “e”-crossing task is a commonly used manipulation of self-control in ego-depletion. However, a key part of the task is that all participants must first establish a habit of crossing out every “e” they observe (e.g., Baumeister et al., 1998). Hagger et al.’s (2016) version of the “e”-crossing task did not include an opportunity for participants to establish such a habit. Without first establishing a habit, Hagger et al. (2016) was manipulating the *intrinsic demands of the task* at T1, rather than manipulating whether participants were required to inhibit a prepotent response. It is possible, therefore, that this simple methodological change explains why the authors failed to observe a consistent ego-depletion effect. The conclusion that Hagger et al. (2016) did not manipulate self-control correctly is consistent with the finding that there was no consistently observed difference between conditions in self-reported fatigue after T1, a key indication of ego-depletion (Dang, 2016).

Other multi-laboratory replications have since been conducted to assess the size and robustness of ego-depletion (Dang et al., 2021; Vohs et al., 2021). Conclusions from these other replication attempts are mixed. Dang and colleagues' (2021) multi-laboratory replication found a small but significant effect of ego-depletion (d=.16), whereas the results from Vohs and colleagues' (2021) replication were inconclusive. However, Vohs and colleagues (2021) have received similar criticisms to Hagger et al. (2016) concerning the appropriateness of their tasks in demanding self-control (Englert & Bertrams, 2021).

Boredom and Operationalizations of Self-Control

Baumeister and colleagues have suggested that many of the failures to find an ego-depletion effect do not represent genuine failures to replicate because they do not create the appropriate conditions for ego-depletion to occur (Cunningham & Baumeister, 2016; Baumeister & Vohs, 2016). In the initial demonstrations of the ego-depletion effect, self-control was operationalized as the inhibition of some prepotent response (Baumeister et al., 1998; Baumeister et al., 2000). However, many studies have instead operationalized self-control as task difficulty so that a harder version of the task is used in the depletion condition, relative to the control condition (e.g., Hagger et al., 2016). Operationalizing self-control as task difficulty is often done because it is assumed that since difficult tasks intrinsically require more effort, more self-control will be necessary to complete them relative to performing a simpler version of the task that intrinsically requires less effort. This operationalization of self-control may be problematic because performing a simple cognitive task may require more effort than the intrinsic demands of the task suggest (Hsu et al., 2017; Dang, 2018; Lurquin & Miyake, 2017). For instance, solving arithmetic problems are difficult but doing so only uses self-control to the extent one must persist despite the desire to stop (Baumeister & Vohs, 2018). Therefore, manipulations of task difficulty may yield unintended consequences for behaviour and may not translate directly to differences in self-control (Baumeister & Vohs, 2016).

Recently, Wolff and Martarelli (2020) suggested that manipulating self-control by reducing task difficulty may have the unintended consequence of rendering the control task boring. If the control task is too boring, then self-control may be necessary to direct attention away from distractions to stay on task (Wolff & Martarelli, 2020). Consistent with this account, state boredom has been described as the unpleasant feeling of being unable to engage attention successfully, despite the desire to do so (Eastwood et al., 2012). When bored, attention cannot be engaged, resulting in an underutilization of cognitive potential (Eastwood & Gorelick, 2019).

Although boredom is often conceptualized as a unidimensional construct, as exemplified by the tendency of researchers to measure boredom with a single item (Bieleke et al., 2021; Lin et al., 2020; Milyavaskaya et al., 2019), research suggests that boredom, like other personality characteristics can be thought of as being a multidimensional construct (Fahlman et al., 2013). For instance, the Multidimensional State Boredom Scale is a self-report measure that includes five factors which measure the defining experiential components of state boredom (i.e., time perception, inattention, disengagement, low arousal negative affect, high arousal negative affect; Fahlman et al., 2013). The *time perception* factor captures the often-reported experience that time appears to slow down (e.g., “Time is dragging on”; Danckert & Allman, 2005; London &

Monello, 1974). The *inattention* factor captures the experience that it is often a struggle to concentrate while bored (e.g., “I am easily distracted”; Damrad-Frye & Laid, 1989; Danckert & Merrifield, 2018). The *disengagement* factor captures the often-reported perception that the current activity lacks meaning (“I am stuck in a situation that I feel is irrelevant”; Rafaelli et al., 2018; Van Tilburg & Igou, 2011). The *high arousal negative affect* (e.g., “I feel agitated”) and *low arousal negative affect* (e.g., “I feel empty”) factors capture the experience of fluctuations in arousal levels while bored (Danckert et al., 2018).

People often report experiencing boredom during situations involving monotonous tasks that lack exogenous support for keeping attention focussed (Eastwood et al., 2012; Raffaelli et al., 2018). For example, variations of Go/No-Go tasks are commonly used in boredom research because participants must continuously monitor a display for rarely occurring targets (Eastwood et al., 2012; Scerbo, 1998). The infrequency of targets is hypothesized to offer minimal external support for keeping attention engaged, thereby an ideal environment for boredom to occur. This can be problematic for task performance because boredom signals a desire to be mentally engaged (Danckert et al., 2018), and can subsequently motivate either disengagement of attention from the current activity entirely or increased mental exertion in an attempt to effectively occupy attention with the current task (Eastwood & Gorelick, 2019). Therefore, if a task is too simple (boring), self-control may be necessary to inhibit attention from being involuntarily redirected towards alternative activities and to maintain attention on the boring task to avoid performance decrements (Kaplan & Bermam, 2010; Osgood, 2015). This suggests that a simple control task in the sequential-task paradigm may require the same (or more) self-control than a more difficult depletion task despite the control task being less intrinsically demanding. If the participants in the control condition are exerting self-control to the same extent or more relative to the depletion condition, this would affect the likelihood of identifying an ego-depletion effect (Wolff & Martarelli, 2020).

Previous Research on Boredom and Ego-depletion

Since Wolff and Martarelli (2020), greater attention has been given to the notion of boredom as a potential confound in ego-depletion research. Indeed, some studies have found support for boredom affecting later self-control performance (Bieleke et al., 2021; Lin et al., 2020; Milyavaskaya et al., 2019).

For instance, Milyayaskaya and colleagues (2019) found that experiencing effort and boredom made people more drawn toward rewards. Their study used a variation of the sequential-task paradigm. At T1, participants in the high effort condition were shown a series of numbers on a computer screen and were instructed to add three to each series shown. Participants in the low effort (boredom) condition were also shown a series of numbers but were only instructed to passively observe the numbers as they appeared on the screen. Participants in the control condition went straight into the task at T2. Boredom was measured at T1 using a one-item Likert questionnaire. Participants in the low effort condition reported greater boredom relative to the high effort condition. At T2, participants performed a lottery door task. During this task, event-related potentials were recorded to measure participants' sensitivity to reward. Consistent with boredom affecting later self-control, participants in the low effort condition indicated more reward sensitivity compared to the control condition. This finding was also observed in the high effort condition. No difference in reward sensitivity was observed between the high effort and low effort conditions, suggesting that both boredom and effort may make people drawn toward rewards.

The observation in Milyayaskaya et al. (2019) of no difference in ego-depletion in the low effort and high effort conditions is consistent with Wolff and Martarelli's (2020) claims that simple tasks can be more boring and is consistent with the argument that boredom affects ego-depletion. However, this study does not provide a direct test of the claim that boredom leads to ego-depletion. Additionally, boredom was only measured in the high and low effort conditions, but not in the control condition. It is consequently presumed that participants in the control condition were less bored than the other two conditions before they started the experiment, but this is not confirmed. As well, it is possible that the low effort condition was still more difficult than the control condition that went straight into the task at T2. Without these comparisons, it is hard to say whether their effect is due to boredom, task difficulty, or the combination of both. Therefore, Milyayaskaya et al.'s (2019) findings are suggestive that boredom during simple tasks leads to ego-depletion but are not definitive.

A separate study by Lin and colleagues (2020) found support for the presence of a relationship between task difficulty and boredom. They found that initially performing a difficult task led to boredom and affected later willingness to exerting effort. Their study used a within-subjects variation of the sequential-task paradigm. At T1, participants either watched a short wild-life video (low effort condition) or performed a symbol counting task that instructed participants to separately count the number of small and big squares shown on a computer screen (high effort condition). Boredom, subjective effort, and fatigue were measured at T1 using one-item Likert questionnaires. At T2, participants performed a Stroop task that consisted of mainly congruent trials. Each participant completed both conditions on two separate days. Results revealed that participants reported the high effort task to be more boring than the low effort task. Using drift diffusion modeling to analyze the Stroop data, it was found that performing a more effortful task at T1, compared to performing a less effortful task, lead participants to respond less cautiously while performing the task at T2. These outcomes suggest that boredom and task difficulty lead to less willingness to exert later effort on the Stroop task, consistent with boredom affecting later self-control.

Lin et al.'s (2020) findings establish the presence of a relationship between difficulty and boredom. However, boredom was not found to uniquely contribute to later self-control beyond the contribution of task difficulty. Indeed, in addition to being reported as more boring, the high effort condition was also reported to be more demanding and more fatiguing. It is therefore hard to conclude whether the effect of demand on later self-control is due to boredom, task difficulty, or the combination of both. As a result, the findings from Lin et al. (2020) establishes a relationship between boredom and difficulty but not that boredom causes ego-depletion.

Finally, Bieleke and colleagues (2021) found that increases in state boredom were related to worse self-control performance. Their study used a variation of the sequential-task paradigm. At T1, participants performed a transcription task. Participants in the depletion condition transcribed a piece of text but were instructed to omit the letter "e" from all words, thereby overriding a well-formed writing habit. Participants in the control condition transcribed a piece of text but were given no added instructions. At T2, participants performed a Stroop task. At the end of the task at T1 and while performing the Stroop task at T2, state boredom, perceived task difficulty, fatigue, and effort were measured using single scale items. The depletion condition was reported to be more difficult, effortful, and fatiguing, but not more boring than the control condition at T1. No evidence of ego-depletion was reported at Time 2. Therefore, this failure to replicate the ego-depletion effect cannot be attributed to boredom. Despite not observing a standard ego-depletion effect, subsequent post-hoc analyses revealed that when all conditions were collapsed, greater state boredom at T1 was associated with an increase in response times at T2, consistent with boredom affecting later self-control. Unfortunately, no details were provided about the relationship between boredom and performance at T1, self-reported effort, fatigue, or difficulty. While this relationship between boredom and ego-depletion is promising, more research is needed.

Previous research on the impact of boredom on self-control (Bieleke et al., 2021; Lin et al., 2020; Milyavaskaya et al., 2019) provides evidence in support of Wolff and Martarelli's (2020) claims that boredom affects ego-depletion. However, each of these studies have their own limitations. One recurring issue is that boredom is often confounded with task difficulty (e.g., Lin et al., 2020; Milyayaskaya et al., 2019). Another recurring limitation is that boredom in these studies was measured using a single scale item (e.g., "How bored are you?") administered after the experimental manipulation. Given that state boredom has been observed to be a multi-dimensional construct (Fahlman et al., 2013), responses on a single item may not accurately gauge individual differences in boredom at T1. Despite the limitations of each of these studies, they converge on the idea that boredom can affect ego-depletion.

Present Study

The process of scientific replication is critical for establishing a core set of empirical phenomena to be explained by psychological theories. Failures to replicate an empirical phenomenon are an important part of this process. However, the meaning of a failure to replicate is ambiguous, especially when there are methodological differences between the original demonstration of a phenomenon and the replication attempts. In the present context, the failures to replicate (e.g., Hagger et al., 2016; Lurquin et al., 2016; Vohs et al., 2021) and meta-analyses can be understood as evidence that either the ego-depletion effect does not replicate (Inzlicht et al., 2019) or that the certain operationalizes of self-control are inappropriate (Cunningham & Baumeister, 2016). The goal of the present study is to examine the latter possibility, by testing a key assumption underlying an account of ego-depletion replication failures in which task difficulty is confounded with boredom (Wolff & Martarelli, 2020).

The assumption that will be tested is that managing boredom while completing a simple task requires self-control and should therefore lead to ego-depletion. In order to test the assumption that managing boredom while completing a simple task leads to ego-depletion, a variation of the sequential task paradigm will be used. To address limitations with previous research on boredom and subsequent self-control (Bieleke et al., 2021; Lin et al., 2020; Milyavaskaya et al., 2019), in each experiment, all participants completed the same Go/No-Go task at T1 to avoid a confound between task difficulty and boredom. To take into account the multi-dimensional quality of state boredom, boredom was assessed immediately after the task at T1 using the MSBS (Fahlman et al., 2013). Finally, self-control was assessed at T2 using a solvable anagram task, which is commonly used in studies of ego-depletion (Hagger et al., 2010). Three experiments are reported. The only difference between experiments was the proportion of Go to No-Go trials presented during the task at T1. In Experiment 1 this ratio was 50:50, in Experiment 2 it was 20:80, and in Experiment 3 it was 80:20. If self-control is required to stay on task when bored, greater scores on the MSBS at T1 should result in worse performance on the anagram task at T2 (ego-depletion).

Experiment 1

Experiment 1 sought to examine the relationship between individual differences in state boredom at T1 and subsequent self-control performance (i.e., ego-depletion) at T2. At T1, all participants completed a simple Go/No-Go task on the computer for approximately 10 minutes to induce state boredom. Since Donders (1868, 1969), variations of the Go/No-Go task have been used throughout psychological research to examine processes that involve attention, including mind-wandering (Helton et al., 2009), sustained attention (Chan, 2001; Manly et al., 1999), and perception (Langenecker et al., 2007). Critically, Go/No-Go tasks are commonly employed in boredom research (Raffaelli et al., 2018). Go/No-Go tasks are argued to lack exogenous support for keeping attention engaged (leads to boredom) and therefore require self-sustained attention to maintain performance on the task (Eastwood et al., 2012). If self-control is used to maintain attention on the task while bored, then a Go/No-Go task should create the appropriate conditions for this to occur.

Methods

Participants

There were sixty-six participants in Experiment 1. Participants were undergraduate students from Trent University and participated for partial course credit. All participants self-reported English as their first language. Sample size for this study was based on the meta-analysis reported by Hagger et al. (2010) who estimated an overall effect for ego-depletion (*d*=.62). Participants' data were excluded if there was clear evidence of one of the following criteria: (1) not following instructions on the Go/No-Go task (i.e., exhibiting chance accuracy), (2) careless responding (e.g., having a non-response rate across all questionnaires of ≥ 20%), and (3) non-discriminant responding (e.g., answering a full questionnaire with the same response). Given these criteria, the data from six participants from Experiment 1 were excluded for not following instructions on the Go/No-Go task (*N*=60). Ethics approval for this research was provided by the Trent University Research Ethics Board (REB # 26412). All participants gave informed consent prior to beginning the experiment.

Measures

Multi-Dimensional State Boredom Scale. The 29-item MSBS (Fahlman et al., 2013) measures the extent of boredom felt at a particular moment. The scale consists of five distinct factors of state boredom: disengagement (e.g., "I feel bored"), high arousal negative affect ("I feel impatient right now"), low arousal negative affect (e.g., "I feel empty"), inattention (e.g., "I am easily distracted"), and time perception (e.g., "Time is dragging on"). Answers to each item are recorded on a 7-point Likert scale from 1 ("Strongly disagree") to 7 ("Strongly agree") and were summed to create one total boredom score (α=.96) with higher scores indicating a higher level of boredom. Answers on each subscale item were summed to create a score for each factor. Cronbach's alpha indicated good reliability across factors for Experiment 1 (disengagement, α=.90; high arousal negative affect, α=.89; low arousal negative affect, α=.91; inattention, α=.84; time perception, α=.94). See Appendix 1.

Trait self-control. A 36-item questionnaire reported by Tangney et al. (2004) that measures individual differences in self-control disposition. Participants were asked to reflect and indicate on a five-point Likert scale from 1 (“Not at All”) to 5 (“Very Much So”) to what extent each of the statements indicated how they typically are. Twenty-four items were negatively phrased and therefore were reversed scored. Scores were summed to create a total self-control score. Larger scores indicated higher trait self-control (α=.89). See Appendix 2.

Fatigue and desire to quit. A two-item questionnaire was administered at the end of the experiment. The questionnaire asked participants to rate on a five-point Likert scale from 1 (“Not at All”) to 5 (“Very Much So”) how tired they currently felt relative to the beginning of the experiment and a separate item that asked to what extent they desired to quit the experiment compared to when they first began the experiment. See Appendix 3.

Go/No-Go task. The stimuli were white, capitalized letters (A-Z, except O) and numerals (1-9) displayed in 40 point Miriam font in the center of the screen with a black background. Participants were told to respond by pressing the “X” key on a standard QWERTY keyboard when a letter was shown (Go), and to not respond when a number was shown (No-Go). Participants completed 16 practice trials followed by 120 experimental trials. There was a 50:50 ratio of Go to No-Go trials. All stimuli were presented for 3000ms or until a response was made. The inter-trial interval was 1000ms.

Error responses were recorded when participants failed to respond to Go trials or failed to let the stimuli time-out for No-Go trials.

Solvable anagram task. Self-control at T2 was measured using a solvable anagram task. Each participant was given the same set of 30 anagrams. They were instructed to unscramble each series of letters to form an English word. The anagrams were created from words readable at the grade five level using Worksheet Genius (www.worksheetgenius.com) with anagram difficulty set to medium and hard. All anagrams were between five to nine letters. Following Cunningham and Baumeister's (2016) suggestion, the anagrams were pre-tested on student researchers working in the laboratory to ensure that the anagrams were appropriate for students at Trent University. See Appendix 4.

Procedure

A variation of the sequential-task paradigm was used. Unlike typical versions of this procedure, all participants completed the same tasks in the same order so that individual differences in state boredom would be unconfounded with objective task difficulty. The specific sequence of events (initial questionnaires, boredom induction (T1), interim period, outcome task (T2) was based on an earlier study in our laboratory (Lott, 2019). Some of the questionnaires [State Trait Anxiety Inventory (STAI), Positive and Negative Affect Scale (PANAS) -A and -B, Trait Self-Control] were not relevant to the present study and were therefore not analyzed. All tasks and questionnaires were completed online in the participants web browser using PsyToolKit, which has been shown to have good timing properties (Stoet, 2010, 2017). Participants were required to complete the experiment on a laptop or desktop computer that had access to a web camera and keyboard. Instructions for each task and questionnaire were displayed on screen and explained over a video call with the researcher on Zoom (Zoom Video Communications Inc., 2016). All participants completed the experiment in a quiet space away from distraction while on the video call. Each experimental session lasted approximately 60 minutes.

At the beginning of the experiment, all participants completed the state portion of the State Trait Anxiety Inventory (STAI). Then at T1, all participants completed the Go/No-Go task on their computer which took approximately 10 minutes.

The interim period between the Go/No-Go task (T1) and outcome task (T2) lasted approximately 10 minutes. Immediately after completing the Go/No-Go task, participants reported their state boredom using the MSBS. Additional filler questionnaires were completed in the following order: Positive and Negative Affect Scale (PANAS)-A, the STAI, and finally, the PANAS-B.

At T2, participants completed the solvable anagram task. Participants were provided the option to complete as few or as many anagrams as they would like and were instructed that they could quit the task at any time. However, the task timed-out after 15 minutes had passed. After completing the anagram task, participants were administered the fatigue and desire to quit questionnaire, STAI, and the trait self-control questionnaire.

Results

Two sets of analyses are reported. The first set of analyses examined whether state boredom was confounded with Go/No-Go performance. The second set of analyses examined whether individual differences in state boredom were predictive of ego-depletion variables recorded at T2. For each of the regression models, normality was assessed via visual inspection of the distribution of residuals and the Shapiro-Wilkes test (Shapiro & Wilk, 1965) and homoscedasticity was assessed using Breusch-Pagan test (Breusch & Pagan, 1979). Outliers were removed case wise and were defined as scores with residuals greater than 2 standard deviations from the best fit model.

Go/No-Go Task

Although all participants completed the same Go/No-Go task, it was still possible that state boredom would be confounded with the individual differences in Go/No-Go task performance. If boredom is confounded with task performance, then changes in self-control at T2 may be due to performance differences at T1. Separate regression models were conducted with MSBS total score as the predictor and mean percentage error (PE) and mean response time (RT) as the outcome. See Table 1 for analyses.

Percentage error. Overall, participants made very few errors in Experiment 1 (1.00% of trials). However, I continued with analysis of the error data. Four outlier cases (residuals>2 SD) were excluded prior to the analysis for Experiment 1. MSBS was not a significant predictor of mean PE, $F(1,54)=1.81$, $p=.184$, $R^2=.032$.

Response time. Only correct responses were analyzed. The remaining correct RTs were submitted to a recursive data-trimming procedure (Van Selst & Jolicoeur, 1994). This resulted in the removal of 2.00% of the correct RT data. One outlier case (residuals>2SD) was excluded from the analysis. Boredom was not a significant predictor of mean RT, $F(1,57) = 0.11$, $p=.549$, $R^2=.006$. These results, along with the model for PE, suggest that Go/No-Go task difficulty was unconfounded with boredom during the task.

Table 1

Regression coefficients for associations between multidimensional state boredom scale (MSBS) total scores and Go/No-Go task performance

Variable	*B*	95% *CI* [*LL*, UL]	*beta*	95% *CI* [LL, UL]	*r*	R^2
			Mean Percent Error			
Experiment 1						
Intercept	0.24	[-0.62, 1.10]				
MSBS	0.01	[-0.005, 0.010]	0.18	[-0.09, 0.45]	.18	.032
Experiment 2						
Intercept	-0.10	[-0.66, 0.47]				
MSBS	0.004	[-0.001, 0.01]	0.20	[-0.06, 0.46]	.20	.039
Experiment 3						
Intercept	1.29*	[0.13, 2.45]				
MSBS	0.002	[-0.01, 0.01]	0.06	[-0.22, 0.33]	.06	.003
			Mean Response Times			
Experiment 1						
Intercept	491.66**	[449.01, 534.31]				
MSBS	0.11	[-0.26, 0.49]	0.08	[-0.18, 0.34]	.08	.006
Experiment 2						
Intercept	532.93**	[467.36, 598.50]				
MSBS	0.02	[-0.56, 0.61]	0.01	[-0.26, 0.28]	.01	.0001
Experiment 3						
Intercept	420.58**	[370.68, 470.49]				
MSBS	0.46*	[0.02, 0.91]	0.27	[0.01, 0.53]	.27*	.073*

Note. Confidence intervals are 95% confidence intervals of the regression coefficients. *LL* = lower limit and *UL* = upper limit. *indicates $p < .05$, ** indicates $p < .01$

Table 2

Means, standard deviations, and Pearson's correlations with confidence intervals for multidimensional state boredom scale (MSBS) total score and MSBS factor scores on ego-depletion variables in Experiment 1

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. Fatigue	2.82	0.88									
2. Desire to Quit	1.61	0.80	**.10** [-.18, .36]								
3. Time-on-task	7.89	4.77	**-.09** [-.35, .17]	**-.18** [-.43, .08]							
4. Correct	10.32	4.88	**-.24** [-.48, .03]	**-.20** [-.45, .07]	**.44**** [.20, .63]						
5. MSBS	109.20	37.00	**.52**** [.29, .69]	**.15** [-.11, .40]	**-.06** [-.31, .20]	**-.33*** [-.54, -.07]					
6. Disengage	38.93	13.35	**.50**** [.28, .68]	**.16** [-.10, .41]	**-.07** [-.32, .19]	**-.31*** [-.53, -.05]	**.92**** [.88, .95]				
7. High Arousal	16.97	7.87	**.37**** [.11, .57]	**.07** [-.20, .33]	**-.09** [-.34, .17]	**-.24** [-.47, .03]	**.87**** [.79, .92]	**.76**** [.63, .85]			
8. Low Arousal	16.74	8.32	**.38**** [.13, .59]	**.12** [-.15, .37]	**.08** [-.17, .33]	**-.24** [-.47, .02]	**.88**** [.81, .93]	**.74**** [.59, .83]	**.79**** [.67, .87]		
9. Inattention	18.20	5.95	**.46**** [.22, .65]	**-.03** [-.29, .24]	**-.00** [-.26, .25]	**-.05** [-.31, .22]	**.72**** [.57, .82]	**.62**** [.44, .76]	**.63**** [.45, .76]	**.59**** [.39, .73]	
10. Time Perception	18.36	8.84	**.41**** [.17, .61]	**.25** [-.02, .48]	**-.15** [-.38, .11]	**-.44**** [-.63, -.21]	**.70**** [.54, .81]	**.57**** [.37, .72]	**.41**** [.18, .60]	**.54**** [.33, .70]	**.29*** [.04, .51]

Note. Confidence intervals are 95% intervals of the correlation coefficients. Correct = Correctly solved anagrams, Disengage = Disengagement, High Arousal = High arousal negative affect, Low Arousal = Low arousal negative affect.
*indicates $p < .05$, ** indicates $p < .01$

Table 3

Regression coefficients for associations between Multidimensional state boredom scale (MSBS) total scores and ego-depletion variables

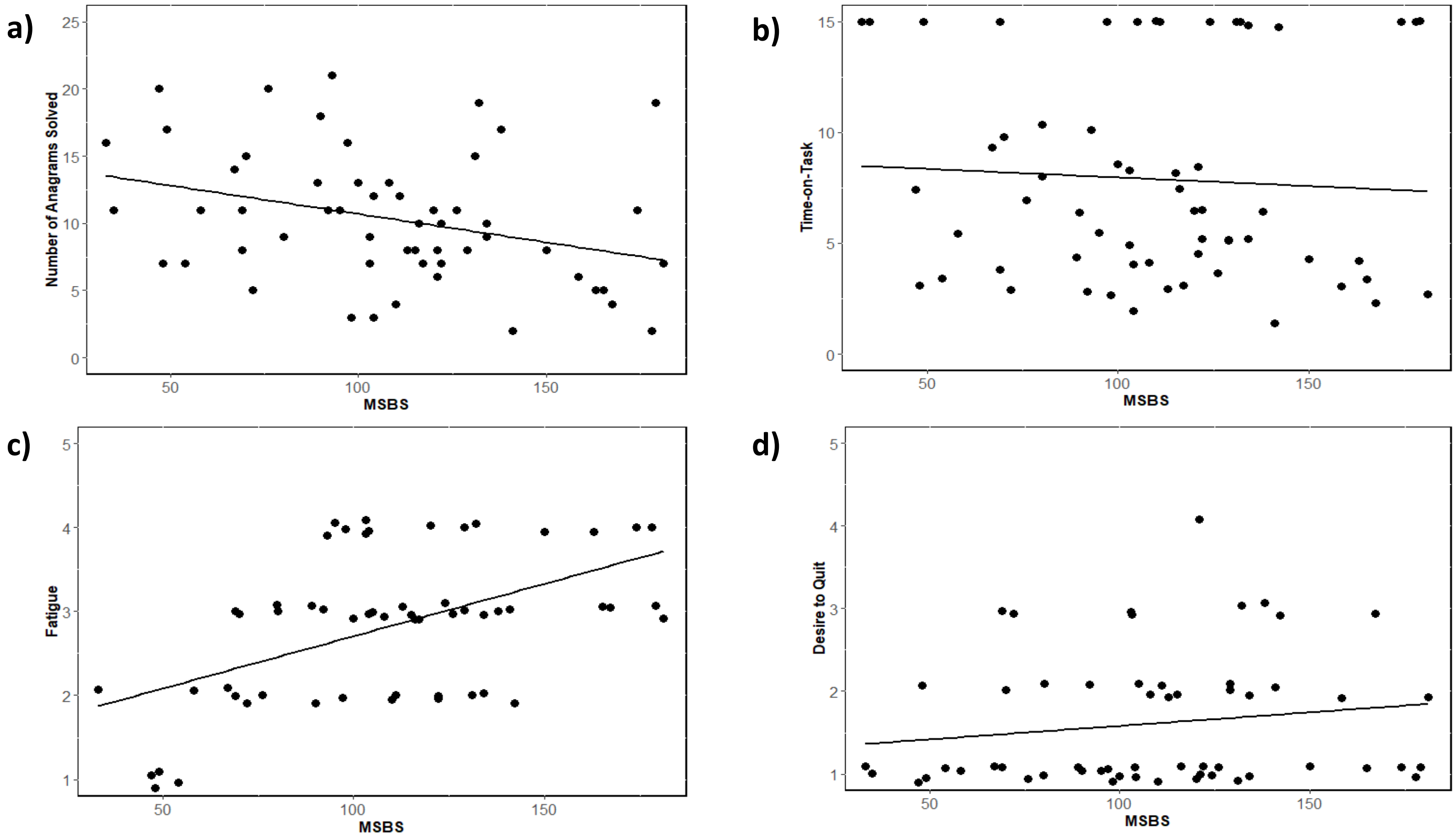
	B	95% CI [LL, UL]	*beta*	95% CI [LL, UL]	*r*	R^2
			Correctly solved anagrams			
Experiment 1						
Intercept	14.85**	[10.96, 18.74]				
MSBS	-0.04*	[-0.08, -0.01]	-0.33	[-0.59, -0.07]	-.33*	.108*
Experiment 2						
Intercept	5.73**	[2.32, 9.14]				
MSBS	0.04**	[0.01, 0.07]	0.35	[0.10, 0.61]	.35**	.126**
Experiment 3						
Intercept	14.19**	[10.20, 18.19]				
MSBS	-0.04*	[-0.07, -0.003]	-0.28	[-0.53, -0.02]	-.28*	.077*
			Time-on-task			
Experiment 1						
Intercept	8.73**	[4.84, 12.63]				
MSBS	-0.01	[-0.04, 0.03]	-0.06	[-0.32, 0.20]	-.06	.004
Experiment 2						
Intercept	7.55**	[3.31, 11.79]				
MSBS	0.002	[-0.04, 0.04]	0.01	[-0.25, 0.27]	.01	.0001
Experiment 3						
Intercept	10.45**	[6.71, 14.19]				
MSBS	-0.03	[-0.06, 0.01]	-0.22	[-0.48, 0.04]	-.22	.047
			Fatigue			
Experiment 1						
Intercept	1.46**	[1.04, 2.53]				
MSBS	0.01**	[0.01, 0.02]	0.52	[0.28, 0.75]	.52**	.267**
Experiment 2						
Intercept	3.51**	[2.84, 4.19]				
MSBS	-0.004	[-0.01, 0.002]	-0.18	[-0.45, 0.09]	-.18	.032
Experiment 3						

Intercept	2.44** [1.38, 3.51]			
MSBS	0.004 [-0.01, 0.01]	0.10 [-0.16, 0.37]	.10	.011
		Desire to quit		
Experiment 1				
Intercept	1.25** [0.59, 1.91]			
MSBS	0.003 [-0.002, 0.009]	0.15 [-0.12, .42]	.15	.023
Experiment 2				
Intercept	1.67** [1.01, 2.34]			
MSBS	-0.001 [-0.01, 0.00]	-0.05 [-0.31, 0.22]	-.05	.002

Note. Confidence intervals are 95% confidence intervals of the regression coefficients. *LL* = lower limit and *UL* = upper limit. Each separate regression includes MSBS as the predictor and ego-depletion variables as the outcomes.
*indicates $p < .05$. , ** indicates $p < .01$.

Figure 1

Multidimension state boredom scale (MSBS) and ego-depletion variables for Experiment 1



Note. Each dot represents an individual participant. Separate regressions were conducted where MSBS total score was the sole predictor and ego-depletion variables were the outcomes.

Ego-Depletion

To test whether boredom at T1 was predictive of self-control at T2, four dependent variables were examined (i.e., correctly solved anagrams, time-on-task, self-reported fatigue, and desire to quit). Two analyses are reported for each dependent variable. First, a separate regression model was conducted where MSBS total score was the predictor and an ego-depletion variable was the sole outcome to test the hypothesis that boredom experienced during simple tasks can lead to ego-depletion. Second, a follow up test was conducted with MSBS factor scores (i.e., disengagement, low arousal, high arousal, inattention, time perception) as the predictors to determine which components of boredom uniquely predicted ego-depletion. For each multiple regression, multicollinearity was examined via inspection of variance inflation factors (Mansfield & Helms, 1981). See Table 2 for the correlation matrix.

Correctly solved anagrams. Residuals for the model predicting correctly solved anagrams from MSBS total score were not normally distributed, W=0.92, p=.001. This issue was addressed once four outliers (residuals>2SD) were excluded, W=0.96, p=.099. Analysis revealed that as state boredom increased, the number of correctly solved anagrams decreased, $F(1,54)=6.51$, p=.014, R^2=.108, consistent with boredom leading to ego-depletion. See Table 3 for analyses and Figure 1 for scatter plot.

The follow up model using the MSBS factor scores as predictors was significant, $F(5, 50)=3.18$, p=.014, R^2=.241. Time perception was the only unique predictor of correctly solved anagrams, B=-0.23, p=.014. As time perception increased, the number of correctly solved anagrams decreased at T2. No other factor was a significant unique predictor (disengagement, *B*=-0.07, *p*=.416; low arousal, *B*=0.07, *p*=.604; high arousal, *B*=-0.10, *p*=.492; inattention; *B*=0.20, *p*=.149).

Time-on-task. Residuals for the model predicting time-on-task from MSBS total score were not normally distributed, *W*=0.85, $p<.001$. No outliers were identified and transforming the data did not resolve issues with normality. I therefore conducted the planned analysis despite the assumption violation. MSBS was not a significant predictor of time-on-task, *F*(1,58)=0.21, *p*=.649, R^2=.004. Although not significant, the slope of this model is consistent with the finding

from the model examining the number of correctly solved anagrams, where increased boredom is associated with worse self-control performance.

The follow up model using the MSBS factor scores as predictors was not significant, *F*(5, 54)=1.58, *p*=.182, R^2=.128. However, low arousal was found to be a significant unique predictor of time-on-task (*B*=0.33, *p*=.017) in that as low arousal increased, the amount of time spent on the task at T2 before quitting also increased (opposite of prediction). Further, there was a trend for high arousal to be a unique predictor as well (*B*=-0.26, *p*=.079). As high arousal increased, the time spent on the task at T2 before quitting decreased (ego-depletion). No other factor was a significant unique predictor (disengagement, *B*=-0.01, *p*=.915; inattention, *B*=0.02, *p*=.874; time perception, *B*=-0.15, *p*=.100).

Fatigue. Inspection of the data revealed no evidence of assumption violations for the model predicting fatigue from MSBS total scores. Four outliers were identified and excluded from analysis. As overall boredom increased, self-reported fatigue at T2 increased, $F(1,54)= 19.67$, $p<.001$, $R^2=.267$, consistent with boredom leading to ego-depletion.

The follow up model using the MSBS factor scores as predictors was significant, $F(5, 50)= 4.74$, $p=.001$, $R^2=.322$. Inattention was found to be a marginally significant predictor of self-reported fatigue, $B=0.05$, $p=.058$. As inattention at T1 increased, self-reported fatigue at T2 increased. No other factor was a significant unique predictor (disengagement, $B=0.02$, $p=.115$; low arousal, $B=-0.01$, $p=.779$; high arousal, $B=-0.01$, $p=.651$; time perception, $B=0.02$, $p=.246$).

Desire to quit. Residuals for the model predicting desire to quit from MSBS total scores were not normally distributed, $W=0.85$, $p<.001$. Outlier removal ($n=4$) did not resolve issues with normality, nor did transforming the data. The untransformed data were therefore analyzed. MSBS was not a significant predictor of desire to quit, $F(1,54)=1.292$, $p=.261$, $R^2=.023$. While not significant, the slope of the model is consistent with the previous analyses from correctly solved anagrams and fatigue where greater boredom is associated with worse self-control.

The follow up model using the MSBS factor scores as predictors was not significant, $F(5, 50)= 0.97$, $p=.448$, $R^2=.088$. No factor score was found to uniquely predict desire to quit (disengagement, $B=0.01$, $p=.466$; low arousal, $B=0.003$, $p=.898$; high arousal, $B=-0.006$, $p=.834$; inattention, $B=-0.03$, $p=.286$; time perception, $B=0.02$, $p=.226$).

Discussion

Experiment 1 sought to examine whether individual differences in state boredom after completing a Go/No-Go task at T1 predicted self-control at T2, measured using a solvable anagram task. As state boredom increased at T1, it was associated with fewer correctly solved anagrams, and greater self-reported fatigue at T2. These outcomes are consistent with self-control being used when bored to maintain attention on a simple task, leading to ego-depletion. Analyses examining the unique contribution of MSBS factor scores on ego-depletion variables revealed no factor that consistently predicted ego-depletion. However, time perception was found to be a unique predictor of anagram performance. The more time was perceived to slow down at T1, the fewer anagrams participants correctly solved at T2. Further, high and low arousal negative affect uniquely predicted the amount of time participants spent on the anagram task before quitting. Consistent with boredom leading to worse self-control, as high arousal negative affect (e.g., "I feel agitated") increased, time spent on the anagram task before quitting decreased. The opposite pattern was observed regarding low arousal negative affect (e.g., "I feel empty"), whereby as low arousal increased, time spent on the anagram task before quitting increased. Inattention was also found to be a unique predictor of self-reported fatigue. Consistent with boredom leading to worse self-control, as inattention increased, self-reported fatigue increased.

Experiment 2

The findings from Experiment 1 suggest that greater state boredom at T1 during a simple Go/No-Go task is related to worse self-control performance at T2. Given recent concerns about the replicability of the ego-depletion effect (e.g., Carter et al., 2015; Hagger et al., 2016), Experiment 2 was designed to replicate, as well as extend the findings from Experiment 1. In Experiment 2, the ratio of Go to No-Go trials was changed from 50:50 in Experiment 1 to 20:80. In all other ways, Experiment 2 was identical to Experiment 1. This change was motivated by the observation that invoking boredom is typically done using a smaller ratio of Go to No/Go trials, which is believed to provide less external support for keeping attention engaged (Eastwood et al., 2012). It was therefore predicted that reducing the proportion of Go to No-Go trials would make the task more boring relative to Experiment 1 and that with less external support for attention, more self-control should be necessary to maintain attention on the task. Therefore, if self-control is used to stay on task when bored, then greater boredom at T1 would be predictive of worse self-control performance on the anagram task at T2.

Methods

Participants

There were 63 participants for Experiment 2. The same exclusion criteria from Experiment 1 were used in Experiment 2. Given these criteria, the data from two participants were excluded for careless responding (N=61). Participant recruitment followed the same procedure as in Experiment 1.

Measures

Go/No-Go. All materials remained identical to Experiment 1 with one exception. While in Experiment 1 there was a 50:50 ratio of Go to No-Go trials, in Experiment 2 this ratio was changed so that there was a 20:80 ratio of Go to No-Go trials.

Procedure

The experimental procedure for Experiment 2 remained unchanged from Experiment 1.

Results

Data in Experiment 2 were analyzed in the same way as in Experiment 1. See Table 4 for the correlation matrix and Figure 2 for scatter plots

Go/No-Go Task

Percentage error. Overall, participants made few errors in Experiment 2 (0.52%). One outlier case was excluded prior to analysis (residuals>2SD). MSBS was not a significant predictor of mean PE, $F(1,58)=2.34$, $p=.130$, $R^2=.039$.

Response time. Correct RTs were submitted to the same recursive data-trimming procedure as in Experiment 1 (Van Selst & Jolicoeur, 1994). This resulted in the removal of 1.78% of the raw correct RT data. Three outlier cases (residuals>2SD) were excluded from the analysis. MSBS was not a significant predictor of mean RT, $F(1,56) =0.007$, $p=.933$, $R^2<.001$. These results, along with the model for PE are consistent with the findings from Experiment 1 and suggest that Go/No-Go task difficulty was unconfounded with boredom during the task.

Table 4

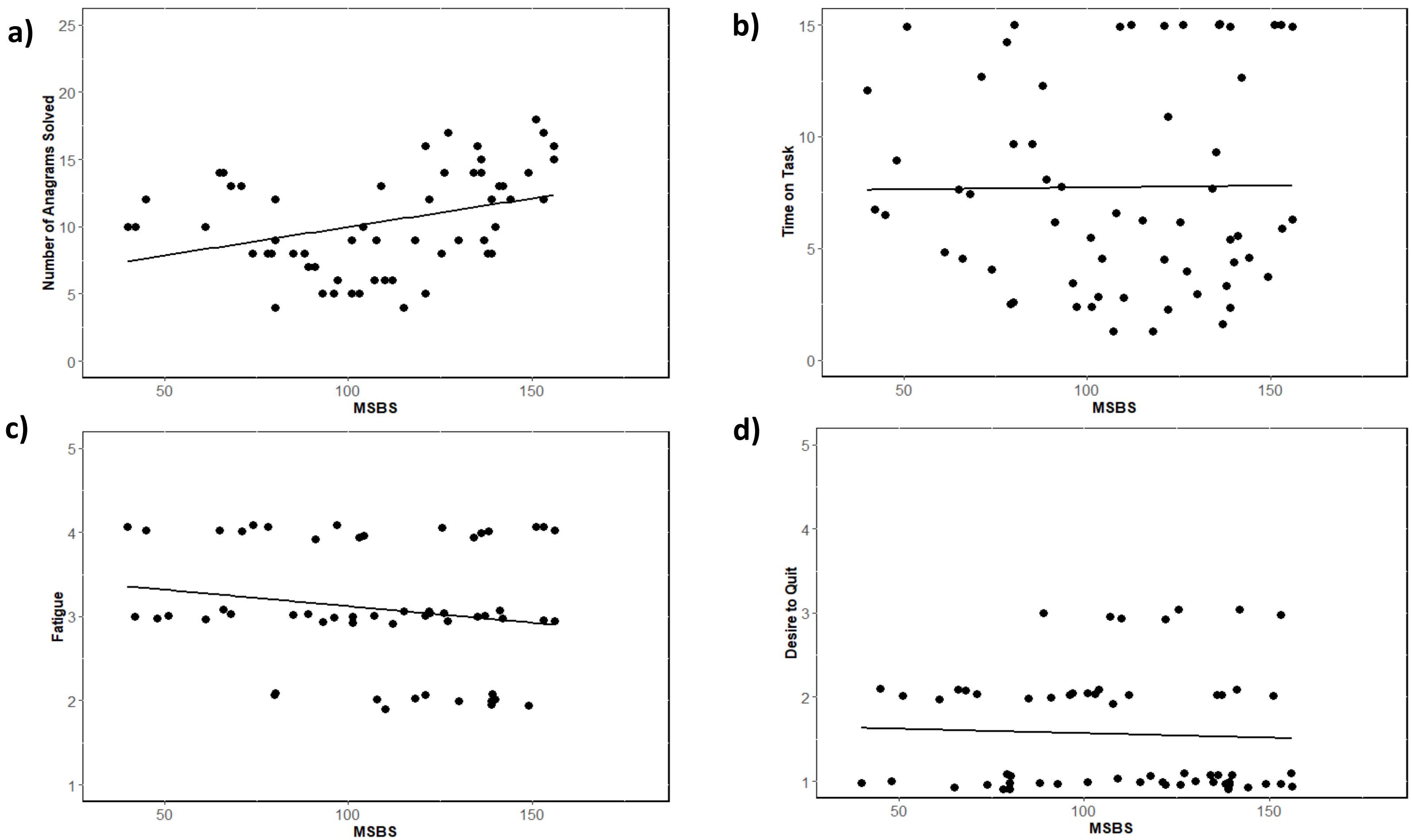
Means, standard deviations, and Pearson's correlations with confidence intervals for multidimensional state boredom scale (MSBS) total score and MSBS factor scores on ego-depletion variables in Experiment 2

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. Fatigue	3.09	0.73									
2. Desire to Quit	1.60	0.76	**.18** [-.09, .43]								
3. Time-on -task	7.73	4.69	**.15** [-.12, .40]	**-.10** [-.35, .15]							
4. Correct	10.38	3.74	**.10** [-.18, .37]	**-.13** [-.38, .14]	**.48**** [.26, .66]						
5. MSBS	107.66	32.34	**-.19** [-.44, .08]	**-.15** [-.39, .11]	**.01** [-.24, .26]	**.35**** [.11, .56]					
6. Disengage	38.03	12.99	**-.16** [-.41, .11]	**-.08** [-.33, .18]	**-.04** [-.29, .22]	**.31*** [.05, .52]	**.94**** [.90, .96]				
7. High Arousal	16.31	6.72	**-.20** [-.45, .07]	**-.17** [-.40, .09]	**.01** [-.24, .26]	**.28*** [.03, .51]	**.80**** [.69, .88]	**.69**** [.53, .80]			
8. Low Arousal	18.20	7.74	**-.18** [-.43, .09]	**-.17** [-.41, .09]	**.09** [-.17, .33]	**.44**** [.21, .63]	**.80**** [.69, .88]	**.73**** [.58, .83]	**.62**** [.43, .75]		
9. Inattention	17.07	6.36	**-.17** [-.42, .10]	**-.04** [-.29, .21]	**-.04** [-.29, .21]	**.28*** [.02, .50]	**.85**** [.76, .91]	**.76**** [.63, .85]	**.66**** [.49, .78]	**.57**** [.37, .72]	
10. Time Perception	18.05	6.51	**-.03** [-.29, .24]	**-.18** [-.42, .08]	**.06** [-.20, .30]	**.03** [-.23, .28]	**.49**** [.27, .66]	**.34**** [.09, .54]	**.20** [-.05, .43]	**.16** [-.10, .40]	**.36**** [.11, .56]

Note. Confidence intervals are 95% intervals of the correlation coefficients. Correct = Correctly solved anagrams, Disengage = Disengagement High Arousal = High arousal negative affect, Low Arousal = Low arousal negative affect.
*indicates $p < .05$, ** indicates $p < .01$

Figure 2

Multidimension state boredom scale (MSBS) and ego-depletion variables for Experiment 2



Note. Each dot represents an individual participant. Separate regressions were conducted where MSBS total score was the sole predictor and ego-depletion variables were the outcomes.

Ego-Depletion

Correctly solved anagrams. Residuals from the model predicting correctly solved anagrams from MSBS were not normally distributed, W=0.92, p<.001. Issues with normality were resolved once three outlier cases were excluded, W=0.96, p=.056. Analysis revealed that as state boredom increased, the number of correctly solved anagrams also increased, F(1,56)=8.07, p=.006, R^2=.126. This relationship is opposite to the one observed in Experiment 1 where increased boredom was negatively associated with anagram task performance.

The follow up model using MSBS factor scores as predictors was significant, F(5, 52)=2.60, p=.036, R^2=.200. Low arousal was the only unique predictor of correctly solved anagrams, B=0.21, p=.021. The greater low arousal negative affect reported, the more anagrams correctly solved at T2. This is in contrast to Experiment 1, where time perception was a negative unique predictor of anagram performance. No other factor was a significant unique predictor (disengagement, B=-0.02, p=.756; high arousal, B=0.01, p=.908; inattention; B=0.05, p=.661; time perception, B=-0.02, p=.820).

Time-on-task. Residuals from the model predicting time-on-task from MSBS total score were not normality distributed, W=0.88, p<.001. No outlier cases were identified and transforming the data did not resolved issues with normality. The untransformed data were therefore analyzed. MSBS was not a significant predictor of time-on-task, F(1,59)=0.008, p=.929, R^2<.001. Although not significant, the slope of the model is consistent with the analysis on the number of correctly solved anagrams for Experiment 2, whereby increased boredom is associated with better self-control performance.

The follow up model using MSBS factor scores as predictors was not significant, $F(5,55)=0.47$, $p=.799$, $R^2=.041$. No MSBS factor was found to be a unique predictor of time-on-task (disengagement, $B=-0.08$, $p=.368$; low arousal, $B=0.15$, $p=.204$; high arousal, $B=0.03$, $p=.835$; inattention, $B=-0.06$, $p=.727$; time perception, $B=0.08$, $p=.444$).

Fatigue. Residuals from the model predicting fatigue from MSBS total score were not normally distributed, $W=0.91$, $p<.001$. Outlier removal did not resolve issues with normality ($n=6$), nor did transforming the data. Therefore, the untransformed were analyzed. MSBS was not a significant predictor of self-reported fatigue, $F(1,53)=1.74$, $p=.193$, $R^2=.032$. Although not significant, the slope of the model is consistent with the analysis on the number of correctly solved anagrams for Experiment 2, whereby increased boredom is associated with better self-control performance.

The follow up model using MSBS factor scores as predictors was not significant, $F(5,49)=0.46$, $p=.801$, $R^2=.045$. No factor score was found to uniquely predict self-reported fatigue (disengagement, $B=0.004$, $p=.798$; low arousal, $B=-0.009$, $p=.645$; high arousal, $B=-0.01$, $p=.501$; inattention, $B=-0.01$, $p=.757$; time perception, $B=0.002$, $p=.896$).

Desire to quit. Residuals from the model predicting desire to quit from MSBS total scores were not normally distributed, $W=0.827$, $p<.001$. Issues with normality were not resolved via outlier removal ($n=2$), nor via transforming the data. The untransformed data were therefore analyzed. MSBS was not a significant predictor of desire to quit, $F(1,53)=1.74$, $p=.193$, $R^2=.032$. While not significant, the slope of the model is consistent with the analysis on the number of correctly solved anagrams for Experiment 2, whereby increased boredom is associated with better self-control performance.

The follow up model using MSBS factor scores as predictors was not significant, $F(5,53)=1.19$, $p=.325$, $R^2=.101$. Time perception was found to be a marginally significant unique predictor of desire to quit, $B=-0.03$, $p=.091$. As time perception increased, participants desire to quit the experiment decreased. No other MSBS factor was found to uniquely predict desire to quit (disengagement, $B=0.01$, $p=.278$; low arousal, $B=-0.02$, $p=.247$; high arousal, $B=-0.02$, $p=.256$; inattention, $B=0.02$, $p=.305$)

Discussion

Experiment 2 sought to replicate the observation that increases in state boredom at T1 during a Go/No-Go task predicted worse self-control at T2. In addition, Experiment 2 sought to extend the findings to a more typical version of the Go/No-Go task used in boredom research by decreasing the ratio of Go to No-Go trials thereby reducing the exogenous support offered by the Go/No-Go task at T1. It was hypothesized that this change would increase the deleterious impact of boredom on self-control. Inconsistent with these predictions and the findings from Experiment 1, as state boredom increased at T1, the number of correctly solved anagrams increased, suggesting that increased boredom during the Go/No-Go task led to better self-control at T2. When examining the unique contribution of the MSBS factors, low arousal negative affect (e.g., “I feel empty”) was found to uniquely predict the number of anagrams solved. As low arousal at T1 increased, the number of anagrams correctly solved increased. The direction of this relationship is consistent with the finding from Experiment 1, where greater low arousal uniquely predicted more time spend on the anagram task before quitting. Additionally, although not significant, greater boredom at T1 was related to less self-reported fatigue, less desire to quit the experiment at T2, and more time spent on the anagram task before quitting.

Therefore, when the proportion of Go to No-Go trials was 20:80, boredom seemed to have had a "therapeutic" effect on later self-control and suggests that decreasing the frequency of responding did not increase reliance on the self to maintain attention on the task.

Experiment 3

The strength model of self-control suggests that if self-control is used to stay on task when bored, then greater boredom at T1 should result in worse self-control performance at T2. This negative association was observed in Experiment 1 when the proportion of Go to No-Go trials at T1 was 50:50. In Experiment 1, greater boredom at T1 was associated with *worse* anagram performance and more fatigue at T2. However, the opposite association was observed in Experiment 2 when the proportion of Go to No-Go trials at T1 was 20:80. Indeed, greater boredom at T1 was associated with *better* anagram performance at T2. The findings from Experiment 2 suggest that changing the proportion of Go to No-Go trials so that there were fewer Go trials and more No-Go trials, changed the impact boredom had on subsequent self-control in that rather than being deleterious for later performance, boredom was therapeutic. Therefore, the properties of the task did not change how boring the task was but did change the psychological outcome the task had.

A possible explanation for this "therapeutic" outcome of boredom on self-control may be due to the infrequent responses allowing the need for engagement to be satisfied outside of the task, such as via mind wandering (Danckert & Merrifield, 2016). Instead of *supporting* attentional engagement on the task, increased responding in the Go/No-Go task may *require* more attention engagement without providing support. Consequently, increasing the percentage of Go trials may increase the need for self-control of attentional engagement. Indeed, previous research has shown that when the need to monitor for incoming targets during a Go/No-Go task is reduced, participants can fully disengage from the task without harming performance but still report the task to be boring (Hitchcock et al., 1999). Therefore, in Experiment 2 when there were fewer Go trials, the task was still insufficient to maintain engagement (i.e., still perceived as boring) but the need to control attention to stay on task was reduced, thereby allowing time for engagement to be satisfied elsewhere. In this way, the effect boredom has on self-control may be different depending on the time allowed for disengagement from the task. Experiment 3 sought to test this explanation.

In Experiment 3 the ratio of Go to No-Go trials was 80:20 as opposed to 50:50 in Experiment 1 and 20:80 in Experiment 2. If how frequent responding is alters the consequences of boredom on self-control, then changing the proportion of Go to No-Go trials so that responding is more frequent (e.g., 80%) should result in greater boredom at T1 leading to worse self-control at T2. This is because more self-control will be required to inhibit the desire to disengage from the current task in the face of boredom so that accurate responses can be made within the limited time-window.

Methods

Participants

There were 62 participants for Experiment 3. The data from two participants were excluded for not following instructions on the Go/No-Go task (i.e., chance responding) and the data from one participant was excluded for careless responding (i.e., having a no-response rate over 20%; *N*=59). Participant recruitment followed the same procedure as in Experiment 1 and 2.

Measures

The present experiment differs from Experiments 1 and 2 in three ways. First, a 80:20 ratio of Go to No-Go trials was used. Second, given that desire to quit was not predicted by boredom in Experiment 1 or 2, data from this questionnaire were not collected for Experiment 3. Third, a three-item questionnaire assessing the different aspects of subjective effort (e.g., "How hard did your try") was administered during the interim period. These questions are based on previous research that suggests the perceived effortfulness of a task is a function of three related but distinct aspects of effort (i.e., task difficulty, volitional effort, and affective consequences of the task; Hsu et al., 2018). The inclusion of these items was intended to explore how different aspects of subjective effort may be predictive of ego-depletion and are not analyzed here.

Procedure

The experimental procedure for Experiment 3 remained unchanged from Experiment 1 and 2.

Results

Data in Experiment 3 were analyzed in the same way as in Experiment 1 and 2. See Table 5 for the correlation matrix and Figure 3 for scatter plots.

Go/No-Go Task

Percentage error. Overall, participants made few errors in Experiment 3 (1.71%). Three outlier cases were excluded from analysis (residuals>2SD). MSBS was not a significant predictor of mean PE, $F(1,54)=0.17$, $p=.680$, $R^2=.003$.

Response Time. Correct RTs were submitted to the same recursive data trimming procedure as in Experiment 1 and 2 (Van Selst & Jolicoeur, 1994). This resulted in the removal of 2.07% of the correct RT data. One outlier case was identified and exclude from analysis. Contrary to Experiment 1 and 2, MSBS was found to be a significant predictor of mean RT in Experiment 3, $F(1,56)=4.39$, $p=.041$, $R^2=.073$. As state boredom increased, the longer participants took to respond on average during the Go/No-Go task.

Table 5

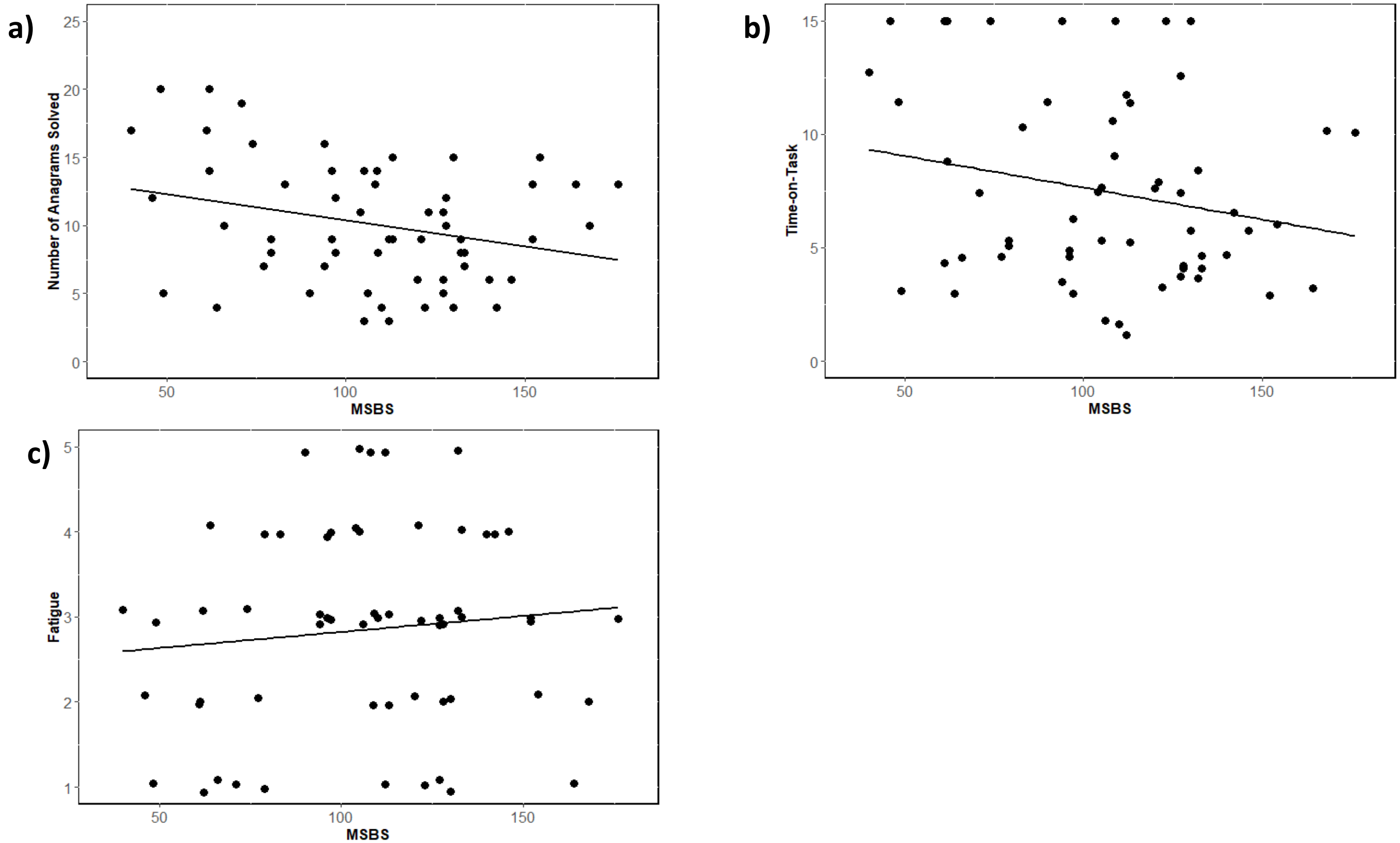
Means, standard deviations, and Pearson's correlations with confidence intervals for multidimensional state boredom scale (MSBS) total score and MSBS factor scores on ego-depletion variables in Experiment 3

Variable	*M*	*SD*	1	2	3	4	5	6	7	8
1. Fatigue	2.85	1.19								
2. Time-on-task	7.55	4.27	**-.22** [-.46, .04]							
3. Correct	10.02	4.56	**-.32*** [-.53, -.06]	**.62**** [.42, .76]						
4. MSBS	106.76	32.67	**.10** [-.16, .35]	**-.16** [-.40, .10]	**-.27*** [-.49, -.01]					
5. Disengage	38.32	12.03	**.16** [-.10, .40]	**-.15** [-.39, .11]	**-.25** [-.48, .01]	**.96**** [.93, .97]				
6. High Arousal	16.71	6.64	**.16** [-.10, .40]	**-.17** [-.41, .09]	**-.32*** [-.54, -.07]	**.91**** [.85, .94]	**.85**** [.75, .91]			
7. Low Arousal	16.37	7.74	**-.01** [-.27, .24]	**-.03** [-.29, .23]	**-.17** [-.41, .09]	**.84**** [.74, .90]	**.76**** [.62, .85]	**.72**** [.56, .82]		
8. Inattention	17.56	5.76	**.22** [-.04, .45]	**-.13** [-.37, .14]	**-.10** [-.35, .16]	**.76**** [.63, .85]	**.73**** [.58, .83]	**.67**** [.49, .79]	**.51**** [.29, .68]	
9. Time Perception	17.81	6.57	**-.12** [-.36, .15]	**-.20** [-.43, .06]	**-.24** [-.47, .02]	**.66**** [.48, .78]	**.53**** [.32, .69]	**.51**** [.30, .68]	**.43**** [.19, .61]	**.30*** [.05, .52]

Note. Confidence intervals are 95% intervals of the correlation coefficients. Time = Time-on-task, Correct = Correctly solved anagrams, Disengage = Disengagement, High Arousal = High arousal negative affect, Low Arousal = Low arousal negative affect. *indicates $p < .05$, **indicates $p < .01$.

Figure 3

Multidimension state boredom scale (MSBS) and ego-depletion variables for Experiment 3



Note. Each dot represents an individual participant. Separate regressions were conducted where MSBS total score was the sole predictor and ego-depletion variables were the outcomes

Ego-depletion

Correctly solved anagrams. Inspection of the data revealed no evidence of assumption violations for the model predicting correctly solved anagrams from MSBS total scores. One outlier was excluded from analysis. Analysis revealed that as MSBS increased, the number of correctly solved anagrams decreased, $F(1,56)=4.65$, $p=.035$, $R^2=.077$, consistent with boredom leading to ego-depletion and the results from Experiment 1.

The follow up model using MSBS factor scores as predictors was not significant, $F(5,52)=1.61$, $p=.174$, $R^2=.134$. However, there was a trend for high arousal to be a significant unique predictor of the number of correctly solved anagrams, $B=-0.31$, $p=.071$. As high arousal increased, the number of correctly solved anagrams decreased. No other factor was a significant unique predictor (disengagement, $B=-0.04$, $p=.739$; low arousal, $B=0.08$, $p=.524$; inattention, $B=0.10$, $p=.521$; time perception, $B=0.03$, $p=.766$).

Time-on-task. Inspection of the residuals revealed the normality assumption to be violated, $W=0.93$, $p=.003$. Outlier removal ($n=1$) did not resolve issues with normality, nor did transforming the data. The untransformed data were therefore analyzed. MSBS was not a significant predictor of time-on-task, $F(1,56)=2.76$, $p=.102$, $R^2=.047$. Although not significant, increased boredom was associated with worse self-control performance at T2 consistent with the analysis of the number of correctly solved anagrams.

The follow up model using MSBS factor scores as predictors was not significant, $F(5,52)=1.40$, $p=.241$, $R^2=.118$. No factor score was a unique predictor of time-on-task (disengagement, $B=-0.03$, $p=.784$; low arousal, $B=0.16$, $p=.162$; high arousal, $B=-0.17$, *p*=.307; inattention, *B*=-0.02, *p*=.913; time perception, *B*=-0.13, *p*=.205).

Fatigue. Inspection of the residuals revealed the normality assumption to be violated, *W*=0.95, *p*=.022. No outliers were identified and transforming the data did not resolve issues with normality. Therefore, the untransformed data were analyzed. MSBS was not a significant predictor of self-reported fatigue, $F(1,57)=0.62$, $p=.434$, $R^2=.012$. While not significant, the slope of this model is consistent with the analysis from the number of correctly solved anagrams where increased boredom is associated with worse self-control performance.

The follow up model using MSBS factor scores as predictors was not significant, $F(5,53)=1.74$, $p=.141$, $R^2=.141$. However, there was a trend for time perception to be a significant unique predictor, *B*=-0.05, *p*=.084. As time perception increased, it was associated with a decrease in self-reported fatigue at T2. No other factor was a significant predictor of fatigue (disengagement, *B*=0.02, *p*=.402; low arousal, *B*=-0.05, *p*=.118; high arousal, *B*=0.04, *p*=.358; inattention, *B*=0.03, *p*=.508).

Discussion

Experiment 3 sought to test the hypothesis that increasing the frequency of responding during the task at T1 (i.e., 80:20 ratio of Go to No-Go trials) would increase endogenous demand to stay on task when bored thereby resulting in worse self-control at T2. Consistent with predictions, greater state boredom at T1 was predictive of worse anagram task performance at T2. High arousal negative affect (e.g., “I feel impatient”) was found to be a marginally unique predictor of anagram performance. Higher arousal at T1 was predictive of worse anagram performance at T2, replicating the findings from Experiment 1 whereby increased high arousal was predictive of less time spent on the anagram task before quitting. Unlike Experiment 1, time perception at T1 was found to be a marginally unique predictor of fatigue at T2 in the opposite direction. The slope of the relationship indicated that as time was perceived to slow down, it was associated with a decrease in self-reported fatigue.

Unlike Experiments 1 and 2, state boredom was associated with Go/No-Go task performance. This finding is consistent with previous research on boredom and sustained attention (e.g., Thackray et al., 1977; Hunter & Eastwood, 2018). Increased response times are argued to reflect increasing disengagement from the task with increasing boredom (Eastwood et al., 2012). Decrements in sustained attention performance have been attributed to increased decrements in self-regulation which fails to keep attention on the task with time-on-task (Luna et al., 2022; Thompson et al., 2015). Therefore, this finding is consistent with our prediction that increasing the frequency of Go responses would place increased demands on self-control in the face of boredom. If anything, the finding of increased boredom leading to decrements in performance at T1 is evidence that self-control was failing for some of the individuals who were highly bored. If so, then this would explain why the relationship between boredom and self-control was numerically smaller in Experiment 3 than in Experiment 1.

General Discussion

There has been substantial debate about the replicability of the ego-depletion effect. One recuring criticism of these replication failures is that studies are using inappropriate operationalizations of self-control in the sequential-task paradigm (Baumeister & Vohs, 2016; Cunningham & Baumeister, 2016; Dang, 2016; Lurquin & Miyake, 2017). For instance, studies often manipulate task difficulty instead of the inhibition of a pre-potent response (e.g., Hagger et al., 2016). A specific concern raised by Wolff and Martarelli (2020) is that manipulations of self-control using differences in task difficulty may be confounded with boredom. According to this account, some failures to observe ego-depletion in the sequential task paradigm may arise because the simple, but boring tasks used in the control condition require self-control to stay on-task. The present study investigated this claim across three experiments by assessing whether self-reported state boredom measured after a simple Go/No-Go task at T1, predicted subsequent self-control performance in the sequential-task paradigm. This approach permitted assessing the role of boredom independent of task complexity / difficulty and measured state boredom as a multi-dimensional construct. Each experiment varied the proportion of Go to No-Go trials to assess how the properties of the boring task at T1 influenced the association between boredom and self-control.

In Experiment 1, when the Go/No-Go task at T1 had a 50:50 ratio of Go to No-Go trials, it was found that increased boredom at T1, was associated with fewer correctly solved anagrams and greater self-reported fatigue at T2. These outcomes are consistent with the claim that experiencing boredom while maintaining attention on a simple task can lead to ego-depletion. Indeed, poor performance on anagram solving tasks (see Hagger et al., 2010) and fatigue are considered important indications of the presence of ego-depletion (Baumeister & Vohs, 2016).

Experiment 2 extended the findings from Experiment 1. In Experiment 2 the proportion of trial type was changed so that there was a 20:80 ratio of Go to No-Go trials. It was predicted that decreasing target frequency would decrease the exogenous attentional support offered by the task, consequently increasing the deleterious impact of boredom on later self-control. Contrary to predictions, greater state boredom at T1 was associated with *better* self-control performance at T2. Specifically, increased boredom at T1 was predictive of more correctly solved anagrams at T2. Further, although not significant, the same pattern was observed for self-reported fatigue, desire to quit, and time spent on the anagram task before quitting. Therefore, boredom appeared to have a "therapeutic" effect on later self-control when the frequency of responding was low. This is the opposite of our prediction that reducing the responding would increase the deleterious effects of boredom.

Experiment 3 tested the hypothesis that increasing the frequency of Go trials would increase endogenous demand to stay on task when bored. In Experiment 3 when the Go/No-Go task at T1 had an 80:20 ratio of Go to No-Go trials, it was found that as boredom increased at T1, it was associated with fewer correctly solved anagrams. The same pattern was observed, although not significant, between boredom at T1, self-reported fatigue, and time spent on the anagram task at T2 before quitting. These findings were consistent with predictions.

The observation of a significant relationship between state boredom at T1 and ego-depletion in each experiment provides strong evidence that boredom affects ego-depletion. Counter to Wolff and Martarelli's (2020) initial hypothesis, the effects of boredom do not always lead to ego-depletion and may in certain contexts be restorative. Below I speculate about the conditions that determine the nature of the relationship between boredom and ego-depletion.

On The Relationship Between Boredom and Ego-Depletion

Experiments 1 – 3 evoked boredom at T1 using a simple Go/No-Go task. The Experiments differed only in the ratio of Go to No-Go trials. In Experiment 1 the ratio was 50:50, in Experiment 2 the ratio was 20:80 and in Experiment 3 it was 80:20. Despite seeming trivial, this change in task properties yielded qualitative changes in the relationship between state boredom and self-control. Here, I consider several different explanations for the change in the relationship between boredom and self-control. First, I will consider a quantitative account of this relationship. I will then consider two qualitative accounts.

One possibility for the changing relationship between boredom and self-control is that changing the ratio of Go to No-Go trials changed how bored participants were at T1. For instance, high levels of boredom have deleterious effects on task performance, whereas low levels of boredom may be more manageable and may in fact motivate participants to try harder during the experiment. There are two findings inconsistent with this account. First, there is no evidence of a curve-linear relationship between boredom and ego-depletion in any of the three experiments. Given that there was a large range of individual differences in boredom within each experiment (Experiment 1, $MSBS_{range}$ = 33-181; Experiment 2, $MSBS_{range}$ = 40-156, Experiment 3, $MSBS_{range}$ = 40-176) there should have been evidence of a curvilinear relationship whereby increases in boredom were associated with better self-control for participants who reported low levels of boredom (and vice versa for participants who reported high levels of boredom). This relationship between boredom and self-control, however, was not observed within experiments. Second, there is no evidence of a difference in state boredom across the three experiments measured using the MSBS total score, $F(2,169)=0.05$, MSE=

1147.618, p=.954. Therefore, the properties of the tasks at T1 did not change the level of boredom induced between tasks but did change the relationship between boredom and self-control.

A second possibility is that the ratio of Go to No-Go trials yielded qualitative changes in the nature of the boredom experienced at T1 due to the number of response changes. When the ratio of trials is 50:50, the probability of exhibiting the same behaviour on trial N and trial N+1 is 50%. Given the high likelihood of changing one's behaviour on each trial (respond vs. do not respond), an individual would have to sustain attentional engagement on the task to maintain an overall high level of accurate responding. In contrast, when the ratio of trials is 20:80 or 80:20, the probability of changing your response from trial N to trial N+1 is only 20%. This means that accurate responding could be achieved by adopting a bias towards a single response. This could lead to increased passivity and disengagement during the task at T1. This account is inconsistent with the current findings. If the probability of behavioural changes on the succeeding trials changed the nature of boredom experienced, then the outcome of boredom and self-control should be consistent across Experiments 2 and 3 where the probability of changing your response during the task at T1 in both experiments was 20%. However, opposite associations were found across Experiments 2 and 3, whereby greater boredom at T1 lead to greater self-control at T2 in one case but not the other. Therefore, it is unlikely that the number of behavioural changes altered the nature of boredom experienced during the Go/No-Go task.

A third possibility is that the nature of boredom is affected by the frequency of responding. A "higher" proportion of Go trials requires that the participant sustain attentional engagement on the task because they need to regularly respond within a limited time-window. According to this account, though it is true that the Go/No-Go task provides minimal exogenous support for keeping attention focussed (Eastwood et al., 2012; Scerbo, 1998), the ratio of Go to No-Go trials affects whether self-control is required to sustain attentional engagement. When Go trials are frequent, self-control is required to inhibit the desire to disengage from the current task in the face of boredom so that accurate responses can be made within the limited time-window. In contrast, when Go trials are infrequent (Experiment 2), self-control is not required to maintain task engagement in the face of boredom because good task performance does not require responding. Therefore, when the Go trials are infrequent, less self-control is used to overcome the prepotent desire to disengage from the task. Additionally, without a requirement for regular responses from the participant, they can disengage from the task to pursue more satisfying or fulfilling activities (Bench & Lench, 2013; Eastwood et al., 2012) such as mind-wandering (Danckert & Merrifield, 2016) without harming task performance (Hitchcock et al., 1999). Therefore, the combination of spending less effort to stay on task and allowing engagement to be satisfied outside of the task may have the consequence of being restorative or “therapeutic” to self-control.

Consistent with the frequency of responding affecting the nature of boredom, high arousal negative affect (e.g., “I feel impatient”; Fahlman et al., 2013) was found to be a unique, negative predictor of self-control when the tasks administered at T1 required frequent responding (Experiments 1 and 3). High arousal is argued to increase during boredom as an individual attempts to bolster attentional processes to engage with the task (Danckert et al., 2018; Eastwood et al., 2012; Gerritsen et al., 2014). Therefore, the unique relationship between greater high arousal at T1 and worse self-control at T2 in Experiments 1 and 3, may reflect the increased need for self-control associated with the task.

In Experiment 2, however, when responding was less frequent, low arousal (e.g., "I feel empty"; Fahlman et al., 2013) was found to be a unique predictor of better self-control. Arousal is hypothesized to lower during the beginning stages of boredom in response to the under stimulation and monotony of the current situation (Danckert et al., 2018). Low arousal during boredom is argued to precursor the pursuit of other more engaging and satisfying activities (Bench & Lench, 2013; Van Tilburg & Igou, 2011). It is possible that engagement was satisfied via mind-wandering during the task at T1 (Danckert & Merriefield, 2016), which concurrently restored depleted resources. Such an explanation would be consistent with the strength model of self-control. Alternatively, the experience of low arousal may not have changed T1 behaviour but instead motivated engagement during the relatively more interesting T2 task, resulting in better performance. Such an explanation would be consistent with cost/benefit models of self-control (Inzlicht & Schmeichel, 2012, Inzlicht et al., 2014; Kurzban, 2016; Kurzban et al., 2013) or even Baumeister's conservation hypothesis (Baumeister & Vohs, 2018). Regardless, the unique predictive relationship between increased low arousal and better self-control is therefore consistent with the suggestion that satisfying engagement outside of a boring task may benefit later self-control performance.

The present study's observations suggest that not only is the experience of boredom multifaceted, but these dimensions of experienced boredom may have qualitatively different consequences for self-control. Consistent with this idea, an experience sampling study by Goetz and colleagues (Goetz et al., 2014) found evidence of different types of experienced boredom (i.e., indifference, apathetic, calibrating, searching, and reactant). These distinct experiences were all reported as boredom but were found to vary in their level of arousal and valence. Further, differences in experienced boredom were associated with the kinds of tasks being completed. For instance, negatively valenced, high arousal types of boredom were found to be associated with tasks that offered less agency to explore alternative avenues for engagement (e.g., listening in class), whereas positively valenced, low arousal boredom types were reported to be the most prevalent during tasks that offered greater agency (e.g., shopping). Therefore, tasks that enabled the opportunity for engagement to be satisfied outside of the task were still reported as boring relative to those lacking in agency, but the underlying experience and consequences of that boredom differed by context. This evidence, taken together with the findings from the current study, supports the idea that there may be distinct experiences and psychological consequences of boredom that are induced under different tasks.

The notion that boredom can lead to either better or worse self-control suggests that manipulating intrinsic task demand may not be sufficient for ego-depletion to be observed in the sequential-task paradigm. Rather than providing an adequate baseline for comparison, simple control tasks may demand more self-control than initially intended, or even benefit later performance depending on the properties of the task. Therefore, manipulations that differ the intrinsic demands of a task to induce ego-depletion are insufficient, as difficult tasks do not exclusively effect self-control. This suggestion is consistent with the concerns raised by Baumeister and colleagues that many of the failures to replicate ego-depletion do not create the appropriate conditions for ego-depletion to occur (Cunningham & Baumeister, 2016; Baumeister & Vohs, 2016). Consequently, closer attention must be paid to understanding which procedures are effective manipulations of self-control.

Future Directions

Converging evidence supports the link between boredom and self-control. High boredom proneness has been related to both poor self-control (Isacescu & Danckert, 2018) and executive dysfunction (Gerritsen et al., 2014). This prior research suggests that frequent failures to engage attention are mainly due to limitations in mechanisms involved in self-regulation. This previous research posits that all individuals experience boredom in a uniform way. The present study extends on previous research and suggests that experiencing boredom while completing a task does not necessitate later self-control deficiencies. Rather, the outcome of boredom on later deficits in self-control is dependent on whether the properties of the boring task demand self-control to stay on task to maintain high performance. These findings suggest that boredom is not a unitary experience. It is, therefore, possible that there also exist individual differences in the type of boredom experienced. Further research is needed to validate this possibility.

Although the current investigation is not the first to examine the link between boredom and self-control, it is the first to show that the impact of boredom on self-control changes depending on the properties of the task used to induce boredom. Further, given current concern regarding the replicability of the ego-depletion phenomenon (e.g., Carter et al., 2015; Hagger et al., 2016) and the unexpected finding from Experiment 2, future research should seek to replicate the findings from the current experiments. Furthermore, much of the previous research relating the impact of task properties and boredom have focussed on responding as serving as an external support for keeping attention focussed (Eastwood et al., 2012). The present research provides an alternative avenue of research investigating the role of responding as an endogenous demand. Future research could test how frequency of responding changes the endogenous demand required by the task and how this impacts self-control. For instance, research could examine whether different aspects of subjective (Bambrah et al., 2019; Hsu et al., 2017) or objective effort (André et al., 2020) when responding is frequent or infrequent predicts later performance on a self-control task. The unique contribution of arousal on self-control may also offer an interesting avenue for future investigations.

Conclusions

To conclude, the present investigation found that greater state boredom led to worse self-control at T2 when responding on the boring Go/No-Go task at T1 was frequent. However, better self-control at T2 was observed when responding was infrequent during the T1 task. These findings have implications for theories of boredom and ego-depletion research. The former suggests that the phenomenology and related psychological consequences of boredom may be different depending on the properties of the boring task. The latter suggests that manipulations of task difficulty may not be sufficient for ego-depletion to be observed because self-control is impacted by simple control tasks.

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Appendix 1

Multidimensional State Boredom Scale (MSBS)

Fahlman, S. A., Mercer-Lynn, K. B., Flora, D. B., & Eastwood, J. D. (2013). Development and validation of the Multidimensional State Boredom Scale. *SAGE, 20*(1), 68-85. Doi: 10.1177/1073191111421303

Please respond to each question indicating how you feel right now about yourself and your life, even if it is different from how you usually feel.

	Strongly Disagree						Strongly Agree
Time is passing by slower than usual.	1	2	3	4	5	6	7
I am stuck in a situation that I feel is irrelevant.	1	2	3	4	5	6	7
I am easily distracted.	1	2	3	4	5	6	7
I am lonely.	1	2	3	4	5	6	7
Everything seems to be irritating me right now.	1	2	3	4	5	6	7
I wish time would go by faster.	1	2	3	4	5	6	7
Everything seems repetitive and routine to me.	1	2	3	4	5	6	7
I feel down.	1	2	3	4	5	6	7
I seem to be forced to do things that have no value to me.	1	2	3	4	5	6	7
I feel bored.	1	2	3	4	5	6	7
Time is dragging on.	1	2	3	4	5	6	7
I am more moody than usual.	1	2	3	4	5	6	7
I am indecisive or unsure of what to do next.	1	2	3	4	5	6	7

I feel agitated.	1	2	3	4	5	6	7
I feel empty.	1	2	3	4	5	6	7
It is difficult to focus my attention.	1	2	3	4	5	6	7
I want to do something fun, but nothing appeals to me.	1	2	3	4	5	6	7
Time is moving very slowly.	1	2	3	4	5	6	7
I wish I was doing something more exciting.	1	2	3	4	5	6	7
My attention span is shorter than usual.	1	2	3	4	5	6	7
I am impatient right now.	1	2	3	4	5	6	7
I am wasting time that would be better spent on something else.	1	2	3	4	5	6	7
My mind is wandering.	1	2	3	4	5	6	7
I want something to happen but I'm not sure what.	1	2	3	4	5	6	7
I feel cut off from the rest of the world.	1	2	3	4	5	6	7
Right now it seems like time is passing slowly.	1	2	3	4	5	6	7
I am annoyed with the people around me.	1	2	3	4	5	6	7
I feel like I'm sitting around waiting for something to happen.	1	2	3	4	5	6	7
It seems like there's no one around for me to talk to.	1	2	3	4	5	6	7

Appendix 2

Trait Self-Control

Tangney, J. P., Baumeister, R. F., & Boone, A. L. (2004). High self-control predicts good adjustment, less pathology, better grades, and interpersonal success. *Journal of Personality*, *72*(2), 271–324

Using the scale provided, please indicate how much each of the following statements reflects how you typically are.

	Not at All				Very Much So
1. I am good at resisting temptation	1	2	3	4	5
2. I have a hard time breaking bad habits	1	2	3	4	5
3. I am lazy	1	2	3	4	5
4. I say inappropriate things	1	2	3	4	5
5. I never allow myself to lose control	1	2	3	4	5
6. I do certain things that are bad for me if they are fun	1	2	3	4	5
7. People can count on me to keep on schedule	1	2	3	4	5
8. Getting up in the morning is hard for me	1	2	3	4	5
9. I have trouble say no	1	2	3	4	5
10. I change my mind fairly often	1	2	3	4	5
11. I blurt out whatever is on my mind	1	2	3	4	5
12. People would describe me as impulsive	1	2	3	4	5
13. I refuse things that are bad for me	1	2	3	4	5
14. I spend too much money	1	2	3	4	5
15. I keep everything neat	1	2	3	4	5

16. I am self indulgent	1	2	3	4	5
17. I wish I had more self discipline	1	2	3	4	5
18. I am reliable	1	2	3	4	5
19. I get carried away by my feelings	1	2	3	4	5
20. I do many things on the spur of the moment	1	2	3	4	5
21. I don’t keep secrets very well	1	2	3	4	5
22. People would say that I have iron self-discipline	1	2	3	4	5
23. I have worked or studied all night at the last minute	1	2	3	4	5
24. I’m not easily discouraged	1	2	3	4	5
25. I’d be better off if I stopped to think before acting	1	2	3	4	5
26. I engage in healthy foods	1	2	3	4	5
27. I eat healthy food	1	2	3	4	5
28. Pleasure and fun sometimes keep me from getting work done	1	2	3	4	5
29. I have trouble concentrating	1	2	3	4	5
30. I am able to work effectively toward long term goals	1	2	3	4	5
31. Sometimes I can’t stop myself from doing something even if I know it is wrong	1	2	3	4	5
32. I often act without thinking through all the alternatives	1	2	3	4	5
33. I lose my temper too easily	1	2	3	4	5
34. I often interrupt people	1	2	3	4	5
35. I sometimes drink or use drugs to excess	1	2	3	4	5
36. I am always on time	1	2	3	4	5

Appendix 3

Fatigue and Desire to Quit

Please circle the number that relates the most to you on a scale from 1 to 5.

	Not at All				Very Much So
Compared to the beginning of the experiment, how tired do you feel right now?	1	2	3	4	5
Compared to how you felt at the beginning, how much do you want to quit the experiment?	1	2	3	4	5

Appendix 4

Solvable Anagram Task

For this part of the experiment, you are asked to complete a series of anagrams. Anagrams are strings of letters that you must unscramble to form into English words.

You can complete as few or as many anagrams as you would like and can quit the task at ANY time. Click the 'continue' when you are done, and it will bring you to the next questionnaire.

tdoisue outside	mbnuer number	dsyledun suddenly	ftreah father	nceods second	eealv leave
ounrd round	tressi sister	jmduep jumped	ifsednr friends	ardoun around	ichrdnle children
atptirnom important	ssetemoim sometimes	tnerdeiff different	yonug young	etgreoth together	nirgdu during
rdegna garden	ughbtro brought	eowkn woken	ndoepe opened	olilofngw following	nlboloa balloon
anlima animal	hrdbtaiy birthday	iwngmism swimming	etneewb between	gmnonir morning	hltgi light