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Self-control contributions to university students' neuroenhancement behaviour

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Self-Control Contributions to University Students' Neuroenhancement Behaviour

by

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ABSTRACT

Students' use of substances with the intent to enhance cognitive and/or academic functioning (referred to as "neuroenhancement") has received increased academic attention in recent years. However, additional research regarding individual differences that increase risk of engagement in neuroenhancement is needed. Across three studies (total $N = 410$), the current dissertation sought to broaden the extant work in this area by investigating one candidate mechanism for university students' engagement in neuroenhancement: self-control.

In Study 1, associations of lifetime engagement in various modes of neuroenhancement (e.g., "legal neuroenhancement" using legal substances such as caffeine, over-the-counter substances, and nicotine; neuroenhancement using illicit drugs; and neuroenhancement via non-medical use of prescription stimulants [NMUPS] and other prescription drugs) with trait self-control (as measured via a multi-method approach) were investigated. Results demonstrated an association of self-control with neuroenhancement broadly, but demonstrated a differential pattern of associations of multivariate self-control across the various modes of neuroenhancement. Thus, this study highlighted poor self-control as an important characteristic of students who engage in neuroenhancement broadly and emphasized the importance of differentiating substance-specific classes of neuroenhancement.

Study 2 sought to investigate the impacts of state self-control depletion on neuroenhancement outcomes (i.e., willingness to engage in neuroenhancement, self-reported likelihood of future engagement in neuroenhancement behaviour). Participants were randomly-assigned to complete either a purportedly "self-control-depleting" or non-

depleting condition of a well-established experimental paradigm (Baumeister et al., 1998). Although *trait* self-control was inversely related to intent to engage in neuroenhancement, the study failed to demonstrate an effect of *state* self-control depletion on neuroenhancement (operationalized as attitudes and future neuroenhancement intent).

Finally, Study 3 investigated self-control as a potential contributing factor to the previously-demonstrated association of poor academic functioning with engagement in NMUPS. As a secondary aim, this study also compared this association across NMUPS history variables derived across two time-frames (i.e., dichotomous coding of lifetime and past 30-day history of NMUPS) and two measurement methods (i.e., 30-day NMUPS history, as measured via a single question vs. through an adapted timeline follow-back approach). Although the pattern of associations varied across models, self-control and GPA both contributed to the statistical prediction of neuroenhancement history. In the case of past 30-day history (measured dichotomously), associations of GPA with neuroenhancement were fully accounted for by self-control. Interestingly, timeline follow-back measurement of NMUPS was associated with neither GPA nor the self-control variables.

Across these three studies, variations in self-control were demonstrated to be associated with students' engagement in substance use for cognitive enhancement purposes. Findings are discussed in the context of the Drug Instrumentalization Theory (Mueller & Schumann, 2011) and existing models of neuroenhancement as a behaviour aimed at self-medication of undiagnosed or subclinical cognitive symptoms (e.g., inattention). Implications for assessment of neuroenhancement are also discussed.

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LIST OF ABBREVIATIONS

ADHD	Attention-deficit/hyperactivity disorder
ADT	Academic Diligence Task
AUC	Area under the curve
BAARS-IV	Barkley Adult ADHD Scale – Fourth Edition
BFI	Big Five Inventory
BIS-11	Barratt Impulsiveness Scale – 11
DDT	Delay discounting task
GPA	Grade point average
NMUPS	Non-medical use of prescription stimulants
RT	Reaction time
SCS	Self-Control Scale
THC	Δ^9-tetrahydrocannabinol
TLFB	Timeline follow-back
TPS	Tuckman Procrastination Scale
UPPS-P	Urgency, Premeditation, Perseverance, Sensation Seeking, Positive Urgency

I. LITERATURE REVIEW

Humans have a profound capacity to plan, organize, and monitor their thoughts, emotions, and behaviour in order to bring themselves closer to desired long-term goals. This capacity is particularly critical in the university setting, where students are faced with the need to manage both academic and social demands on their time. In such a setting, self-control is crucial for success; however, self-control is subject to variation between individuals, such that some individuals possess less capacity to exert self-control across situations (Tangney, Baumeister, & Boone, 2004). Moreover, it has been suggested that self-control is subject to depletion, and therefore may not be available when needed (Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Vohs, & Tice, 2007; Baumeister, Gailliot, DeWall, & Oaten, 2006; Inzlicht, Berkman, Elkins-Brown, & Inzlicht, 2015; Inzlicht & Schmeichel, 2012; Maples-Keller, Berke, Miller, & vanDellen, 2016). Given the importance of self-control for success in the university setting (Duckworth & Seligman, 2005), it is unsurprising that emerging evidence suggests students have increasingly sought alternative methods for supplementing one's self-control when it has been exhausted (Englert & Wolff, 2015), often incurring considerable personal risk in the process (Clauson, Shields, McQueen, & Persad, 2008; Greenhill et al., 2002; Volkow & Swanson, 2003).

This dissertation comprises a set of studies that collectively seeks to examine associations of self-control with one such specific constellation of risky behaviours known as "neuroenhancement", defined as the use of one or more substances with the intent to bolster one's cognitive functioning or otherwise maximize academic performance (Eickenhorst, Vitzthum, Klapp, Groneberg, & Mache, 2012). As such, this

chapter reviews extant literature related to self-control—including its manifestations as both a source of inter-individual and intra-individual variation and its theoretical, neurophysiological, and developmental foundations—and provides a framework for investigating the relations of this important dimension to the neuroenhancement construct.

Self-Control

Defining Self-Control

Although self-control clearly represents an important human function, there is considerable disagreement regarding the specific parameters of the self-control construct (de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012). Condensing across disparate definitions, however, the literature generally suggests that self-control represents an individual's ability to inhibit or modulate his or her current cognition, emotions, or behavioural impulses in favor of bringing himself or herself closer to a desired future state (Baumeister, 2013; Duckworth & Kern, 2011; Tangney, Baumeister, & Boone, 2004). This valued end state is informed by the individuals' internalization of societal norms, legal and ethical standards, and his or her own values and goals (Baumeister, 2013).

Dispositional vs. state self-control. Self-control research has consistently demonstrated that self-control varies between individuals. It has also been proposed that self-control varies within individuals (e.g., following self-control "exertion"). Thus, prominent views allow for conceptualization of self-control as both a dispositional and state-specific construct. It therefore follows that low levels of either trait or state self-

control may lead to self-regulatory failure (Baumeister, Bratslavsky, Muraven, & Tice, 1998).

Dispositional self-control (or "trait self-control") refers to an individual's *general* capacity to exert self-control. Several studies have demonstrated that dispositional self-control varies across individuals, with some people generally displaying better self-control than others (Tangney et al., 2004); however, within the individual, dispositional self-control remains relatively invariant over time/across development (Hay & Forrest, 2006; Mischel, Shoda, & Peake, 1988) and predicts outcomes across a range of functional domains (de Ridder et al., 2012; Tangney et al., 2004).

Though self-control varies between persons, it has also been suggested that an individual's level of self-control is subject to influence by environmental, motivational, and situational factors (de Ridder et al., 2012); for example, a wealth of studies conducted across multiple independent labs has supported the notion that an individuals' ability to enact self-control may dwindle following exertion of self-control (e.g. Baumeister, Gailliot, DeWall, & Oaten, 2006; DeWall, Baumeister, Gailliot, & Maner, 2008; DeWall, Baumeister, Stillman, & Gailliot, 2007; Hagger & Chatzisarantis, 2013; Muraven, Tice, & Baumeister, 1998; Post, Boyer, & Brett, 2006; Tuk, Zhang, & Sweldens, 2015; Tyler & Burns, 2009); conversely, in this model, one may be less susceptible to self-control depletion after systematic "practice" of willpower exertion (Baumeister, Gailliot, DeWall, & Oaten, 2006; Oaten & Cheng, 2006) or following glucose intake (Gailliot et al., 2007; Gailliot & Baumeister, 2007; Hagger & Chatzisarantis, 2013).

Although significant debate remains regarding the replicability of this "self-control depletion effect" (e.g. Baumeister & Vohs, 2016; Hagger & Chatzisarantis, 2016; discussed in greater detail below), there does exist a large body of evidence supporting the supposed "depletability" of self-control resources. Thus, although overall levels of self-control tend to be relatively stable within the individual over time, one prominent view suggests that the availability of self-control resources to the individual at any given time may be subject to external and internal influences. As a result, state levels of self-control may vary situationally within the parameters dictated by the individuals' trait self-control level.

Self-control vs. impulsivity. In defining self-control, this construct may be differentiated from several other intimately-related, yet distinct constructs. For example, it has been argued that self-control and the construct of impulsivity constitute overlapping yet discrete aspects of human behavioural functioning (Duckworth & Kern, 2011; Kalenscher, Ohmann, & Güntürkün, 2006; Tangney et al., 2004). Impulsivity is a multifactorial construct comprising both cognitive/behavioural (e.g., failure to plan ahead, difficulties regulating attention, acting without forethought) and emotional features (affective dysregulation, sensation-seeking, and pursuit of risky behaviours; Knezevic, 2013). Generally, impulsivity is thought to result from lower-level or "bottom-up" cognitive processes. It has been suggested, therefore, that impulsivity is conceptually distinct from self-control, which reflects the tendency to employ top-down cognitive processes to inhibit these impulses (Duckworth & Kern, 2011).

Consistent with this view of impulsivity and self-control as separable yet interrelated constructs, impulsivity appears to be distinct from self-control on a

neurophysiological level; while impulses appear to originate from the activation of primarily subcortical regions such as the basal ganglia, amygdala, and lateral temporal lobe cortex (Lieberman, 2007), tasks requiring exertion of self-control have been shown to activate primarily frontocortical regions of the brain, such as the lateral orbitofrontal cortex (Horn, Dolan, Elliott, Deakin, & Woodruff, 2003). Thus, although they represent distinct constructs, self-control and impulsivity may be viewed as opposing processes which interact to produce expression or inhibition of a cognitive, emotional, or behavioural impulse. However, it should be noted that, though it is not precisely accurate to consider impulsivity and self-control as opposite ends of a single dimension, these constructs are at times treated as such (e.g., measures of trait impulsivity are frequently employed as measures of self-control; Duckworth & Kern, 2011).

Self-control vs. self-regulation. There has also been some disagreement between authors regarding whether self-control and self-regulation are synonymous. At times, some have discussed self-control as a component of the broader process of self-regulation. Self-regulation has been argued to represent a much broader construct which includes both self-control and the capacity to regulate other states (e.g., homeostasis) outside of conscious awareness (Hagger, Wood, Stiff, & Chatzisarantis, 2010). In a slightly different interpretation of the construct, de Ridder and colleagues (2012) state that "self-control focuses on the efforts people exert to stimulate desirable responses and inhibit undesirable responses, and that self-control thereby *constitutes an important prerequisite for self-regulation*" (p. 77; emphasis added). Although both of these accounts suggest that these constructs are apparently separate, these terms are often in

practice used interchangeably (Baumeister et al., 2007; Duckworth & Kern, 2011; Kotabe & Hofmann, 2015; Tangney et al., 2004).

Neurodevelopmental Contributions to Self-Control

In order for an individual's level of state and trait self-control to be fully understood, it must be situated in its appropriate neurodevelopmental context. This section aims to briefly review the existing research investigating the development of self-control.

Initial indicators of development of neural mechanisms for self-control are apparent in early childhood (Fox & Calkins, 2003; Posner & Rothbart, 2000; Rueda, Posner, & Rothbart, 2005). For example, as early as approximately 30 months post-partum, children demonstrate the ability to exert inhibitory control on a developmentally-modified version of the Stroop task (Posner & Rothbart, 2000). Additionally, although infants can engage in some simple forms of inhibition of behaviour (Garon, Bryson, & Smith, 2008), children gain an increased ability to modulate and inhibit their behavioural impulses in toddlerhood and throughout the preschool years (Fox & Calkins, 2003). Effortful control of one's attention to relevant internal and external stimuli has been found to increase throughout the preschool years and beyond, with continued development seen into adulthood (Fox & Calkins, 2003); thus, what may appear to be impaired self-control relative to adult-general norms may in fact be normative in the context of childhood, adolescence, and even emerging adulthood.

The developmental progression of self-control has been demonstrated to coincide with observed maturation of the frontolimbic regions of the brain (Casey, Jones, & Hare, 2008). However, it must be noted that portrayal of an overall pattern of development and

greater functionality of these areas ignores discrepant developmental trajectories for the involved regions. For example, development of the corresponding subcortical regions of the limbic system responsible for affectivity and reward responsiveness does not necessarily proceed in concert with development of the frontal regions that are responsible for inhibiting these affective, behavioural, and cognitive impulses (Casey et al., 2008). The discordant developmental trajectories of these two regions can result in the emotionality and greater propensity for sensation-seeking and risk-taking often noted in adolescence.

Although this evidence points to a typical pattern of neurobiological progression for the development of self-control, such a model (if universally-applied) fails to account for the variation between individuals, particularly same-age peers (Casey et al., 2008; Fox & Calkins, 2003; Romer, Duckworth, Sznitman, & Park, 2010). It has been suggested that self-control develops as a result of transactional relations between a child's neurobiological development (which may, at baseline, vary from that of peers) and factors such as a child's temperament, parental warmth and control, and the parental scaffolding and modeling of behavioural, cognitive, and affective regulation (Casey et al., 2008; Fox & Calkins, 2003).

Thus, self-control appears to develop as part of a complex interchange between neurobiological and environmental processes, with different self-control-related skills coming "on line" at different points in development. As such, there are points in development (e.g., adolescence and young adulthood) during which a somewhat lower level of self-control and a somewhat higher level of impulsivity is relatively normative. However, recall that there is considerable inter-individual variation in self-control

capacity, even within university-age young adults. As such, some students may possess the requisite self-control abilities to balance competing requirements of academic, familial, extracurricular, and social obligations. By contrast, others may be unable to keep up with such diverse demands.

Theories of Self-Control

In light of the complexities of the self-control construct, multiple attempts have been made to construct a theoretical framework explaining self-control, its mechanisms of operation, sources of inter- and intra-individual variation, and the sequelae of both high and low levels of the construct. According to de Ridder and colleagues (2012), theories of dispositional self-control can broadly be classified into three categories: (1) those positing a "*discounting model of impulsiveness"*, (2) "*hot-cool system approaches"*, and (3) the *"self-regulatory strength model of self-control"* (p. 78). Briefly reviewed here are major perspectives espoused within each of these accounts on self-control.

Discounting models. The first class of theories of self-control proposed by de Ridder and colleagues (2012) encompasses some of the most well-known and most thoroughly-researched notions of self-control in the social sciences. These models (e.g. Ainslie, 1975; Gottfredson & Hirschi, 1990; Mischel, Shoda, & Peake, 1988) define self-control as the capacity to delay immediate gratification in favor of more important longer-term gains. Thus, self-control failure occurs when individuals de-value (or "discount") more valuable future outcomes in favor of less valuable yet more immediate outcomes.

Gottfredson and Hirschi's (1990) Self-Control Theory. A chief model that includes a discounting component was put forth in the late twentieth century by criminologists Gottfredson and Hirschi (1990). In their theory, these authors propose that criminal deviance can be wholly accounted for by low self-control, and that self-control is expressed in six "elements". These elements include: (1) "a concrete here and now orientation", or a tendency to favor immediate gratification over rewarding stimuli obtained after a delay; (2) "lack [of] diligence, tenacity, or persistence in a course of action", again reflecting a preference for immediate gratification over rewards which require effort in their attainment; (3) tendency to be "adventuresome, active, and physical" and (4) "indifferent, or insensitive to the suffering or needs of others"; (5) the tendency to "have minimal tolerance for frustration" and (6) "little ability to respond to conflict through verbal rather than physical means" (pp. 89-90). While the focus of these authors' work was primarily on the mechanisms for criminal behaviour, they additionally assert that low self-control is also related to a range of suboptimal yet non-criminal outcomes (e.g., alcohol and tobacco use, gambling, risky sex).

Gottfredson and Hirschi (1990) suggest that these elements tend to co-occur in individuals—an assertion echoed by more recent work; indeed, subsequent theorists have suggested that the tendency of these six traits to converge indicates that self-control is a single, unidimensional construct reflecting discounting of delayed rewards in a preference for smaller, more immediate rewards (Grasmick, Tittle, Bursik, & Arneklev, 1993). Of note, however, other authors have alternately suggested that the six elements of Gottfredson and Hirschi's (1990) model constitute individual constructs, reflecting a

multidimensional structure of the self-control trait (e.g., Arneklev, Grasmick, & Bursik, 1999; Vazsonyi, Pickering, Junger, & Hessing, 2001).

Hot/cool cognition. A second class of self-control-related theories is that comprising "hot/cool cognition" approaches (de Ridder et al., 2012). These models (e.g. Loewenstein, 1996; Mischel, Shoda, & Rodriguez, 1989) consider self-control to be a component of a rational, higher-order cognitive network that works to regulate behaviour in line with the organism's long-term goals. This system is thought to be capable of overriding lower-level impulses and emotions but requires the individual's conscious effort to do so.

The strength model of self-control. While the temporal discounting and hot/cool cognition approaches to self-control have seen broad use and continue to inform current work in this area, the preponderance of recent research in the field has focused on the *strength model of self-control,* a more recent (and controversial) model of human self-control. In one study considered foundational to this theory, Baumeister and colleagues (1994) posited that, much like a muscle, the employment of self-control to override an established behaviour or response routine draws upon a finite internal reserve; it is the availability (or lack thereof) of these "willpower" stores which confers self-control "strength", i.e. the likelihood of self-control success. Critically, all acts requiring self-control (e.g., self-control of emotion, cognition, or diverse domains of behaviour) are hypothesized to draw upon a single reserve under this model. When these limited resources become exhausted through exertion of self-control, one is said to be in a state of "ego depletion" or self-control depletion, in which the individual is at increased risk of self-control failure for any task requiring self-control (Baumeister, 2013; Baumeister et

al., 1998; Baumeister & Heatherton, 1996; Inzlicht & Schmeichel, 2012; Vohs et al., 2008; Vohs, Baumeister, & Ciarocco, 2005). The central tenets of the strength model of self-control have been borne out across numerous empirical studies employing diverse paradigms to experimentally manipulate and measure self-control (e.g. Baumeister, Gailliot, DeWall, & Oaten, 2006; Chan et al., 2015; DeWall, Baumeister, Gailliot, & Maner, 2008; DeWall, Baumeister, Stillman, & Gailliot, 2007; Hagger & Chatzisarantis, 2013; Muraven, Tice, & Baumeister, 1998; Post, Boyer, & Brett, 2006; Robinson, Schmeichel, & Inzlicht, 2010; Tuk, Zhang, & Sweldens, 2015; Tyler & Burns, 2009; Wolff, Baumgarten, & Brand, 2013), although some authors have reported null findings in their attempts to produce "self-control depletion" effects (e.g., Lurquin et al., 2016; Xu et al., 2014).

However, despite the large body of single studies that have supported the existence of the so-called *ego depletion* effect, recent efforts to test and refine the strength model have resulted in tempered enthusiasm regarding the theory. For example, although some meta-analytic efforts have emerged in support of the viability of the ego-depletion effect (Blázquez, Botella, & Suero, 2017; Hagger et al., 2010), others have suggested that this effect is small or non-existent (Carter, Kofler, Forster, & McCullough, 2015; Carter & McCullough, 2014). Similarly, large-scale pre-registered replication attempts have produced conflicting results (Garrison, Finley, & Schmeichel, 2018; Hagger et al., 2016). In the context of larger concerns regarding the replicability of social science phenomena in general (Heino, Fried, & LeBel, 2017; Świątkowski & Dompnier, 2017), there also exist concerns that the sizeable literature supporting the existence of an "ego depletion effect" is subject to publication bias and questionable research practices

(e.g., *p*-hacking) that lead to bias in the published scientific literature (Friese, Loschelder, Gieseler, Frankenbach, & Inzlicht, 2018). A need for theoretical refinement of the mechanisms of the "ego depletion" effect also remains; for example, it has been suggested that the "ego depletion" effect is not distinct from other variables already specified in literature describing factors producing performance decrements (e.g., effort/motivation, fatigue, task difficulty; Hagger et al., 2010).

As there are significant limitations to the bodies of evidence both supporting and refuting the existence of an "ego depletion" effect, research regarding the demonstrability and replicability of the effects hypothesized under the strength model of self-control is currently inconclusive (Friese et al., 2018). As such, although the strength model of self-control has been instrumental in shaping research on the topic over the past few decades, it also remains unclear whether this represents a truly unique and valid effect (as the strength model suggests) or a largely erroneous finding reflecting a greater problem in psychological science more broadly. Moreover, there remains need for greater specification of the mechanisms of "ego depletion", and whether they are distinct from other, more commonplace phenomena (e.g., fatigue). Therefore, although it remains a prominent theory for the explanation of state variance in self-control, the strength model continues to evolve as the body of research supporting, refuting, and refining the model expands.

Correlates of Self-Control

Compared to the self-control capacities of neurotypical adults, somewhat lower self-control is a normative part of development at some earlier stages of life, such as childhood, adolescence, and even young adulthood. However, while appropriate self-

control may confer protective effects on the individual, lower self-control compared to same-age peers has been linked to a range of suboptimal outcomes at all stages of the lifespan. This section will briefly review the literature investigating the correlates of self-control, with particular attention paid to emerging adulthood as is relevant for the present project.

Personality correlates. Self-control has been linked to a variety of personality traits. For example, several studies have demonstrated associations between trait self-control and Big Five personality traits (McCrae & Costa, 1987)—including positive associations with conscientiousness, openness to experience, and agreeableness (Krueger, Caspi, Moffitt, White, & Stouthamer-Loeber, 1996; Tangney et al., 2004), and inverse associations with neuroticism (Lange, Wagner, Müller, & Eggert, 2017; Tangney et al., 2004). Strong inverse associations have also been demonstrated between self-control and the traits of narcissism and aggression (Kim, Namkoong, Ku, & Kim, 2008).

Psychological functioning. Given that self-control allows the individual to inhibit or alter his or her cognitive and affective states and exert top-down control over his or her impulses (Baumeister et al., 1998), it is not surprising that poor self-control has been linked to a variety of suboptimal psychological outcomes; one meta-analysis found that there was, on average, a medium-sized correlation between self-control and well-being and adjustment (de Ridder et al., 2012). For example, university students' scores on a self-report measure of dispositional self-control have been shown to be related to a range of psychological outcomes, including internalizing problems (e.g., depression, anxiety, obsessive-compulsive symptoms, poor self-esteem, somatization) and externalizing problems (anger, hostility; Tangney et al., 2004). It should be noted that the

relation between self-control and psychological well-being may be bidirectional, such that stress and distress may limit one's ability to exert self-control; conversely, those with self-control deficits may have poorer control over their internal cognitive and affective states (Tangney et al., 2004).

Low levels of self-control are at the core of several disorders characterized by poor impulse control, including conduct disorder, antisocial personality disorder, and intermittent explosive disorder (APA, 2013). Poor self-control is likewise at the core of attention-deficit/hyperactivity disorder (ADHD). This disorder is relatively common among children and adults and is characterized by developmentally-inappropriate levels of inattention and/or hyperactivity/impulsivity (American Psychiatric Association, 2013). One widely-held theory of ADHD suggests that the disorder may reflect a core deficit in self-regulation, manifested as inability to successfully direct attention and control impulses (Nigg, 2016). Accordingly, a large body of work has demonstrated associations between the symptoms of ADHD and poor trait self-control (Braaten & Rosén, 2000; Scheres, Lee, & Sumiya, 2007; Schweitzer & Sulzer-Azaroff, 1995; Unnever & Cornell, 2003; Wilson, Mitchell, Musser, Schmitt, & Nigg, 2011).

Eating behavior correlates. Small-sized relations also appear to exist between self-control and health and eating-related behaviours (de Ridder et al., 2012). For example, Peluso and colleagues (1999) found trait self-control to be negatively related to disordered eating behaviours and highly restrained eating. A separate study demonstrated an inverse association between university students' dispositional self-control and a range of eating disorder-relevant schemata and behaviours, including body dissatisfaction, thinness drive, and bulimia (Tangney et al., 2004). Thus, self-control appears to be a

protective factor against both cognitive and behavioural patterns that could jeopardize one's health (particularly those associated with eating disorders).

Risk-taking and criminality. Low self-control has been associated with criminality and antisocial/delinquent behaviour. Perhaps the most influential work on the topic was conducted by Gottfredson and Hirschi (1990), who suggested that criminal behaviour was solely attributable to poor self-control. Studies have since demonstrated that self-control is disproportionately low among incarcerated samples (Longshore, 1998; Longshore, Rand, & Stein, 1996; Tittle & Botchkovar, 2005) and predicts youth criminality (Baron, 2003). At both state and trait levels, lower self-control has also been associated with greater risk-taking behaviour (Freeman & Muraven, 2010; Keane, Maxim, & Teevan, 1993; Wills, Vaccaro, & McNamara, 1994; Wood, Pfefferbaum, & Arneklev, 1993).

Substance abuse. An association has likewise been identified between self-control and substance use. Individuals with low trait and state self-control have been shown to be at increased risk of excessive drinking (Peluso et al., 1999; Tangney et al., 2004; Wills et al., 1994); in one study, self-control was found to be inversely related to university students' alcohol use problems, such that individuals with higher levels of trait self-control had fewer drinking problems—a relation that remained statistically-significant after controlling for social desirability (Tangney et al., 2004). Self-control has also been shown to be inversely related with risk of illicit substance use (Baron, 2003; Wills, Gibbons, Gerrard, Murry, & Brody, 2003; Wills et al., 1994; Wills & Stoolmiller, 2002; Wills, Walker, Mendoza, & Ainette, 2006), with a sizeable literature specifically linking increased delay discounting to substance use risk (de Wit, 2009).

Academic difficulties. One finding with particular relevance to university students is the consistent positive relation between self-control and academic outcomes. Across numerous studies, this effect is, on average, medium-sized (de Ridder et al., 2012). Trait self-control variation has been shown to predict future academic functioning; for example, in a classic study of self-control that assessed preschoolers' ability to delay gratification, Mischel and colleagues found that preschoolers' self-control predicted their academic functioning at the end of high school (Mischel et al., 1988). Individuals with lower levels of trait self-control have also been shown to earn lower grades overall (Tangney et al., 2004;Tibbetts & Myers, 1999; Wolfe & Johnson, 1995), engage more frequently in procrastination (Steel, 2007), skip class more frequently (Gibbs & Giever, 1995), and be at greater risk of academic dishonesty (Bolin, 2004; Cochran, Wood, Sellers, Wilkerson, & Chamlin, 1998; Tibbetts & Myers, 1999). Interestingly, self-control has been shown to more strongly predict academic functioning than even intelligence (Duckworth & Seligman, 2005), highlighting the important association between self-control and students' functioning in this domain.

Academic difficulties such as those associated with poor self-control in the university setting stand in conflict with the expectation of success placed on many students. In order to meet the demands of the university setting despite self-control difficulties, some students may attempt to bolster their cognitive functioning. Accordingly, the remainder of this chapter will summarize relevant research from the literature investigating "neuroenhancement", a class of behaviours hypothesized (in the current work) to serve as a compensatory routine for poor self-control.

Neuroenhancement

What is Neuroenhancement?

Neuroenhancement (also known as "cognitive enhancement" or colloquially as "brain doping"; Arria & DuPont, 2010; Bostrom & Sandberg, 2009; Farah, Smith, Ilieva, & Hamilton, 2014; Forlini & Racine, 2009; Franke, Bagusat, Rust, Engel, & Lieb, 2014; Franke, Bonertz, Christmann, Engeser, & Lieb, 2012; Lucke & Partridge, 2013; Schelle et al., 2015) refers to the use of a range of substances with the intention to improve one's cognitive functioning (Eickenhorst et al., 2012). While neuroenhancement has been documented across the lifespan (e.g. Cassidy et al., 2015) and in various professional environments (e.g., surgeons: Franke et al., 2013; university faculty: Holloway & Bennett, 2015), the most frequent (or well-identified) participants in neuroenhancement appear to be university students, who engage in neuroenhancement to support their academic achievement (Maier, Haug, & Schaub, 2016b). However, given concerns about the health implications of neuroenhancement (discussed below), this topic is worthy of research attention regarding the motives and consequences of engagement in substance use for neuroenhancement purposes.

Historical Foundations of Neuroenhancement

Inquiry into the factors that drive neuroenhancement among university students must begin with an examination of the greater societal context in which university students' neuroenhancement behaviour occurs. Neuroenhancement has gained considerable attention in recent years. The subject has been covered widely in the empirical literature (Partridge, Bell, Lucke, Yeates, & Hall, 2011), as evidenced by publications on the topic in top-tier journals such as *Nature* (e.g. Greely et al., 2008);

however, interest in the subject is also evident in the popular media, with coverage in sources such as *60 Minutes* ("Boosting Brain Power," 2010) and the *New York Times* (Petrounin, 2014). The popularity of the subject highlights the salience of the topic for both academics and laypeople alike. However, interest in expanding the capabilities of the human mind is certainly not new to the twenty-first century; as one author has stated, "to a large extent, human history is very much the history of enhancement" (Buchanan, 2011, p. 24). The known use of naturally-occurring psychoactive substances for enhancement of cognitive and affective states dates back millennia (Angrist & Sudilovsky, 1978). As such, neuroenhancement is indeed very much woven into the fabric of our global society.

Alkaloids derived from the herb *Ephedra* (also known as *ma-huang*), for example, are currently best known for their use as a precursor to methamphetamine and in dietary supplements; however, various species of *Ephedra* have been used throughout history—as early as 2700 BC in China (Lee, 2011). *Ephedra* appears to have been used historically for numerous purposes, including the achievement of effects similar to modern-day synthetic stimulant drugs (Lee, 2011). Similar histories surround the use of other naturally-occurring substances with intent to enhance cognitive and/or affective experience, such as the use of *khat* in Africa and the Arabian peninsula (El-Menyar, Mekkodathil, Al-Thani, & Al-Motarreb, 2015) and *coca* in South America (Martin, 1970).

As scientific capabilities for extraction and synthesis of psychoactive compounds have increased in recent centuries, so too has interest in use of such substances to enhance human cognitive abilities. For example, amphetamines were first introduced in

the early twentieth century for use in medical applications; however, interest soon turned to their potential use for cognitive enhancement in neurotypical individuals (Kerley, Copes, & Griffin, 2015). Best known is their instrumental use for such purposes in the United States military during World War II, when soldiers were provided with amphetamines to use as desired to promote alertness and cognitive performance despite sleep deprivation. However, amphetamines were also widely available to the general public during this time and were used widely "for maintaining optimal performance in an increasingly fast paced modern life" (Bell, Lucke, & Hall, 2012, p. 26). Amphetamines saw particularly widespread use among workers who perceived them as necessary for completion of their work, including laborers, truck drivers, athletes, and—of course—university students (Kerley et al., 2015).

Beginning in the 1970s, amphetamines became more tightly-controlled as their potential for abuse and addiction became clear; however, around that time, both amphetamine- and methylphenidate-based stimulant medications for treatment of ADHD began to see increased medical use. As may be expected, the non-medical use of these drugs for enhancement of cognition resurged soon after (Kerley et al., 2015), with universities acting as a "hot spot" for illicit/non-medical use (Herman-Stahl, Krebs, Kroutil, & Heller, 2007; Smith & Farah, 2011).

Of course, a parallel exists in the use of legal lifestyle substances, such as coffee and nicotine, for their purported central nervous system effects; the use of these substances likewise dates back millennia (Mishra & Mishra, 2013; Wood et al., 2013). The mythos of coffee as a neuroenhancer, for example, is seen in an Ethiopian legend depicting a goatherd who ingested *bunn* (the fruit and leaves of the coffee plant) after

discovering his suddenly-energetic flock chewing the plant. According to this narrative, the goatherd found himself instantaneously full of energy and creativity (Pendergrast, 2010). Though this storied discovery of coffee was purportedly an impetus for the spread of "coffee culture" throughout Ethiopia (Pendergrast, 2010), it was the forces of colonialization (and increased trade throughout the regions in which substances such as coffee and tobacco naturally occur) that prompted increased Western—and eventually global—use of many of these substances (Mishra & Mishra, 2013; Wood et al., 2013).

The legacy of legal substances such as caffeine and nicotine has paralleled that of now-controlled substances such as amphetamine, and the introduction of new products containing these substances has only increased their use as "neuroenhancers". For example, caffeine also has a history of use by individuals who perceive neuroenhancement as a necessary requirement for keeping up with the demands of modern society. This is particularly evident among university students. While coffee and caffeine pills have long been used by students intending to enhance their concentration and wakefulness, there has also been a tremendous increase in the use of high-caffeine content beverages (e.g. "energy drinks") since the debut of Red Bull in the United states in the late 20th century (Reissig, Strain, & Griffiths, 2009). In the current social context of the "biohacking"/"life hacking" movements and wide marketing of "brain training" programs (Wexler, 2017), it may be argued that neuroenhancement using lifestyle substances is a common part of life for both university students (Franke et al., 2014; Mache, Eickenhorst, Vitzthum, Klapp, & Groneberg, 2012) and professionals/members of the general public (Wexler, 2017).

Current Definitions of the Neuroenhancement Construct

Although neuroenhancement clearly reflects a constellation of historically-established and culturally-sanctioned behaviours, this construct has only begun to attract substantial scholarly attention in recent years. A primary task of the recent work investigating neuroenhancement has been to elucidate a concrete definition of the construct; however, there is no clear consensus within the literature regarding how neuroenhancement may best be defined. A prominent definition (Maier, Haug, & Schaub, 2016a) suggests that neuroenhancement constitutes use of substances with the subjective intent to enhance one or more cognitive functions (e.g., alertness, concentration, focus, motivation, creativity) or to otherwise facilitate optimal academic/work performance (e.g., by reducing negative affectivity). However, there remain discrepancies in the subcategorization of this class of behaviour. Specifically, there are two diverging perspectives on classifying neuroenhancement: the first defines neuroenhancement not as a single construct, but rather as several discrete, substance-specific categories of behaviour. In contrast, the second category defines neuroenhancement as a unified behavioural construct defined by intent to enhance cognition—regardless of the substance used as a means to that end. Literature surrounding these two perspectives is briefly summarized here.

Neuroenhancement as constituting discrete, substance-specific categories of behaviour. In studying neuroenhancement, the majority of studies have differentiated between different modes of neuroenhancement. According to one framework (Franke et al., 2014), three sub-categories of neuroenhancement may be identified: (1) neuroenhancement involving the non-medical use of prescription drugs, (2)

neuroenhancement involving use of illicit drugs of abuse (e.g., cocaine, cannabis, heroin, Speed), and (3) legal neuroenhancement or "soft enhancement" involving legal substances such as caffeine, nicotine, and over-the-counter products and supplements. The former two categories are often separated from legal neuroenhancement (e.g., Eickenhorst et al., 2012; Maier et al., 2016b; Maier & Schaub, 2015) and have been referred to collectively as "pharmacological cognitive enhancement" (e.g. Franke et al., 2013). This substance-specific approach to classifying neuroenhancement characterizes the majority of existing studies of the neuroenhancement construct; for example, one frequent focus of research has been undergraduates' non-medical use of prescription stimulant medications typically used in the treatment of ADHD (e.g., Lookatch, Dunne, & Katz, 2012; McCabe, 2008; McCabe & Cranford, 2012; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2010; Rabiner et al., 2010; Upadhyaya et al., 2010).

Neuroenhancement as a unitary behavioural construct. In contrast to the classification of neuroenhancement as comprising multiple substance-specific categories (as described above), it has recently been suggested that the notion of neuroenhancement should evolve from a substance-based perspective to a behaviourally-based perspective (Englert & Wolff, 2015): thus, the use of any substance with the intent to enhance cognition would qualify as neuroenhancement.

This approach draws upon Drug Instrumentalization Theory (Müller & Schumann, 2011) as a conceptual framework for understanding neuroenhancement. Contrary to other theories that depict substance use as maladaptive, this theory suggests that non-addictive use of psychoactive substances may be instrumental and may actually increase evolutionary fitness; that is, would-be users identify a discrepancy between their

current mental/affective state and a desired mental/affective state, such as successful social, sexual, or cognitive/academic performance, euphoria, or successful coping with distress. Would-be users draw upon learned associations of substances with their perceived effects, eventually selecting the substance that they believe will effectively "enhance" their current state to bring it closer to their desired mental state.

This perspective would suggest that at the core of all neuroenhancement behaviour is the intention to instrumentally enhance one's cognitive state; as such, all neuroenhancement behaviour may be represented as a unitary behavioural construct, given that all neuroenhancement behaviour reflects the user's intention to enhance cognition. The substance used, then, is less important than the user's perception of the substance as effective in bringing them closer to their desired mental state. In line with this theoretical framework, several studies have treated neuroenhancement as a unified construct (Englert & Wolff, 2015; Wolff et al., 2013; Wolff & Brand, 2013) or have included "soft enhancers" such as caffeine in their definition of neuroenhancement as a reflection of this perspective (Franke, Christmann, Fellgiebel, Huss, & Lieb, 2011; Franke et al., 2014; Franke, Lieb, & Hildt, 2012; Schelle et al., 2015; Wolff, Baumgarten, & Brand, 2013; Wolff et al., 2014). In support of this view, there is considerable overlap between the different "modes" of neuroenhancement, such that an individual who engages in one form of neuroenhancement is significantly more likely to engage in neuroenhancement using multiple categories of substances (e.g. Wolff & Brand, 2013).

A note of caution regarding use of the "neuroenhancement" term. Although a considerable body of work has begun to point to the magnitude of the neuroenhancement issue—particularly on university campuses—a brief caveat regarding

terminology is warranted. "Neuroenhancement" is termed as such to represent the user's intent (i.e., to "enhance" neurocognitive/affective functioning), and is not intended to reflect the outcome of the corresponding substance use. However, it has been (appropriately) suggested that the "neuroenhancement" term may perpetuate the popular perception that so-called neuroenhancement substances actually improve cognition in neurotypical individuals (Arria, 2016). As will be reviewed below, this finding has not been unequivocally borne out; as such, caution is certainly warranted regarding the use of this term.

Unfortunately, other nomenclatures for the construct in question are likewise limited. Alternatives apply only to the use of specific classes of substances (e.g., "non-medical use of prescription stimulants"; Blanco et al., 2007; Hanson et al., 2013; Kroutil et al., 2006; McCabe, Knight, Teter, & Wechsler, 2005; McCauley et al., 2011; Teter, McCabe, Cranford, Boyd, & Guthrie, 2005) and are therefore incompatible with the definition of neuroenhancement as a single behavioural construct (Englert & Wolff, 2015). It must also be noted that motives for use of a given substance are certainly not limited to neuroenhancement. For example, university students alternately endorse non-medical use of prescription stimulant medications for recreational use (i.e., to get high) or appetite suppression (i.e., weight loss; Rabiner et al., 2009). Thus, from the perspective of motives for substance use, a term such as "non-medical use of prescription stimulants" may identify a heterogeneous population, likely including but certainly not limited to individuals who use stimulants with the intent to enhance cognitive functioning.

Given the lack of an acceptable alternative that is inclusive of use of *any* psychoactive substance with the aim of improving cognitive/affective performance, then,

the term "neuroenhancement" will be used throughout the present project. While this terminology unites the present investigation with a large extant literature on the topic (Eickenhorst et al., 2012; Englert & Wolff, 2015; Maier et al., 2016b, 2016b; Maier & Schaub, 2015; Normann & Berger, 2008; Repantis, Schlattmann, Laisney, & Heuser, 2010; Singh & Kelleher, 2010; Wolff & Brand, 2013; Zelli, Lucidi, & Mallia, 2015), the reader is asked to remain mindful of the limitations of this term while reading the ensuing discussions of the construct.

Modes of Neuroenhancement

This section will briefly review the literature surrounding each of the above-described categories of neuroenhancement, with specific attention paid to the substances most commonly employed for neuroenhancement within each category, their use prevalence, and any evidence supporting an enhancing effect on cognition when used in neurotypical individuals. As numerous potential substances fall into each category, however, an exhaustive review of all possible neuroenhancement substances is beyond the scope of the present chapter. For excellent recent reviews on the subject, the reader is referred to work by Baroni and Castellanos (2015), Fond and colleagues (2015), Franke and colleagues (2014), and Maier and Schaub (2015).

Neuroenhancement involving non-medical use of prescription drugs. Research has revealed that university students may pursue neuroenhancement through non-medical use of prescription drugs (i.e., use of these drugs without a valid prescription; some definitions have also included individuals who possess a valid prescription but who use that medication in excess of prescribed dosage; e.g. Arria & Wish, 2006). The most common form of non-medical use of prescription drugs for

neuroenhancement appears to involve the use of prescription stimulants (e.g. ADHD medications such as methylphenidate [e.g., Ritalin, Concerta] and amphetamine [Adderall]), with lifetime prevalence estimates among university students ranging from 5.3% to 35% (reviewed in Weyandt et al., 2013), and with increasing prevalence over the past decade (McCabe, West, Teter, & Boyd, 2014). Given that the majority of research investigating this category of neuroenhancement has examined the non-medical use of prescription stimulants, this section will be devoted to discussion of these substances; however, note that although considerably less common, use of other prescription medications for neuroenhancement has been documented (e.g., beta blockers, Modafinil; Repantis, Schlattmann, Laisney, & Heuser, 2010; Schelle et al., 2015).

Methylphenidate and medicinal formulations of amphetamine are classified as psychostimulants. Similar to stimulant drugs of abuse such as cocaine and methamphetamine, these psychostimulant medications are believed to positively impact levels of extracellular dopamine in the brain (Volkow & Swanson, 2003). However, the specific mechanisms by which this is accomplished vary slightly according to each specific stimulant; whereas amphetamine stimulates increased release of dopamine in the synaptic terminal, methylphenidate blocks the reabsorption of dopamine into the post-synaptic neuron (Leonard, McCartan, White, & King, 2004; Volkow & Swanson, 2003). The resultant influx of dopamine in areas such as the striatum is believed to be responsible for reports of an impact of these drugs on attention; in these regions, the increase in available dopamine is thought to facilitate neuronal firing relevant to the target task and decrease background firing rates (Volkow & Swanson, 2003).

As a result of these purported effects on attention, methylphenidate and amphetamine formulations represent a cornerstone of treatment of ADHD in children and adults alike (Dussault & Weyandt, 2011). However, though multiple studies have demonstrated improvement in the real-world functioning of individuals with ADHD upon administration of stimulant medications, the literature has not consistently borne out an effect for these drugs on enhancing cognition in neurotypical individuals (Arria, 2016; Baroni & Castellanos, 2015; Repantis et al., 2010). Overall, there is comparatively little research investigating the effects of stimulant medications on neurotypical individuals (Weyandt et al., 2013), and conclusions drawn from the few existing studies are limited by factors such as varying populations studied, differences in dosage between studies, the specific medication administered, and inconsistency in cognitive outcome variables included (Baroni & Castellanos, 2015). Further, systematic reviews and meta-analyses on the topic (e.g., Ilieva, Hook, & Farah, 2015; Linssen, Sambeth, Vuurman, & Riedel, 2014; Smith & Farah, 2011) have often varied considerably with regards to the specific studies included, further muddying conclusions drawn from this literature (Baroni & Castellanos, 2015).

Mindful of these limitations, what can be said about the effects of stimulant medications on neurotypical individuals' cognition? The findings are mixed. With regards to attention, the majority of studies using neurotypical volunteers (71%) failed to find any effect of such medications on objective measures of attention and vigilance, although nearly half (48%) of studies found a small effect of methylphenidate administration on neurotypical individuals' processing speed (Linssen et al., 2014). There is inconsistent evidence for any benefit to neurotypical individuals' working

memory upon administration of these drugs (Smith & Farah, 2011); although an ordinal analysis of the literature found that 65% of studies identified a positive effect for working memory upon stimulant administration in neurotypical individuals (Linssen et al., 2014), a meta-analysis found that, across studies, the effect of stimulants on neurotypical individuals' working memory was essentially null (Ilieva et al., 2015).

Evidence for an enhancing effect of stimulant medications on objective measures of learning and delayed recall is likewise inconsistent. One systematic review found that the effects of stimulants on neurotypical individuals' cognition were largest in the domain of long-term verbal memory (Smith & Farah, 2011); however, another analysis of studies on neurotypical individuals found that less than a third (31%) of studies identified any effect in this domain (Linssen et al., 2014). No effects have been identified for visual learning and memory upon administration of stimulant medications to neurotypical volunteers (Linssen et al., 2014).

With regards to effects of stimulant medications on higher-order cognitive functioning, there is minimal support for the notion that neurotypical individuals benefit from stimulant administration. For example, only a handful (18%) of applicable studies found an effect of single-dose methylphenidate on reasoning/problem solving (Linssen et al., 2014). However, there is some evidence to suggest that stimulant medications may have a small, positive effect on some aspects of self-control; for example, a meta-analysis identified a small effect on neurotypical individuals' inhibitory/cognitive control (Ilieva et al., 2015). A study by Schmidt and colleagues (2017) likewise demonstrated a preferential effect of methylphenidate (versus MDMA and placebo) on neurotypical participants' inhibitory control performance. Similarly, several studies have suggested

that neurotypical individuals feel more motivated following single administration of stimulant medication (reviewed in Ilieva & Farah, 2015). Of particular relevance to the strength model of self-control, one study demonstrated that administration of methylphenidate to neurotypical volunteers attenuated the effects of self-control depletion following a demanding task (Sripada, Kessler, & Jonides, 2014).

In sum, effects of stimulant medications such as methylphenidate and amphetamines (Adderall) are often small, and typically are only identified in a minority of studies. Therefore, there is at best mixed evidence to support the notion that stimulant medications such as these constitute "smart pills" when taken by neurotypical individuals. However, there is some evidence to support a motivational or self-regulatory effect of stimulant medications in neurotypical individuals.

Neuroenhancement using drugs of abuse. The second broad category of neuroenhancement is that involving drugs of abuse, including both alcohol and illicit drugs of abuse such as cannabis, non-medicinal amphetamines, and cocaine (Maier & Schaub, 2015). Given that alcohol and illicit drugs appear to be used quite rarely by university students with the explicit purpose of cognitive enhancement (in one study, lifetime prevalence rates for alcohol and illicit drug neuroenhancement were 1.8% and 1.3%, respectively; Schelle et al., 2015), the limited literature investigating this form of neuroenhancement will be only briefly summarized here.

This category of neuroenhancement encompasses a broad range of substances with varying effects on the central nervous system. Drugs such as cocaine and non-medicinal amphetamines are central nervous stimulants which have demonstrated potential to enhance users' level of alertness in a similar fashion to the stimulant

medications described above (Maier & Schaub, 2015). With central nervous system depressant properties, the mechanisms of action for alcohol and cannabis differ from those of the illicit stimulant drugs (Abood & Martin, 1992; Söderpalm, Ericson, Olausson, Blomqvist, & Engel, 2000), and the rationale for using such drugs with the intent to enhance cognition may be less intuitive as a result. However, as Maier and Schaub (2015) point out, the mechanism for students' use of these substances as neuroenhancers may be that they facilitate cognitive functioning *indirectly* via a reduction of stress. Additional research is needed investigating the specific motives of the apparently small group of students who use such drugs as neuroenhancement.

Legal or "soft" neuroenhancement. The category of "soft enhancement" encompasses the use of caffeine (including caffeinated beverages such as coffee, tea, and energy drinks, as well as caffeine tablets), nicotine, and over-the-counter products (e.g., vitamins, gingko biloba) with intent to enhance cognitive functioning (Maier & Schaub, 2015). As these substances are widely available and the use of many such substances is a routine aspect of many individuals' day-to-day lives (Maier & Schaub, 2015), this class of behaviours is the most common form of neuroenhancement. Prevalence estimates for "soft enhancement" are variable and depend on the scope of the definition (e.g., caffeine only vs. inclusion of other substances); for studies adopting a more inclusive definition of this behaviour aimed at neuroenhancement (e.g., *instrumental* use of caffeine-containing beverages and tablets, energy drinks, nicotine, and over-the-counter supplements *for cognitive enhancement*), prevalence estimates are quite high; for example, Schelle and colleagues (2015) found that 45.6% of university students endorsed a lifetime history of use of "soft enhancers" for neuroenhancement. Similarly, Wolff and Brand (2013)

identified a 62.6% lifetime prevalence rate of "soft enhancement". In Wolff and colleagues' (2014) study, 83.2% of the sample endorsed this form of neuroenhancement behaviour. Although these rates vary across studies, they share the noteworthy finding that a sizeable proportion of undergraduate students self-report use of these substances with the specific intent to enhance cognitive functioning.

Caffeine. Caffeine is a naturally-occurring, legal stimulant (Wood et al., 2013). Caffeine works primarily by blocking the A_1 and A_{2A} receptors for the neuromodulator adenosine. As adenosine contributes to drowsiness and fatigue, then, this function of caffeine promotes the drug's known stimulant effects by preventing the action of adenosine on postsynaptic neurons (Wood et al., 2013). Caffeine also appears to prompt increased release of dopamine in the prefrontal cortex (in contrast to stimulant drugs with a greater addiction potential, such as amphetamines, which also trigger dopamine release in the ventral striatum; Fond et al., 2015).

Caffeine has been demonstrated to have a range of "enhancing effects"; for example, moderate amounts of the substance have been demonstrated to improve athletic performance (Burke, 2008). Medically, the utility of caffeine has been demonstrated for some conditions, including migraine (Lipton et al., 1998) and apnea of prematurity among infants born preterm or at very low birth weight (Schmidt et al., 2007). Among university students and in society as a whole, however, enhancement of cognition and academic/work performance constitutes a primary motive for caffeine use. Indeed, caffeine constitutes the most widely used substance for neuroenhancement (Eickenhorst et al., 2012). While coffee has long held a central role on university campuses, energy drinks have quickly gained popularity among university students. These products are

particularly marketed to young adults, often with promises of improved attention, concentration, and endurance (Reissig et al., 2009). Accordingly, university students endorse use of energy drinks for improved wakefulness, energy, and ability to study or complete academic work, along with more recreational motives (Malinauskas, Aeby, Overton, Carpenter-Aeby, & Barber-Heidal, 2007). Finally, a less-common but significant form of neuroenhancement via caffeine use is the ingestion of caffeine tablets. Many students attempting to increase their attention and vigilance rely upon caffeine-based products such as these, both to cope with day-to-day academic demands and while preparing for larger projects and exams (Maier & Schaub, 2015).

In light of the wide use of caffeine with the intention to improve cognitive functioning, it is relevant that the expansive literature on caffeine effects has not clearly borne out an absolute enhancing effect for caffeine on cognition. Briefly, caffeine has been demonstrated to increase attention and vigilance above placebo with relative consistency, although the greatest effects are seen in individuals who are sleep deprived or experiencing withdrawal due to abstinence in the context of habitual caffeine use (Franke et al., 2014; Wood et al., 2013); as such, it has been suggested that caffeine effects may be better represented as a "return to baseline" following sleep deprivation or withdrawal rather than an absolute bolstering of cognition above and beyond baseline levels (James & Rogers, 2005). Across studies, the effects of caffeine on higher-order cognitive functions such as learning and memory are essentially null when controlling for the attention and vigilance effects of the substance (Nehlig, 2010). Thus, caffeine appears to be most effective in restoring attention and vigilance in individuals who are in a state of sleep deprivation or withdrawal from caffeine use; however, there does not

appear to be significant literature supporting higher-order cognitive enhancement using caffeine.

Nicotine. A second common "soft enhancement" substance is nicotine. Nicotine is a naturally-occurring compound with central nervous system stimulant properties. This drug broadly works within the central nervous system as a nicotinic acetylcholine receptor agonist, although it is also an antagonist in its action on some types of receptors (Fond et al., 2015). Nicotine stimulates the release of a range of neurochemicals, including dopamine, serotonin, acetylcholine, and glutamate, facilitating change in the level of activation of the prefrontal cortex, hippocampus, and amygdala (Heishman, Kleykamp, & Singleton, 2010). Nicotine has been long consumed in the form of tobacco products, such as cigarettes, cigars, chewing tobacco, or nicotine chewing gum. A recent addition to this list are so-called "e-cigarettes", which are marketed broadly to adolescents and young adults (de Andrade, Hastings, & Angus, 2013) and which many users prefer due to perceived harm reduction over traditional forms of nicotine use (although there is no scientific consensus that e-cigarettes are indeed healthier; Pepper & Brewer, 2014).

Numerous studies have examined the cognitive impacts of nicotine consumption on a variety of basic and higher-order cognitive functions. A meta-analysis of 41 double-blind, placebo-controlled trials conducted by Heishman and colleagues (2010) demonstrated that nicotine facilitated small to medium-sized improvements in human fine motor speed and graphomotor output, accuracy and speed of alerting attention, speed of orienting attention, speed of working memory output, and accuracy of short-term episodic memory. Studies included sampled non-smokers or non-deprived smokers; as

such, the authors conclude that the results likely reflect true effects of nicotine (rather than withdrawal reversal effects, although it is worth noting that nicotine withdrawal is characterized by concentration deficits; Hughes, 2007). As such, there is evidence from high-quality experimental studies that nicotine may prompt small to moderate improvements in discrete domains of cognitive functioning.

Does "soft enhancement" constitute neuroenhancement? There is some scholarly debate regarding whether "soft enhancers" such as caffeine, nicotine, and over-the-counter products should be included in the overall neuroenhancement construct. For example, Maier and Schaub (2015) separate "soft enhancement" from so-called "pharmacological neuroenhancement". Although these authors acknowledge that "soft enhancement" substances are frequently used with the intent to enhance cognitive functioning, they suggest that "the natural quality of these substances and their ease of obtainment via supermarket and pharmacies are the reasons why their use is not classified as neuroenhancement" (p. 158). Others have similarly excluded "soft enhancers" from their definition of neuroenhancement (e.g. Eickenhorst et al., 2012). It should be noted, however, that substances in other categories are naturally-derived (e.g., cocaine, cannabis, alcohol) and are widely available (certainly alcohol); therefore, the argument for the exclusion of "soft enhancers" from "true pharmacological neuroenhancement" remains somewhat unsatisfactory.

In contrast, several authors have included use of caffeine (either in caffeine-containing beverages or in tablet form), nicotine, and over-the-counter supplements in the construct of neuroenhancement (Franke, Christmann, Fellgiebel, Huss, & Lieb, 2011; Franke et al., 2014; Franke, Lieb, & Hildt, 2012; Schelle et al., 2015; Wolff, Baumgarten,

& Brand, 2013; Wolff et al., 2014). This view is in line with the notion that neuroenhancement constitutes a single, unitary construct (e.g., Englert & Wolff, 2015). Additionally, several studies have demonstrated considerable overlap between individuals who engage in so-called "soft enhancement" and those who engage in other forms of neuroenhancement, such as non-medical use of prescription stimulants (Arria et al., 2010; Eickenhorst et al., 2012; Schelle et al., 2015; Woolsey et al., 2014), supporting the notion of a single "neuroenhancement" construct.

Perceived Effects of Neuroenhancement

Given that there is only mixed evidence that commonly-used neuroenhancement substances enhance cognitive functioning in neurotypical individuals, why then do individuals engage neuroenhancement? In accordance with Drug Instrumentalization Theory (Müller & Schumann, 2011), an important factor may be students' subjective perceptions and expectations of enhancement upon use of such substances.

There is evidence to suggest that "soft enhancers" are broadly perceived to be effective in enhancing neurotypical individuals' cognitive functioning. For example, it is widely-believed that caffeine has the ability to sharpen attention and concentration in neurotypical individuals (Fond et al., 2015); indeed, *the belief alone* that one has consumed caffeine has been shown to have an impact on both mood and performance (Dawkins, Shahzad, Ahmed, & Edmonds, 2011). Similarly, many smokers cite perceived cognitive enhancement as primary benefit of nicotine use (West, 1993). Like research on caffeine, studies of expectancies related to nicotine use demonstrate that the belief that nicotine *could* enhance cognition led to measurably improved motivation to perform well on a cognitive task, greater experience of reward, and greater craving reduction (Harrell

& Juliano, 2012). These studies suggest that expectancies of improved cognition following use of "soft enhancers" are commonplace and may act as a potential mechanism for the use of these substances for neuroenhancement.

Research has also supported the idea that students who engage in non-medical use of prescription stimulants may similarly expect that these substances positively impact cognition. One of the most commonly-reported motives for university students' non-medical use of prescription stimulants is intended enhancement of one or more cognitive domains (e.g., improved alertness, motivation, or attention for one's studies; Carroll, McLaughlin, & Blake, 2006; Clegg-Kraynok, McBean, & Montgomery-Downs, 2011; DeSantis, Noar, & Webb, 2009; Dussault & Weyandt, 2011; McCabe, Cranford, Boyd, & Teter, 2007; Prudhomme White, Becker-Blease, & Grace-Bishop, 2006; Rabiner et al., 2009; Teter et al., 2005; Teter, McCabe, LaGrange, Cranford, & Boyd, 2006; White, Becker-Blease, & Grace-Bishop, 2006).

Findings from qualitative studies of non-medical prescription stimulant use provide further evidence that users perceive these substances as effective for cognitive enhancement. For example, DeSantis, Noar, and Webb (2010) report several students' accounts of their experience of enhancement upon using prescription drugs non-medically; as one student stated, "'Sometimes when I cram…I need to study for a long period of time and it really helps with that'" (p. 162). Another student in the same study reported that stimulant medication helped to "'block everybody out around… I get really into the details…and I can concentrate like a laser on my organic chemistry, or whatever'" (p. 162). These accounts highlight students' perceptions of cognitive enhancement following non-medical prescription stimulant use. It is therefore perhaps

not surprising that the frequency of nonmedical use of prescription stimulants has been shown to be related to one's positive expectancies regarding stimulant effects (Looby & Earleywine, 2011).

Health Risks Associated with Neuroenhancement

Often underappreciated by students who elect to engage in neuroenhancement behaviour is the resultant risk which accompanies "neuroenhancement". Although many students are aware of the risks associated with illicit stimulants such as cocaine or methamphetamine, for example (Desantis & Hane, 2010), students may perceive non-medical use of prescription stimulants as low risk given that these drugs are approved by the United States Food and Drug Administration for the treatment of ADHD (DeSantis et al., 2010). However, prescription stimulants are associated with potential for adverse effects and addiction, suggesting that the use of these substances without the oversight of a medical professional may be quite risky (Greenhill et al., 2002; Volkow & Swanson, 2003). Even the use of "soft enhancers", too, can pose risk of negative health consequences; although the risks associated with use of nicotine-containing tobacco are widely known, less broadly appreciated are the potential medical risks associated with high levels of caffeine use, such as physiological dependence, insomnia, tachycardia, seizures, and even death (Clauson et al., 2008; Ogeil & Phillips, 2015). Thus, while neuroenhancement may be perceived as relatively innocuous, this is clearly a dangerous misconception.

Factors Associated with Neuroenhancement Behaviour

Considering the increasing prevalence of neuroenhancement and the considerable risks associated with neuroenhancement behaviour, efforts have been made to identify

characteristics of those individuals who engage in neuroenhancement. The research on this subject is reviewed here. As a function of the frequent adoption of a "substance-specific" definition of neuroenhancement and the disproportionate attention paid within the literature to some forms of neuroenhancement, the majority of these studies have investigated non-medical use of prescription drugs generally, and non-medical use of prescription stimulants specifically. When such studies exist, however, research investigating the correlates of other forms of neuroenhancement is integrated below.

Demographic correlates. Several **s**tudies have investigated the demographic correlates of the non-medical use of prescription drugs. In general, males have been found to have higher rates of non-medical use of prescription stimulants than females (Franke, Bonertz, et al., 2012; McCabe et al., 2014; Wilens et al., 2008); this finding has been mirrored in a study of "soft enhancement" using caffeinated beverages (Franke et al., 2011). Likewise, individuals of Caucasian or Hispanic backgrounds are three times more likely to use prescription stimulants non-medically compared to African-American students (Wilens et al., 2008). Involvement in a Panhellenic organization (i.e., fraternity or sorority) has also been shown to be a risk factor for neuroenhancement involving the non-medical use of prescription stimulants (Desantis & Hane, 2010; DeSantis, Webb, & Noar, 2008) and caffeinated beverages (Franke et al., 2011). Finally, marriage and cohabitation appear to be protective against non-medical use of prescription drugs (Dollar & Hendrix, 2015).

Personality correlates. It has been suggested that the personality of individuals who engage in neuroenhancement may be substantially different from that of their abstinent peers. For example, individuals who engage in neuroenhancement via non-

medical prescription drug use have been shown to be less conscientious and more neurotic (Benotsch, Jeffers, Snipes, Martin, & Koester, 2013; Sattler & Schunck, 2016); one study also demonstrated a relation between openness to experience and nonmedical prescription drug use (Benotsch et al., 2013). Non-medical use of prescription stimulants has also been linked to elevated levels of the dark triad personality trait Machiavellianism and low levels of empathy (Maier, Wunderli, et al., 2015); it is possible that this pattern reflects a selection bias related to a general lack of risk aversion, as non-medically-utilized stimulants are often obtained illegally (Wilens et al., 2008). Accordingly, a relation between non-medical use of prescription stimulants and trait impulsivity has also been identified (Lookatch et al., 2012; Maier, Wunderli, et al., 2015).

Academic functioning. Individuals who engage in neuroenhancement have been shown to have poorer outcomes along several dimensions of academic functioning. For example, individuals who use prescription stimulants non-medically tend to self-identify as having greater academic concerns than non-users (Rabiner, Anastopoulos, Costello, Hoyle, McCabe, et al., 2009; Rabiner et al., 2010). Both students who engage in nonmedical use of prescription stimulants for neuroenhancement and those who engage in "soft enhancement" also report greater study-related stress than non-user peers (Schelle et al., 2015). University students who use prescription stimulants non-medically tend to be absent from class more frequently (Arria et al., 2013) and endorse less optimal study habits, such as cramming (DeSantis et al., 2008; Ilieva & Farah, 2015). These behaviours may perhaps contribute to the finding that university students who engage in non-medical use of prescription stimulants have lower GPA than non-user peers (Arria et al., 2013; Clegg-Kraynok et al., 2011; Rabiner, Anastopoulos, Costello, Hoyle, McCabe,

et al., 2009; Rabiner et al., 2010) and of poorer grades in individuals who use caffeine tablets for neuroenhancement (Franke et al., 2011).

Other substance use. The literature also reveals that individuals who engage in non-medical use of prescription drugs are at risk for a range of other substance-use-related outcomes. For example, the non-medical use of prescription drugs has been linked to greater problems related to cannabis and alcohol use (Arria et al., 2013), greater overall use of alcohol and other drugs (Rabiner et al., 2010; Teter, McCabe, Boyd, & Guthrie, 2003), increased polysubstance use (Eickenhorst et al., 2012; McCabe et al., 2005a), and risk of future substance use disorders and binge drinking (Benotsch et al., 2013). Likewise, university students who engage in "soft enhancement" have been shown to be at increased risk for other categories of neuroenhancement, compared to non-user peers (Wolff & Brand, 2013).

Psychological functioning. Associations have been identified between neuroenhancement and several aspects of psychological functioning. For example, non-medical use of prescription stimulant use and "soft enhancement" have been linked to greater perceived stress/strain related to academic demands (Maier, Liechti, Herzig, & Schaub, 2013; Wolff & Brand, 2013; Wolff et al., 2014). Similarly, both "soft enhancement" and prescription drug neuroenhancement have been shown to be associated with the perception that the individual is faced with overwhelming demands (Wolff & Brand, 2013). Students who use prescription stimulants non-medically also endorse greater anxiety overall (Dussault & Weyandt, 2011), greater test anxiety specifically (Sattler & Wiegel, 2013), and greater symptoms of depression (Dussault & Weyandt, 2011; Rabiner et al., 2010; Wilens et al., 2008). Overall, this research suggests

that those students who engage in neuroenhancement experience greater risk of psychological challenges, including those related to their subjective experience of the demands of the university environment.

Attention-deficit/hyperactivity disorder. One relevant theme which has emerged from studies of the relation between psychological functioning and neuroenhancement is an association of the latter with the symptoms of ADHD. Elevated overall self-report symptoms of ADHD have been repeatedly found among nonmedical prescription stimulant medication users (e.g., Peterkin, Crone, Sheridan, & Wise, 2011; Upadhyaya et al., 2010). Non-medical use of prescription stimulants has also been shown to relate to ratings for the specific ADHD symptom domains of inattention (Arria et al., 2011; Ilieva & Farah, 2015; Rabiner et al., 2010) and hyperactivity/impulsivity (Dussault & Weyandt, 2011; Rabiner et al., 2010). This finding remains robust after controlling for demographic and polysubstance use features of this group (Arria et al., 2011).

One possible explanation for this finding is that these individuals actually possess subclinical or undiagnosed ADHD (Wilens et al., 2008). Accordingly, some students justify their neuroenhancement via non-medical use of prescription stimulants in terms of self-medicating undiagnosed ADHD (Desantis & Hane, 2010). Relevant to the current investigation, however, the elevated symptoms of ADHD reported in individuals who engage in neuroenhancement may also be explained in terms of self-control. Recall that, according to a popular theoretical account, ADHD is often characterized by a core deficit in self-regulation (Nigg, 2016); thus, it may be suggested that elevated ADHD symptoms among students who engage in neuroenhancement may reflect their poorer self-control,

which impacts their own self-regulation of their attention, cognition, emotions, and behaviour.

Investigation of this possible relation between neuroenhancement and self-control is the chief purpose of this project. As such, the remainder of this chapter will address evidence supporting this possibility and will introduce three studies designed to investigate the potential relations of self-control with university students' neuroenhancement.

Self-Control and Neuroenhancement

Recent research has begun to expand to consider self-control as potentially important factor in university students' neuroenhancement behaviour. From a theoretical perspective, it is plausible that the perceived motivational effects of neuroenhancement may relate to self-control; namely, students engage in neuroenhancement as a means of bolstering their motivation for academic tasks when they are unable to rely upon their own self-control. From the perspective of Drug Instrumentalization Theory (Müller & Schumann, 2011), university students may identify a discrepancy between their current mental state (i.e., insufficient self-control, either as a result of a dispositional deficiency in self-control or a situational depletion of self-control) and the desired mental state (i.e., sufficient self-control to complete a given academic task). As a result, students instrumentally use substances that they perceive to be effective for neuroenhancement. Thus, students' neuroenhancement may be a means of artificially supplementing self-control resources when they are insufficient to meet the demands of academic life.

A similar theoretical account specific to state variation in self-control has been put forth by Englert and Wolff (2015). These authors situate neuroenhancement behaviour

within the strength model of self-control, citing research demonstrating that (as would be predicted by the strength model) individuals who have no history of neuroenhancement revert to their established behavioural response (i.e., abstinence from neuroenhancement; Wolff et al., 2013). Further, it has been demonstrated that neuroenhancement using methylphenidate can prevent self-control depletion (Sripada et al., 2014). Overall, however, the prospect of an association between state self-control variation and neuroenhancement remains under-investigated in the published literature.

A parallel argument can be made in support of a relation between dispositional (i.e., trait) levels of self-control and neuroenhancement; that is, that individuals who possess lower levels of trait self-control are more likely to use neuroenhancement (possibly in an attempt to compensate for this deficit). Though no studies have directly examined dispositional self-control in relation to neuroenhancement, a parallel may be drawn to the sports performance enhancement literature given comparable performance enhancement motives for these two classes of behaviour. In a study by Chan and colleagues (2015), individuals with poorer trait self-control were more likely to endorse positive attitudes toward sports-related doping, had greater intent to engage in doping, and were less likely to engage in doping avoidance behaviours. Thus, dispositional self-control was found to be inversely related to a range of factors related to engagement in "enhancement" within the specific context of sport.

In addition to evidence from the sports doping literature, a number of studies have demonstrated a relation between neuroenhancement and traits related to self-control. As described above, neuroenhancement has been shown to be associated with the symptoms of ADHD, which have been linked to a core deficit in self-control (Nigg, 2016).

Similarly, trait impulsivity has been shown to discriminate between students who engage in neuroenhancement and those who do not (Lookatch et al., 2012; Maier, Wunderli, et al., 2015). Although impulsivity and self-control are not synonymous (as described above), the high degree of overlap between these traits provides support for the prospect of an association between dispositional self-control and neuroenhancement.

Additionally, the association of neuroenhancement and the Big Five personality trait of conscientiousness (Benotsch et al., 2013; Sattler & Schunck, 2016) may likewise intimate a relation between self-control and neuroenhancement. Conscientiousness has been shown to be highly correlated with self-control (Tangney et al., 2004), to the extent that they are often treated as highly related (Olson, 2005; Steel, 2007) or even interchangeable (Moffitt et al., 2011). Thus, the demonstrated relation between conscientiousness and neuroenhancement provides preliminary support for a similar link to dispositional self-control.

The Current Studies

Although these lines of empirical inquiry have begun to suggest an association of both dispositional and state levels of self-control with university students' neuroenhancement, several questions remain unaddressed by the existing literature. It is the aim of the current project to address several limitations in this body of work.

First, although several studies have implicated constructs *related to* self-control in neuroenhancement behaviour, there have yet been no studies (to this author's knowledge) that have directly measured self-control in its associations with neuroenhancement. Further, those studies that have investigated similar constructs have relied primarily on self-report questionnaires for the measurement of self-control-related constructs. Given

that best practice in the measurement of self-control employs a multi-method approach (Duckworth & Kern, 2011), investigations of how *both self-report and performance-based measures* of self-control relate to neuroenhancement are needed. Questions also remain regarding how one's definition of neuroenhancement (as multiple substance-specific classes of behaviour versus a single, unified construct) may affect the pattern of relations between self-control and neuroenhancement. In Chapter II, a study is outlined that seeks to address these limitations in an examination of the association between dispositional self-control and neuroenhancement.

A second area requiring further inquiry involves the relation between *state* variations in self-control and neuroenhancement. Overall, this topic remains under-investigated. Although one study attempted to experimentally manipulate self-control and measure the resultant effects on neuroenhancement (Wolff et al., 2013), the exclusion of individuals with a history of neuroenhancement limited the ability of this study to draw conclusions about whether these students, too, revert to their "dominant behavioural response" (i.e., neuroenhancement) following self-control depletion. Additionally, there exists a fundamental need to replicate any effect of "ego depletion" on neuroenhancement given overall concerns around the reproducibility of the "ego-depletion" effect (Friese et al., 2018). Chapter III describes a study that aimed to expand upon the work by Wolff and colleagues (2013) and potentially provide further credence for a role of self-control depletion as an impetus for neuroenhancement behaviour.

Third, little existing work has directly examined how self-control may contribute to the suboptimal real-world outcomes seen in individuals who engage in neuroenhancement. Chapter IV outlines a study that sought to explore a potential role for

self-control in the academic difficulties identified in individuals who use prescription stimulants non-medically with the intent to enhance cognition.

In sum, the studies reported herein sought to expand the current knowledge base regarding the relations between dispositional and state levels of self-control and university students' neuroenhancement behaviour, and to explore how this relation may relate to students' real-world functioning (i.e., academic outcomes). In addition to contributing data regarding the prevalence and correlates of neuroenhancement in the Canadian university setting (which to date remains sparse), it is anticipated these studies may both broaden our understanding of why students worldwide may engage in neuroenhancement behaviour and assist in identifying students who may be at risk for the range of suboptimal outcomes associated with engagement in neuroenhancement.

Finally, please note that these chapters are each designed to be submitted for peer review and scholarly publication as three independent works. There exists some overlap in the literature reviewed in each chapter as a function of this structure.

II. EXAMINING ASSOCIATIONS OF NEUROENHANCEMENT CLASSIFICATIONS WITH DISPOSITIONAL SELF-CONTROL

Human beings have long been captivated by the prospect of enhancing the abilities of the mind. For example, the documented use of naturally-occurring psychoactive substances (e.g., *coca*) for such purposes dates back for centuries (Bell et al., 2012). However, with the synthesis of new psychoactive substances (e.g., cocaine, amphetamines) and increased availability of legal products containing high doses of other stimulants (e.g., caffeine-based energy drinks; Malinauskas, Aeby, Overton, Carpenter-Aeby, & Barber-Heidal, 2007), the past century has seen increasingly widespread (and socially-sanctioned) use of such substances with the intent to enhance cognitive functioning.

While the use of such substances has allowed for increased cognitive functioning for individuals with neurocognitive disorders like attention-deficit/hyperactivity disorder (ADHD; e.g. Surman, Hammerness, Pion, & Faraone, 2013), so-called "neuroenhancement" by neurotypical individuals—in particular, university students—has recently garnered increased research attention. The neuroenhancement construct, broadly defined, constitutes use of psychoactive substances (including *legal neuroenhancement* using "lifestyle" substances such as caffeine and nicotine, and *pharmacological cognitive enhancement* including the non-medical use of prescription drugs and use of illicit drugs such as cannabis, cocaine, and Speed; e.g. Eickenhorst et al., 2012; Franke et al., 2013) with the intent of enhancing cognition or otherwise bolstering academic/work performance (e.g., creativity). Of note, there is only inconclusive evidence to support actual enhancing effects for many of these substances (Baroni & Castellanos, 2015;

Nehlig, 2010), and there are considerable and often under-appreciated risks associated with their use (including caffeine; Clauson, Shields, McQueen, & Persad, 2008; Greenhill et al., 2002; Volkow & Swanson, 2003). Thus, neuroenhancement constitutes a major concern for university students' health and well-being.

Features Associated with Neuroenhancement

Given the gravity of the neuroenhancement issue, previous studies have sought to identify risk factors for university students' engaging in neuroenhancement behaviour. One theme that has emerged across such studies is an association of neuroenhancement with suboptimal regulation of one's behaviour, cognition, and emotions, both because of situational variation in this important capacity as well as individual differences in ones' general ability to control his or her internal state and behaviour. This paper proposes that these disparate findings may be parsimoniously conceptualized under the construct of self-control.

Dispositional self-control as a potential explanation of university students' neuroenhancement behaviour. Self-control (also known as self-regulation) is a broad construct which reflects an individual's ability to override or alter impulses in service of long-term goals by activating top-down cognitive processes (Duckworth & Kern, 2011). A vast literature supports the conceptualization of self-control as a trait or dispositional feature that is relatively stable across time and situations and that predicts functional outcomes into the future (e.g., Galla et al., 2014; Mischel et al., 1988).

A wealth of studies using diverse samples have linked trait self-control to such important domains as psychological adjustment, relationship functioning and commitment, health and eating behaviours, substance use, and risk taking and criminality

(reviewed in de Ridder et al., 2012). Relevant to the present population, dispositional self-control has also been implicated in university students' academic achievement (Tangney et al., 2004; Wolfe & Johnson, 1995), academic honesty (Bolin, 2004; Cochran et al., 1998) and class attendance (Gibbs & Giever, 1995). From this line of research, it is clear that self-control is vital to success across multiple domains of university students' functioning.

To date, no published studies have explicitly demonstrated a relation between a measure of dispositional self-control and neuroenhancement behaviour. However, this link may be inferred through studies that have investigated constructs closely related to self-control. Most closely related is the construct of impulsivity. Although the constructs of impulsivity and self-control are typically not viewed as interchangeable, several authors have argued that self-control is the antithesis of impulsivity (Duckworth & Kern, 2011; Tangney et al., 2004); whereas impulsivity is thought to reflect the "winning out" of bottom-up behavioural, emotional, and cognitive impulses, self-control is said to emerge from the employment of top-down control to modulate impulses in line with goals.

One study that has supported an association between neuroenhancement and impulsivity was conducted by Lookatch and colleagues (2012); this study demonstrated a link between non-medical use of prescription stimulant drugs and self-reported impulsivity (as measured by the Urgency, Premeditation, Perseverance, Sensation Seeking Positive Urgency [UPPS-P] Impulsive Behavior Scale; Whiteside & Lynam, 2001). A similar finding emerged from work done by Maier and colleagues (Maier, Wunderli, et al., 2015). Here, neuroenhancement was shown to be associated with scores

on the Barratt Impulsiveness Scale (Patton, Stanford, & Barratt, 1995), a core self-report measure of impulsivity. It should also be noted that the Barratt Impulsiveness Scale is frequently employed as a measure of self-control (de Ridder et al., 2012), illustrating the intimate conceptual relation between self-control and impulsivity.

The symptoms of ADHD represent a second constellation of self-control constructs linked to neuroenhancement. According to a prominent theory of ADHD (Nigg, 2016), both the cognitive symptoms (e.g., poor attention/concentration) and behavioural symptoms (e.g., hyperactivity, impulsivity) of ADHD may be conceptualized as resulting from a central self-regulatory deficit. The behavioural manifestation of poor self-control (e.g., in acting without forethought and in poor control over motor impulses such as the urge to fidget or be out of one's seat) as the hyperactive/impulsive symptoms of ADHD is likely self-evident. Perhaps less apparent, however, is the link between the inattentive symptom presentation of ADHD and self-control. Though the hyperactive/impulsive symptoms of ADHD manifest as poor self-control behaviourally, individuals with the inattentive symptoms of ADHD are posited to demonstrate poor control over their attention (both to external and internal stimuli) and other aspects of cognition.

Several studies have demonstrated an association between ADHD symptoms and neuroenhancement behaviour – to the extent that it has been suggested that individuals engage in neuroenhancement (particularly via non-medical use of prescription stimulant medications) as an attempt to self-medicate for unidentified or sub-clinical ADHD (e.g., Wilens et al., 2008). For example, overall self-reported ADHD symptoms have been shown to be positively related to neuroenhancement (Peterkin et al., 2011; Upadhyaya et

al., 2010). Likewise, neuroenhancement has also been shown to be positively related to self-report scores for the specific symptom dimensions of inattention (Ilieva & Farah, 2015; Rabiner et al., 2010) and hyperactivity/impulsivity (Dussault & Weyandt, 2011). Individuals who endorse history of non-medical prescription stimulant use have also been shown to perform more poorly on an objective measure of attention (Ilieva & Farah, 2015). In sum, these studies support poor self-control of behaviour and cognition in individuals who engage in various forms of neuroenhancement.

One final source of support for a potential association of dispositional self-control with neuroenhancement comes from studies of personality correlates of neuroenhancement behaviour. For example, the Big Five personality trait of conscientiousness reflects personality features related to self-discipline, industriousness, dependability, and perseverance (McCrae & Costa, 1987). Conceptually, this construct shares many commonalities with the notion of self-control; indeed, these two constructs are often treated, at minimum, as highly related (Olson, 2005; Steel, 2007), and at times have been used synonymously (Moffitt et al., 2011). Self-control has also been inversely linked to neuroticism, the Big Five trait reflecting negative affectivity and general affective distress (McCrae & Costa, 1987). Conscientiousness and neuroticism demonstrate large correlations with self-control in the empirical literature (Tangney et al., 2004), and both have been implicated in ADHD (Miller, Miller, Newcorn, & Halperin, 2008)—which, as described above, is likewise relevant to self-control. Neuroenhancement (specifically, nonmedical use of prescription drugs in hopes of enhancing cognition) has been shown to be negatively related to conscientiousness and positively related to neuroticism (Benotsch et al., 2013; Sattler & Schunck, 2016). Thus,

a connection between neuroenhancement behaviour and self-control can again be inferred from both constructs' links with Big Five personality features.

Limits of existing work. Although the reviewed literature has begun to lay the foundation for demonstrating an association between neuroenhancement and dispositional self-control, gaps remain in the extant body of work in this area. One limitation is the clear heterogeneity in self-control constructs employed across studies, as reviewed above. Though it has been recommended that self-control research employs a multi-method approach (Duckworth & Kern, 2011), the emergence of the extant evidence from diverse perspectives and research traditions has resulted in a literature that is conceptually fragmented. Therefore, research combining indirect measures of self-control (e.g., those tapping conscientiousness, ADHD symptoms, and impulsivity) with measures designed to *directly* measure self-control would provide clarity and unity to the literature linking neuroenhancement to these self-control-related constructs.

A second issue limiting the ability draw conclusions about a potential association between neuroenhancement and dispositional self-control is the lack of a unified definition for the neuroenhancement construct. A prominent method defines neuroenhancement in terms of specific categories of substances used. One such taxonomy subdivides neuroenhancement into three categories: (1) legal neuroenhancement (also referred to as "soft neuroenhancement") using lifestyle substances such as caffeine, nicotine, and over-the-counter herbal supplements; (2) non-medical use of prescription drugs, such as ADHD medications (e.g., methylphenidate, amphetamine formulations) and wakefulness-promoting agents used in the treatment of disorders such as narcolepsy (e.g., Modafinil); and (3) neuroenhancement using illicit

drugs of abuse (Maier, Wunderli, et al., 2015). Of note, the latter two categories are often viewed as distinct from legal/"soft" neuroenhancement and as such are referred to collectively as "pharmacological cognitive enhancement" (e.g., Franke et al., 2013). The approach of operationalizing neuroenhancement as distinct, substance-specific categories of behaviour is widely used in the research literature; for example, numerous studies have specifically investigated the prevalence and correlates of non-medical use of prescription stimulant drugs (e.g., Lookatch et al., 2012; McCabe, 2008; McCabe & Cranford, 2012; Rabiner et al., 2010, 2010; Upadhyaya et al., 2010).

Alternately, it has been suggested that neuroenhancement may be defined as a single unitary construct, defined by the use of any psychoactive substance with the intent to enhance cognition (Englert & Wolff, 2015). Informed by Drug Instrumentalization Theory (Müller & Schumann, 2011), this approach conceptualizes neuroenhancement not in terms of the specific class of substance used, but rather as a "means-end relationship" in which individuals identify a discrepancy between their current and desired mental states. This approach suggests, then, that the actual substance used (and the presence or absence of any substance-related effects) is not relevant; rather, all neuroenhancement behaviour is united under a single intent.

If, as the first approach suggests, neuroenhancement truly represents discrete categories that may be defined on the bases of classes of substances employed for this purpose, it would follow that the pattern of variables (e.g., self-control related constructs) associated neuroenhancement would potentially vary across categories. Conversely, if neuroenhancement is truly "collapsible" into a unitary behavioural construct, this would imply that the constellation of features associated with neuroenhancement as a whole

would be consistent across all substance-related categories of neuroenhancement. Research is needed to investigate whether potential mechanisms of neuroenhancement, such as dispositional self-control, remain consistent across varying definitions of the neuroenhancement construct.

The Current Study

Overall, the empirical literature has strongly supported a relation between the constructs of neuroenhancement and self-control. However, because these findings emerge from different research traditions and from studies with disparate foci, the existing literature connecting neuroenhancement to self-control is limited by diverse methods of self-control measurement and varying definitions of the neuroenhancement construct itself. The current investigation seeks to bridge this gap by examining whether a multivariate array of self-control variables (as defined both by self-report and performance-based measures) is differentially associated with various modes of neuroenhancement behaviour.

Through examination of this research question, the present study aimed to achieve two goals. First, planned analyses clarified the relation of self-control with the construct of neuroenhancement broadly. Additionally, examination of the pattern of associations of self-control-related variables across classes of neuroenhancement behaviour was expected to provide nosological clarity to the construct of neuroenhancement. Specifically, demonstration of a consistent pattern of associations of the array of self-control variables across classes of neuroenhancement would support a conceptualization of neuroenhancement as a unitary construct. If, in contrast, substantial differences exist in the pattern of associations of self-control variables across neuroenhancement classes,

this result would be more closely aligned with proposed definitions of neuroenhancement as a unitary construct. As such, it is anticipated that the results of the current study will both parsimoniously unite the extant literature and clarify the impact of definitional scope on research investigating the mechanisms and correlates of the neuroenhancement construct.

Methods

Participants

Sample size. Results of an *a priori* power analysis using G*Power (Faul, Erdfelder, Buchner, & Lang, 2009; Faul, Erdfelder, Lang, & Buchner, 2007) suggested that a sample of 166 participants would be needed to detect a medium-sized global effect (f^2 = .15; Cohen, 1992) across the planned analyses (each consisting of two groups and nine response variables). However, for the purposes of increasing likelihood of detection of a smaller effect and ensuring adequate power following removal of any invalid data, a target sample size of 200 participants was selected for the current study.

Recruitment strategy. Participants were recruited using the University of Windsor's psychology department participant pool. The participant pool system provides students with the opportunity to participate in psychological research in exchange for bonus credit in applicable psychology courses (1 credit = 1 hour of participation). Although the pool system allows for the use of exclusionary criteria (i.e., participants not eligible for a given study will be unable to view that study), exclusionary criteria were not deemed necessary for the current study.

Using these methods, 200 participants were recruited to complete measures used in the present study and in the study reported in Chapter IV. Demographic/background

information for the current sample are reported in Table 1; rates of neuroenhancement endorsement for the sample are reported in Table 2. Briefly, slightly more than half of participants identified as female (57.5%). Participants were also primarily Caucasian (55.5%) and in an academic program within the university's Faculty of Arts, Humanities, and Social Sciences (68.8%). Participants were relatively balanced across first year (20%), second year (17.5%), third year (32.0%), and fourth year of their university studies (21.5%). A small minority of participants indicated that they were in their fifth year and beyond (7.5%).

Measures

As part of a larger study (that also included measures used in the study reported in Chapter IV), participants completed the self-report and performance-based measures used to derive variables of interest for the main analyses, as described below. Descriptive statistics for these measures are reported (both for the total sample and according to specific neuroenhancement groups) in Table 3.

Demographics. A brief measure sampling several demographic constructs relevant to the current study was created for use across the three related studies of this project (Appendix A). Questions included inquiry about a variety of neuroenhancement risk/protective factors (e.g., age, gender, Panhellenic affiliation, sports team involvement, relationship status; e.g. Dollar & Hendrix, 2015; Dussault & Weyandt, 2011; Ford, 2008).

History of neuroenhancement behaviour. On review of the literature, no single appropriate measure was available that could meet the needs of the current study (i.e., measurement of history of neuroenhancement, as defined broadly and via use of specific substances with the intent to enhance cognition). As such, a series of was assembled for

this study. Similar to the approach described by previous researchers (e.g. Franke et al., 2011; Gallucci, Martin, & Usdan, 2015; Gallucci, Usdan, Martin, & Bolland, 2014; Maier et al., 2013; Schelle et al., 2015), participants were asked to identify whether they had used a range of substances for the purpose of neuroenhancement, over the course of three time-frames (i.e., lifetime, past year, past 30 days). Participants were also asked to report the frequency of use for each of these substances during these three time-frames (Gallucci et al., 2014, 2015).

Coding history of neuroenhancement. The primary method used for coding neuroenhancement was intended to distinguish specific categories of neuroenhancement behaviour. This was accomplished by creating a variable coding neuroenhancement history for each of the three categories put forth by Franke and colleagues (Andreas G. Franke et al., 2014): (1) legal/"soft" neuroenhancement (e.g. use of caffeine, nicotine, over-the-counter supplements for neuroenhancement), and the two classes collectively referred to as "pharmacological cognitive enhancement" (e.g., Franke et al., 2013): (2) prescription drug neuroenhancement (e.g., use of ADHD medications, beta blockers, prescription wakefulness promoters such as Modafinil, with the intent to enhance cognition) and (3) illicit drug neuroenhancement (e.g., use of illegal substances, such as cocaine, speed with the intent to enhance cognition).

These variables were coded dichotomously, although slightly different approaches were taken to classifying the dichotomous nature of the legal vs. pharmacological cognitive enhancement variables. For legal neuroenhancement, a dummy-coded variable was created for which the reference group (coded "0") reflected no endorsed lifetime history of legal enhancement. Participants who endorsed lifetime history of legal

neuroenhancement were coded positive ("1") on this variable. For the pharmacological cognitive enhancement categories, a variable was created for each category (i.e., illicit drug neuroenhancement, prescription drug neuroenhancement). Participants were coded positive ("1") on each variable if they endorsed lifetime history of the corresponding behaviour. For both illicit substance neuroenhancement and prescription drug neuroenhancement, the reference group reflected participants who denied *any* lifetime history of pharmacological cognitive enhancement generally (i.e., lifetime history of neither illicit drug neuroenhancement nor prescription drug neuroenhancement). Participants who denied the use of the target category for neuroenhancement but who had engaged in an alternate form of pharmacological cognitive enhancement were therefore excluded from comparison (e.g., a participant with no history of illicit substance neuroenhancement but positive history of prescription drug neuroenhancement would not be included in the reference group for analyses pertaining to the illicit substance neuroenhancement category). This coding scheme was employed in order to reduce any confound that would be introduced by including other modes of pharmacological cognitive enhancement in the reference group.

Self-control. The current study utilized a multi-method approach in the measurement of self-control. Specifically, the included measures sampled a variety of foundational self-report measures of self-control. Performance-based measures of self-control were also included as a complement to self-report measurement of this construct. This decision was guided by research demonstrating that self-report measures may be limited by sources of bias in reporting (Podsakoff, MacKenzie, Lee, & Podsakoff, 2003;

Van de Mortel, 2008) and that performance-based measures of self-control account for variance that is distinct from self-report measures (Duckworth & Kern, 2011).

Self-Control Scale. The Self-Control Scale (Tangney et al., 2004) is a 36-item questionnaire designed to measure variation in dispositional self-control. For each item (e.g., "I refuse things that are bad for me"), participants are asked to rate the degree to which the statement applies to him- or herself on a scale from one ("not at all") to five ("very much"). The items of the Self-Control Scale generally emphasize one's capacity to "override or change one's inner responses, as well as to interrupt undesired behavioral tendencies (such as impulses) and refrain from acting on them" (Tangney et al., 2004, p. 274). Thus, items generally reflect individuals' ability to regulate attention/cognition, emotions, and behavioural impulses, and to persist on tasks. The authors of the Self-Control Scale report good psychometric characteristics for the measure, including internal consistency ($\alpha = .89$), test-retest reliability ($r = .89$), and evidence for convergent and discriminant validity. Internal consistency was good in the current sample ($\alpha = .86$).

Barratt Impulsiveness Scale. The Barratt Impulsiveness Scale (BIS-11; Patton, Stanford, & Barratt, 1995) is a 30-item questionnaire that measures a variety of behaviours related to trait impulsivity (and conversely, dispositional self-control). Items of the BIS-11 broadly tap impulsivity related to direction of attention and behaviour, and failure to value long-term goals (Stanford et al., 2009); as such, the focus of this measure is similar to, but distinct from, that of the Self-Control Scale. Responses on the BIS-11 can be used to derive scores for three subscales: Attentional Impulsiveness (e.g. "I don't pay attention"; "I often have extraneous thoughts when thinking"), Motor Impulsiveness (e.g., "I act 'on impulse'"; "I am future oriented"—reverse scored), and Non-Planning

Impulsiveness (e.g. "I plan tasks carefully"). In previous research, internal consistency values for the subscales have been variable ($\alpha_{attentional}$ = 0.74, α_{motor} = 0.59, $\alpha_{non\text{-}planning}$ = 0.72; Stanford et al., 2009). In the current sample, internal consistency of the BIS subscales ranged from questionable (α_{motor} = .67) to acceptable ($\alpha_{attentional}$ = .77, $\alpha_{non\text{-}planning}$ = .70).

Big Five Inventory. The Big Five Inventory (BFI; John, Donahue, & Kentle, 1991; John, Naumann, & Soto, 2008) is a self-report questionnaire measuring variation on the five traits comprising the Five Factor Model of personality (McCrae & Costa, 1987). For each of the 44 items, participants were asked to rate the degree to which a given characteristic applies to him- or herself, using a scale ranging from one ("disagree strongly") to five ("agree strongly"). In comparison to the Self-Control Scale and the BIS-11, the BFI items appear to most often frame the underlying self-control constructs in terms of characterological traits, rather than specific behaviours. From these items, factor scores may be calculated for each of the Big Five traits. Given the scope of the present study, only the factor scores for Conscientiousness (e.g., "can be somewhat careless"—reverse scored) and Neuroticism (e.g., "is emotionally stable, not easily upset"—reverse scored) were utilized. Test-retest reliability for the BFI Conscientiousness and Neuroticism scores has been shown to be acceptable ($r_{conscientiousness}$ = .70, $r_{neuroticism}$ = .76; Rammstedt & John, 2007). The subscale scores have demonstrated acceptable-to-good part-whole correlations in previous studies ($\alpha_{conscientioousness}$ = .77 - .84; $\alpha_{neuroticism}$ range = .85 - .88; Rammstedt & John, 2007). Internal consistency in the current sample was good for both the Conscientiousness subscale (α = .80) and the Neuroticism subscale (α = .84).

Barkley Adult ADHD Rating Scale. Also included in the present study was a measure of participant's current ADHD symptoms, the Barkley Adult ADHD Rating Scale-IV (BAARS-IV; Barkley, 2011). The BAARS-IV quantifies participant's scores for each of the ADHD diagnostic criteria, as originally laid out in the fourth edition of the *Diagnostic and Statistical Manual for Mental Disorders* (American Psychiatric Association, 2000) and as remains unchanged in the updated fifth edition (APA, 2013). For each of the 27 diagnostic criteria, participants were asked to rate how often that item has applied to them over the course of the past six months, using a four-point scale ([1] = "never or rarely" to [4] = "very often"). Researchers may derive both total scores and symptom counts for each of four symptom factors (Inattention, Hyperactivity, Impulsivity, and Sluggish Cognitive Tempo). Additionally, a BAARS-IV total score can be computed; it was the metric that was used in the present investigation. According to the author, the BAARS-IV total score boasts excellent reliability ($\alpha = .91$) and evidence of construct validity (Barkley, 2011). Internal consistency of the BAARS-IV total score was excellent in the current sample ($\alpha = .98$).

Delay Discounting Task. For the current study, delay discounting was included as a performance-based measure of self-control. Delay discounting refers to individuals' tendency to prefer small, immediate rewards over larger, future rewards, to the extent that they begin to devalue rewards that occur after a delay (Mazur, 1987). Delay discounting is implicated in impulsivity and self-control, and there is evidence to suggest that individuals' degree of delay discounting may constitute a trait construct (Kirby, 2009). This variance accounted for by performance-based measures of self-control, such as the

delay discounting task, has been shown to be considerably distinct form self-report measures (Duckworth & Kern, 2011).

In the present study, participants' degree of delay discounting was measured via a computerized task administered using the Psychopy platform v.1.83.04 (Peirce, 2007). This task, designed by Johnson and Bickel (2002), provides participants with a series of choices between reward options, delivered immediately and after varying latencies (on the order of days, months, and years) and of varying monetary values. In line with the majority of research investigating delay discounting (Odum, 2011a), the rewards in this study were purely hypothetical. (It should be noted that there are no observable differences in delay discounting on tasks providing hypothetical vs. actual rewards; Odum, 2011a). For each immediate-delayed reward pair, an *indifference point* is located, at which participants choose the smaller, immediate reward approximately as often as they choose the larger, delayed reward (i.e., they are indifferent to the smaller vs. larger reward).

Several formulae exist for deriving a representative score from delay discounting tasks. For the current study, use of the "area under the curve" of the discounting function (AUC; Myerson, Green, & Warusawitharana, 2001) was selected as the most optimal metric of participants' delay discounting. The AUC is derived from the following equation:

$$x_2 - x_1\ [(y_1 + y_2)/2]$$

In this equation, x_1 and x_2 represent the magnitude of the respective delays. The y values represent the monetary value of the indifference points corresponding to each delay (Odum, 2011a). This equation is applied to each consecutive delay/indifference point

pairing, and the resultant values are added together. Values of the AUC potentially range from 0 to 1 (reflecting complete delay discounting and no delay discounting, respectively). The AUC boasts several advantages over other delay discounting derived scores (e.g., *k*), including that it is atheoretical and tends to be more normally-distributed than the *k* statistic (and therefore preferable for inferential analyses; Myerson et al., 2001).

Stroop color-word task. The Stroop color-word task is among the most frequently-employed measures of self-control (Duckworth & Kern, 2011). In contrast to the delay discounting task, the Stroop task is considered a measure of ability to inhibit prepotent responses. Given high test-retest reliabilities (Franzen, Tishelman, Sharp, & Friedman, 1987; Strauss, 2005), there is evidence to suggest that Stroop performance taps a trait construct (c.f. Odum, 2011b). A version of this task was included as a second performance-based measure of self-control in the present study. In keeping with multiple previous studies of self-control (e.g. Fennis, Janssen, & Vohs, 2009; Gailliot et al., 2007; Gailliot, Schmeichel, & Baumeister, 2006; Inzlicht, McKay, & Aronson, 2006), the Stroop task was administered by computer. The specifics of the Stroop protocol utilized in this study were patterned from work by Gailliot and colleagues (2006).

In each trial of the Stroop task, participants were presented with a color word (e.g. RED, BLUE, or GREEN) which was displayed in either a congruent text color (e.g., BLUE printed in blue-colored text) or an incongruent color (e.g., BLUE printed in red-colored text). Participants were asked to indicate the font color of each displayed word using the computer keyboard (i.e., pressing the *R*, *G*, or *B* key), ignoring the word itself. Participants first completed a practice phase to ensure that they understood the task.

Following the practice phase, participants completed three blocks of the main Stroop task. In blocks one and three, participants completed 30 congruent trials per block. In the second block, participants completed 60 incongruent trials.

In measuring participants' Stroop task performance, self-control was quantified in terms of participants' reaction time in completing the interference trials, as this metric has been demonstrated to be the most stable measure of Stroop-derived self-control (Strauss, 2005). Supplementary scores (e.g., total errors on congruent and incongruent trials; Gailliot et al., 2006) were also calculated and are reported below in order to remain consistent with other studies in the self-control literature.

Procedure

Following approval from the university's research ethics board, an advertisement for the current study was posted to the psychology participant pool website, inviting participants to sign up for a timeslot to participate. At the scheduled time, participants came to the lab and completed the informed consent process. Questionnaire data and self-control tasks were then administered on a computer, in random order, with validity check items interspersed throughout to ensure included data were valid (i.e., free from random / invalid responding). If invalid responses were detected, a prompt (to check all responses prior to proceeding) was automatically administered via the online survey platform.

Data Analysis

Data preparation. Before conducting the main analyses, data were examined for missing data. Analysis of missing data points revealed a sparse pattern of missing data, with 3.73% of values missing across the variables of interest. According to Little's

(1988) test of patterns of data missingness (i.e., "Missing Completely at Random [MCAR]"), these missing data points were missing completely at random (χ^2 (12310) = 9913.09, p = 1.00). Expectation maximization, a commonly-utilized strategy for missing data imputation, was deemed appropriate for imputation of missing data due to the small quantity and random pattern of missing data. All analyses were completed in IBM SPSS Statistics for Windows, version 19 (IBM Corp., Armonk, N.Y., USA).

Data were also checked for violations of the statistical assumptions of multivariate analysis of variance (MANOVA; Field, 2009). MANOVA assumes multivariate normality; examination of skew and kurtosis values (i.e. skewness < |2|, kurtosis < |3|) and visual inspection of variable histograms suggested that dependent variables included in the MANOVA analyses adequately approximated the normal distribution. MANOVA also assumes homogeneity of variance-covariance matrices. Box's test was nonsignificant across models examining the association of multivariate self-control with legal substance neuroenhancement (F(45, 187.24) = 0.95, p = .58), illicit substance neuroenhancement (F(45, 22547.28) = 0.95, p =.57), and prescription drug neuroenhancement (F(45, 25041.72) = 1.00, p = .46), suggesting that this assumption was not violated in the present sample.

The MANOVA assumption of independence of observation was met as a function of sampling procedures; participants were permitted to contribute only one case to the current dataset. It should be noted that MANOVA also assumes that data comprise a random sample of the overall population (Field, 2009). As participants were sampled from the university's participant pool, they may not be representative of the general

population (Gallander Wintre, North, & Sugar, 2001). This must be considered when interpreting results of the MANOVA analyses.

MANOVA also assumes absence of outliers; as such, data were examined for presence of outliers ($z > \pm 3.27$; Tabachnik & Fidell, 2001). Three cases constituted outliers and were therefore excluded from subsequent analyses. The data were also examined for indicators of invalid responding (i.e., participant failed or did not respond to one or more attention check items). An additional seven cases were removed on this basis, resulting in a final sample of $N = 190$ for subsequent analyses.

Main analyses. A series of three MANOVA models was conducted, separately examining the multivariate association of the array of self-control variables with the three dichotomous neuroenhancement history variables (i.e., legal neuroenhancement, illicit neuroenhancement, and prescription drug neuroenhancement). For each model, the nine self-control variables were entered as the dependent variables (Self Control Scale total score; BIS-11 Attentional Impulsiveness, Non-Planning Impulsiveness, and Motor Impulsiveness; BAARS-IV total score; BFI Conscientiousness and BFI Neuroticism; delay discounting AUC; Stroop incongruent trials response time). As sample size was unequal across the cells of the analysis (due largely to the high proportion of participants who endorsed legal neuroenhancement; see Table 3), statistical adjustment for unequal sample size was undertaken using a built-in feature of SPSS.

Although the practice of probing statistically-significant MANOVA effects with multiple follow-up analyses of variance (ANOVAs) is conventional, it has been suggested that this approach ignores the relationship between dependent variables. Additionally, the practice of following a statistically-significant MANOVA with multiple

ANOVAs does not allow for identification of any dimension(s) that underlie the measured constructs and that systematically vary across groups (Field, 2009). In order to enhance ability to establish a theoretical framework for understanding (and differentiating) various classes of neuroenhancement behaviour, statistically-significant MANOVAs were followed by discriminant function analyses (DFAs). Loadings (i.e., correlations of the standardized discriminant function coefficients with the resultant variate in each model) were considered meaningful if they exceeded 0.364, according to the guidelines proposed by Stevens (2002) for samples of this size.

Results

Results for each neuroenhancement model are reported below. As a supplement to results reported for each MANOVA model, variable intercorrelations are presented in Table 4.

Legal neuroenhancement. Results demonstrated a medium-sized, statistically-significant effect of lifetime history of legal neuroenhancement on the multivariate array of self-control variables ($\lambda = .90$, $F(9, 180) = 2.28$, $p = .02$, partial $\eta^2 = .10$; observed power = .91). DFA yielded a single discriminant function (canonical $R^2 = .10$) that significantly differentiated participants who endorsed legal neuroenhancement from those who did not ($\chi^2(9) = 20.06$, $p = .02$). The correlations between standardized coefficients and the discriminant function revealed large loadings of self-rated self-control ($r = -.68$), non-planning impulsiveness ($r = .67$), motor impulsiveness ($r = .63$), attentional impulsiveness ($r = .56$), and ADHD symptoms ($r = .56$) onto the variate. Associations of the variate with neuroticism ($r = .36$), conscientiousness ($r = -.29$), delay discounting AUC ($r = .25$), and Stroop response inhibition ($r = -.22$) did not exceed the *a priori*

threshold (r = 0.364). Examination of the unstandardized function values at group centroids indicated that lower scores on the variate conferred lower risk for legal neuroenhancement history endorsement. Thus, *abstinence* from legal neuroenhancement appeared to be a function of better self-rated self-control (reflected in the linear combination of higher self-rated self-control, lower self-rated impulsiveness, and lower self-rated ADHD symptoms).

Illicit drug neuroenhancement. There was also a medium-sized, statistically-significant multivariate effect of lifetime illicit drug neuroenhancement on the array of self-control variables (λ = .89, $F(9, 151) = 1.94$, p = .03, partial η^2 = .11). Although this analysis was based on a subset of the sample that was marginally smaller than the *a priori* estimated size needed to detect a medium effect (n = 161 vs. estimated required N = 166), observed power exceeded the conventional threshold of .80 (observed power = .88). DFA identified a single discriminant function (canonical R^2 = .11) that significantly differentiated participants who endorsed illicit drug neuroenhancement from those who did not ($\chi^2(9) = 18.22$, p = .03). The correlations between standardized coefficients and the discriminant function revealed large loadings of motor impulsiveness (r = .55), ADHD symptoms (r = .52), and self-rated self-control (r = -.50) onto the variate. Small loadings were also observed for attentional impulsiveness (r = .39) and delay discounting AUC (r = .38). Associations of the variate with Stroop response inhibition (r = -.36), neuroticism (r = .26), conscientiousness (r = -.24), and non-planning impulsiveness (r = .09) did not reach the *a priori* threshold for interpretation. Examination of the function values at group centroids revealed that positive history of illicit substance neuroenhancement was associated with higher scores on the variate. Thus, illicit

substance neuroenhancement appeared to be a function of poorer self-rated self-control (reflected in the linear combination of greater motor impulsiveness, greater ADHD symptoms, and poorer self-control), but (somewhat paradoxically) *less* impulsive performance on the delay discounting task (i.e., higher AUC values, reflecting a more shallow temporal discounting gradient and therefore less decisional impulsiveness among participants with history of illicit substance neuroenhancement; Myerson, 2001).

Prescription drug neuroenhancement. In the model comparing individuals with positive lifetime history of prescription drug neuroenhancement to those with no history of pharmacological cognitive enhancement, the multivariate effect of prescription drug neuroenhancement was small-to-medium-sized (partial $\eta^2 = .08$) but not statistically-significant ($\lambda = 0.92$, $F(9, 163) = 1.59$, $p = .12$). This finding was surprising considering the robust body of research demonstrating an association of non-medical use of prescription drugs (particularly stimulants) with self-control (see above). However, it should be noted that although the subsample used for these analyses ($n = 173$) exceeded the necessary sample size determined by *a priori* power analyses ($N = 166$), observed power was slightly lower than the conventional .80 criterion for power (observed power = .75), suggesting minimally increased possibility of Type II error in this model.

Given the unexpected failure to demonstrate a multivariate effect of prescription drug neuroenhancement on multivariate self-control and marginally increased Type II error probability regarding detection of the multivariate effect in this model, exploratory univariate analyses were used to probe for univariate associations of specific self-control variables (Table 5). Results demonstrated statistically-significant ($p < .05$) associations of lifetime history of prescription drug neuroenhancement with self-reported ADHD

symptoms, overall self-rated self-control, and attentional impulsiveness. With the exception of ADHD symptoms (p = .005), these results did not withstand application of Bonferroni correction for multiple comparisons (p <.006).

Follow-up analyses after removal of irregular delay discounting data. Associations of delay discounting were in the opposite direction than would be anticipated on the basis of poorer self-control among individuals who engaged in the various classes of neuroenhancement behaviour. Although this relation was statistically-significant in Model 2, examination of group means (Table 3) revealed that this pattern existed (although was not statistically-significant) across all classes of neuroenhancement. Because of this unexpected pattern, delay discounting data were examined for irregular patterns impacting the discounting curve (i.e., curve reflects devaluation of larger immediate rewards in favor of smaller delayed rewards). The pattern of results described above was unchanged following removal of affected cases (n = 10).

Discussion

The present study aimed to investigate associations of trait self-control variation with neuroenhancement. Multivariate associations of three modes of neuroenhancement behaviour (legal neuroenhancement, illicit drug neuroenhancement, prescription drug neuroenhancement) with a constellation of self-control variables were explored.

Results suggested that self-control was associated differentially with the three modes of neuroenhancement behaviour. Specifically, there was a statistically-significant multivariate association of self-control with both legal neuroenhancement and illicit drug neuroenhancement. Discriminant function analyses suggested medium-to-large loadings

of self-rated self-control (as measured by the Self Control Scale), ADHD symptoms, motor impulsivity, and attentional impulsivity onto variates explaining both the legal neuroenhancement and illicit neuroenhancement variables. Another mode of impulsivity (non-planning impulsiveness) also loaded heavily onto the variate explaining legal neuroenhancement history, but not onto the illicit substance neuroenhancement variate. Conversely, a performance-based measure of self-control (delay discounting) loaded meaningfully only onto the illicit neuroenhancement variate, although interestingly, the observed direction of this relation was in the opposite direction than would be anticipated by an association of poor self-control with illicit substance neuroenhancement (i.e., higher delay discounting AUC values—typically interpreted as *less impulsive* delay discounting performance—were identified for the illicit substance neuroenhancement group relative to participants who had not engaged in pharmacological cognitive enhancement). Finally, although no statistically-significant *multivariate* effect of prescription drug neuroenhancement history on self-control existed, a statistically-significant (following correction for multiple comparisons) univariate association of self-rated ADHD symptoms with prescription drug neuroenhancement history was identified.

Taken together, these results suggested an overall association of self-control with neuroenhancement that is identifiable *across* substance-specific categories of neuroenhancement. This outcome is consistent with the extant literature, which has demonstrated an association of various facets of self-control with neuroenhancement (e.g., Ilieva & Farah, 2015; Lookatch et al., 2012; Peterkin et al., 2011). Importantly, much of the existing body of work has focused on the substance-specific class of neuroenhancement comprising non-medical use of prescription stimulants. The current

study uniquely highlights an association of lower self-control with neuroenhancement broadly, including both legal neuroenhancement and two classes of pharmacological cognitive enhancement (illicit drug neuroenhancement and prescription drug neuroenhancement).

Notably, the symptoms of ADHD appeared to be a particularly unifying "thread" underlying all three classes of neuroenhancement in the current study. Thus, these results lend credence to the hypothesis that neuroenhancement may constitute self-medication for undiagnosed, under-treated, or sub-clinical ADHD symptoms—an assertion supported by empirical associations of ADHD symptoms with non-medical use of prescription stimulants (e.g., Wilens et al., 2008) and in qualitative interviews of students who engage in this behaviour (Desantis & Hane, 2010). As such, students' perceptions of deficient self-control of attention and impulses (as reflected both on self-report ratings and qualitative self-report) appears to confer general risk for engagement in neuroenhancement.

Despite a shared association of self-control among the three neuroenhancement classes, the pattern of *specific self-control associations* diverged with regards to neuroenhancement mode. Specifically, a similar array of variables appeared to drive associations of both legal and illicit neuroenhancement with multivariate self-control. These included motor impulsiveness, attentional impulsiveness, and overall self-rated self-control (Self-Control Scale). Interestingly, these associations did not replicate for prescription drug neuroenhancement, suggesting that this latter category may be distinct (conceptually, and in the mind of students who engage in neuroenhancement) from legal and illicit drug neuroenhancement.

Additionally, an association of performance-based measures of self-control with neuroenhancement was not consistently demonstrated across various classes of this behaviour. Indeed, response inhibition (Stroop) did not demonstrate meaningful loadings onto the variates predicting either legal or illicit drug neuroenhancement histories, and delay discounting performance loaded only onto the illicit drug neuroenhancement variate. Surprisingly, the observed relation of delay discounting AUC with the variate explaining illicit drug neuroenhancement was in the opposite direction than would be anticipated (at the surface, reflecting less severe decisional impulsiveness and therefore more robust self-control among students who had history of illicit substance neuroenhancement).

This result is paradoxical, given that self-report measures in the same model appear to demonstrate a protective effect of self-control against illicit drug neuroenhancement. However, poor congruence between self-report and performance-based measures of self-control is not unexpected, and indeed, previous research has demonstrated only small correlations between self-report and performance-based measures of a range of psychological and behavioural constructs—including self-control (Duckworth & Kern, 2011). In addition to this issue, it bears noting that unequal cell sizes may have impacted these results. Therefore, replication in additional samples (particularly samples designed to equally recruit individuals with history of various modes of neuroenhancement behaviour) will be necessary to enhance confidence in the reliability of this result.

Despite these practical concerns, it is interesting that (among the current sample) history of illicit substance neuroenhancement most frequently reflected reported use of

cannabis for cognitive enhancement purposes. The variate predicting this behaviour was distinct from that predicting legal neuroenhancement; although both models indicated that individuals who engage in legal neuroenhancement and illicit drug neuroenhancement rate themselves as having poorer self-control, illicit drug neuroenhancement was also differentiated on the basis of *less* decisional impulsiveness (delay discounting AUC). These findings may highlight a meaningful distinction between legal and illicit neuroenhancement; namely, that illicit drug neuroenhancement may reflect a degree of planful behaviour not required for legal substance neuroenhancement (due to the wide availability of legal and over-the-counter neuroenhancement substances versus the greater effort and risk associated with obtaining cannabis and other illicit drugs). As such, would-be consumers of illicit substances for neuroenhancement may be required to obtain these substances in advance of their use, whereas legal neuroenhancement substances are readily available to bolster academic work.

It is interesting to note that, in contrast to research in other substance use groups (who generally demonstrate greater temporal discounting than unaffected controls), an association between cannabis use (for any purpose) and temporal discounting has not been consistently borne out among abstinent users (e.g., Gonzalez et al., 2012) or even following acute administration of Δ^9-tetrahydrocannabinol (THC), the psychoactive compound present in cannabis (McDonald, Schleifer, Richards, & de Wit, 2003). Therefore, further research is certainly needed in order to replicate and fully understand the clinical importance of this result.

It is important to highlight that the use of cannabis for illicit neuroenhancement is also differentiated from legal neuroenhancement on the basis of cannabis's presumed functionality. In addition to the perception that cannabis is able to directly facilitate cognitive processes such as attention and creativity (Green, Kavanagh, & Young, 2003), users report instrumental engagement in cannabis use for its purported stress- and negative affect-reduction effect. Indeed, existing literature has demonstrated an association of anxiety, academic stress, and negative affectivity with cannabis use (Middendorff, Poskowsky, & Isserstedt, 2012). It then seems plausible that, rather than engaging in neuroenhancement impulsively, some students may engage in higher-risk behaviours such as cannabis use to reduce negative affectivity in support of cognitive enhancement. For example, Maier and colleagues (2013) suggest that "a well-rested brain likely learns more efficiently. Thus, for example, the consumption of cannabis or alcohol with the purpose of calming oneself, turning off recurring thoughts, and falling asleep would allow one to be more vigilant and increase concentration the following morning" (pp. 7-8) and as such may qualify as neuroenhancement behaviour. However, given such prior research, it is interesting that neuroticism did not load highly onto the illicit substance neuroenhancement variate in the current study. Further research involving both self-control and a more diverse range of psychological variables will be helpful in continuing to lend clarity to the mechanisms that drive neuroenhancement substance selection.

In addition to unequal sample size, further limitations of the current study must be noted. First, the decision to utilize pharmacological cognitive enhancement-naïve participants (i.e., those who had engaged in neither illicit drug nor prescription drug

neuroenhancement) resulted in a somewhat smaller available subsample of data available for these analyses. Thus, although an attempt was made to over-recruit for the present study in order to allow for adequate power for each of the three models in the final sample, it must be noted that the observed power in for the model explaining prescription drug neuroenhancement was slightly lower than the conventional criterion (.80; observed power for Model 3 = .75). Therefore, a minimal increase in Type II error probability must be acknowledged for this model. Replication in a larger sample may clarify the failure to identify a multivariate effect of prescription drug neuroenhancement history on self-control in the current sample.

Additionally, in keeping with much of the previous literature in this area (e.g., Maier et al., 2013; White, Becker-Blease, & Grace-Bishop, 2006), the current study defined neuroenhancement in terms of lifetime history of this behaviour. However, there certainly exist varying degrees of engagement in neuroenhancement behaviour, ranging from one-time to occasional and daily use. Investigation of frequency of neuroenhancement behaviour in future studies will be an important factor in understanding the neuroenhancement construct (Schleim & Quednow, 2018).

Although it is representative of the university where participants were recruited, the generalizability of the current sample should also be considered. The current sample included a majority of Caucasian (55.0%) participants. Given previous demonstration of effects of ethnicity on neuroenhancement behaviour (Wilens et al., 2008), it remains unclear to what extent the current findings are generalizable to more diverse student groups. Additionally, participant gender has been demonstrated to confer neuroenhancement risk (Dussault & Weyandt, 2011; Ford, 2008). Although the current

sample did include slightly more female than male participants, it must also be noted that gender was, in fact, more equally-distributed in the current study than is common among studies utilizing psychology participant pool samples (which tend to be disproportionately female; Dickinson, Adelson, & Owen, 2012) despite no specific effort to recruit an equal gender distribution in the current study. Although this feature of the current sample likely increases its generalizability to the university student population broadly, it likely decreases the ability to compare current findings to studies based on more typical undergraduate participant samples.

Finally, it should be acknowledged that the prevalence of neuroenhancement has been shown to vary based on university size and competitiveness of one's academic program/school (Desantis & Hane, 2010; McCabe, Knight, Teter, & Wechsler, 2005). As the current sample was recruited from a mid-sized, public university, prevalence estimates may not generalize to more competitive academic environments. Nonetheless, it should be noted that prevalence rates among the current sample were quite high, and in the case of legal neuroenhancement, the sample demonstrated near-ubiquitous engagement in this behaviour.

Despite these limitations, results of the current study have important implications for the scholarly understanding and use of the neuroenhancement construct. Per current results, a common association self-control (namely, ADHD symptoms) and neuroenhancement generally appears to exist. However, although it has been suggested that neuroenhancement may be "collapsible" into a unitary construct (Englert & Wolff, 2015), current findings contend that doing so may wash out subtle distinctions between modes of neuroenhancement. Based on the current study, prescription drug

neuroenhancement appears to be a particularly distinct category, as (unlike legal and illicit neuroenhancement) it failed to demonstrate a relation with multivariate self-control. Thus, ongoing research may benefit from continued treatment of these constructs as distinct in order to enhance ongoing understanding of the risk factors of engagement in the range of neuroenhancement behaviours.

Table 1

Study 1 Participant Demographic Characteristics (N = 200)

		percent endorsed
Gender	Female	57.5
	Male	41.5
	No response	1.0
Ethnic background[1]	Aboriginal/First Nations	1.0
	Black/African	12.0
	East Asian	3.0
	South Asian/Indian	7.5
	Hispanic/Latino	2.5
	Caucasian or non-Hispanic White/European	55.0
	Arab/Middle Eastern	12.0
	Biracial/multiethnic	5.5
	Other	0.5
	Prefer not to answer	1.0
Academic faculty (program of study)	Arts, humanities, and social sciences	68.0
	Education	1.0
	Engineering	2.5
	Kinesiology	5.0
	Law	0.0
	Nursing	4.0
	Business	8.5
	Science	9.0
	Undecided	0.5
	No response	1.5
Honors status	Enrolled in honors program	7.0
	Not enrolled in honors program	91.5
	No response	1.5
Year of study	First	20.0
	Second	17.5
	Third	32.0
	Fourth	21.5
	Fifth	7.0
	Sixth and beyond	0.5
	No response	1.5
		M (SD)
Age		21.59 (4.37)
GPA (%) –university cumulative average*		78.29 (8.16)
GPA (%) – last semester average**		79.43 (8.48)

Note. [1]Categories are not mutually-exclusive. Abbreviation: GPA = grade point average. *university cumulative average only available for students in their second semester and beyond. **students in their first semester were asked to report last semester of high school GPA.

Table 2

Study 1 Descriptive Statistics: Participant Endorsement of Various Modes of Neuroenhancement – Full Sample (N = 200)

Neuroenhancement Category	% Endorsed (Lifetime)
Legal Neuroenhancement	**94.0**
Coffee	84.5
Energy Drinks	60.5
Caffeine Supplements	19.5
Herbal Supplements	33.5
Probiotics	16.0
Alcohol	28.0
Nicotine	17.5
Pharmacological Cognitive Enhancement	**37.0**
Illicit Drug Neuroenhancement	22.5
Marijuana	21.0
Other Illicit Substances	6.0
Neuroenhancement via Non-Medical Use of Prescription Stimulant / ADHD Medication	23.5
Methylphenidate (e.g. Ritalin)	6.0
Amphetamines (e.g., Adderall)	18.5
Modafinil (e.g. Provigil)	0.5
Omecetin (e.g., Cognient) – Foil	0.0
Other/unknown ADHD medication	11.5
Neuroenhancement via Non-Medical Use of Any Prescription Medication[1]	28.0
Beta-blockers	0.5
Other prescription medication	8.0
Any Neuroenhancement	**95.5**

Note. Neuroenhancement categories are not mutually-exclusive. [1]Includes neuroenhancement via non-medical use of prescription stimulant/ADHD medications *and* beta-blockers *and* other prescription medications.

Table 3

Study 1 Descriptive Statistics for Variables of Interest, by Total Sample and Per Neuroenhancement History Groups – Final Sample (N = 190)

	M (SD)					
		Legal Neuroenhancement		Pharmacological Cognitive Enhancement		
	Total Sample	Not Endorsed	Endorsed	Not Endorsed[1]	Illicit Drug Neuroenhancement Endorsed	Prescription Drug Neuroenhancement Endorsed
group *n* (% of final sample)	*N* = 190 (100%)	*n* = 12 (6.3%)	*n* = 178 (93.7%)	*n* = 120 (63.16%)	*n* = 41 (21.57%)	*n* = 53 (27.9%)
BIS						
Attentional	18.10 (4.10)	15.17 (2.66)	18.29 (4.11)	17.68 (3.84)	18.98 (4.72)	19.24 (4.06)
Motor	21.83 (4.47)	18.25 (2.83)	22.07 (4.46)	21.32 (4.17)	23.25 (4.93)	22.53 (4.84)
Non-Planning	25.58 (4.86)	21.42 (4.06)	25.86 (4.79)	25.33 (4.50)	25.67(5.66)	26.42 (5.31)
BAARS-IV						
Total Score	53.60 (14.11)	43.52 (11.33)	54.28 (14.05)	51.74 (12.94)	57.51 (16.24)	58.05 (14.33)
SCS						
Total Score	116.56 (17.30)	131.61 (11.31)	115.55 (17.19)	118.51 (17.04)	111.57 (17.69)	112.22 (16.49)
BFI						
Neuroticism	24.95 (6.97)	21.67 (6.51)	25.17 (6.96)	24.63 (6.53)	26.08 (7.71)	26.08 (8.15)
Conscientiousness	31.62 (5.92)	33.88 (4.48)	31.47 (5.99)	31.89 (5.85)	30.73 (6.19)	30.70 (6.17)
Stroop						
Total RT – Congruent	41.71 (7.35)	44.09 (8.78)	41.55 (7.24)	42.47 (7.66)	40.06 (7.30)	40.52 (6.10)
Total RT – Incongruent	53.69 (13.81)	57.58 (14.39)	53.43 (13.77)	54.86 (14.82)	50.74 (11.57)	52.14 (12.41)
% Correct – Congruent	96.18 (8.35)	98.47 (2.61)	96.03 (8.58)	96.06 (9.44)	95.69 (7.11)	97.05 (4.27)
% Correct – Incongruent	86.83 (24.26)	96.67 (3.02)	86.17 (24.91)	86.46 (23.74)	84.84 (29.05)	87.64 (25.69)
Delay Discounting						
AUC	0.66 (0.27)	0.57 (0.26)	0.67 (0.27)	0.64 (0.28)	0.72 (0.25)	0.72 (0.25)

Note. Groups reflecting legal neuroenhancement and positive history of pharmacological cognitive enhancement (i.e., illicit drug neuroenhancement, prescription drug neuroenhancement groups) are not mutually-exclusive. [1]Non-endorsement of pharmacological cognitive enhancement reflects endorsement of neither illicit drug nor prescription drug neuroenhancement. Abbreviations: BIS = Barratt Impulsiveness Scale 11; BAARS-IV = Barkley Adult ADHD Rating Scale – Fourth Edition; SCS = Self Control Scale; BFI = Big Five Inventory; RT = Reaction Time; AUC = Area Under the Curve.

Table 4

Variable Intercorrelations

	1	2	3	4	5	6	7	8	9	10	11	12[1]	13[2]	14[3]
1. Age	1.00	.05	.09	-.11	.05	-.10	.11	.01	-.07	.10	-.13†	-.00	-.06	-.10
2. Gender		1.00	.11	-.17*	.02	-.10	.04	-.35***	-.13†	.06	-.04	-.04	.03	.06
3. SCS Total Score			1.00	-.63***	-.50***	-.71***	.73***	-.34***	-.56***	.06	-.06	-.23**	-.17*	-.17*
4. BIS Attentional Impulsiveness				1.00	.46***	.50***	-.50***	.36***	.58***	-.04	.15*	.19*	.14†	.18*
5.BIS Motor Impulsiveness					1.00	.38***	-.29***	.10	.24**	-.02	.02	.21**	.19*	.13†
6. BIS Non-Planning Impulsiveness						1.00	-.60***	.26***	.41***	-.04	-.04	.22**	.03	.11
7.BFI Conscientiousness							1.00	-.26***	-.49***	.05	-.07	-.10	-.09	-.09
8. BFI Neuroticism								1.00	.31***	.05	.03	.12†	.09	.09
9. BAARS-IV Total Score									1.00	.03	.04	.19**	.18*	.21**
10. SCWT Incongruent RT										1.00	-.05	-.07	-.13	-.09
11. Delay Discounting AUC											1.00	.08	.13†	.16†
12. Lifetime legal neuroenhancement history[1]												1.00	.05	.11
13. Lifetime illicit drug neuroenhancement history[2]													1.00	.72***
14. Lifetime prescription drug neuroenhancement history[3]														1.00

Note. All correlations based on final sample (N = 190) unless otherwise noted. [1]dummy coded variable (positive lifetime legal neuroenhancement history [n = 178] vs. negative lifetime legal neuroenhancement history [n = 12]). [2]dummy coded variable (positive lifetime illicit drug neuroenhancement history [n = 41] vs. negative lifetime pharmacological cognitive enhancement history [n = 120]). [3]dummy coded variable (positive prescription drug neuroenhancement history [n = 53] vs. negative lifetime pharmacological cognitive enhancement history [n = 120]). †p < .10; *p < .05; **p < .01; ***p < .001. Abbreviations: BIS = Barratt Impulsiveness Scale 11; BAARS-IV = Barkley Adult ADHD Rating Scale – Fourth Edition; SCS = Self Control Scale; BFI = Big Five Inventory; RT = Reaction Time; AUC = Area Under the Curve.

Table 5

Post-Hoc Univariate Analyses – Lifetime History of Prescription Drug Neuroenhancement vs. No History of Pharmacological Cognitive Enhancement (n = 173)

	t	*df*	*p*	*d*
SCS Total Score	2.25	171	.025	.37
BFI Conscientiousness	1.21	171	.229	.20
BFI Neuroticism	-1.25	171	.213	-.21
BIS Attentional Impulsiveness	-2.43	171	.016	-.41
BIS Motor Impulsiveness	-1.67	171	.097	-.28
BIS Non-Planning Impulsiveness	-1.39	171	.167	-.23
BAARS-IV Total Score	-2.86	171	.005*	.47
Stroop Incongruent Trial RT	1.17	171	.245	.19
DDT AUC	-1.78	171	.078	-.29

Note. Abbreviations: BIS = Barratt Impulsiveness Scale 11; BAARS-IV = Barkley Adult ADHD Rating Scale – Fourth Edition; SCS = Self Control Scale; BFI = Big Five Inventory; RT = Reaction Time; AUC = Area Under the Curve. *statistically-significant after Bonferroni correction ($p < .006$).

III. SELF-CONTROL AND NEUROENHANCEMENT: INVESTIGATING THE EFFECTS OF SELF-CONTROL DEPLETION ON NEUROENHANCEMENT ACCEPTABILITY AND INTENT

Success in the university setting requires that students consistently apply a constellation of cognitive skills to meet academic demands and work toward long-term goals. In recent decades, considerable research has documented an increased trend for university students' use of a range of substances with the intent of bolstering these requisite cognitive functions. This behaviour is broadly termed *neuroenhancement*: the use of psychoactive substances (including *soft enhancers*—i.e., legal, lifestyle drugs such as caffeine, nicotine, and over-the-counter herbal supplements; *prescription drugs*, such as attention-deficit/hyperactivity disorder [ADHD] medications and beta blockers; and *drugs of abuse*, such as alcohol, cannabis, cocaine, heroin, and non-medicinal amphetamines) with the intent to improve one or more domains of cognitive functioning (e.g., concentration, attention, alertness, vigilance, or memory; Maier & Schaub, 2015). Although prevalence estimates are lower for neuroenhancement involving non-medical use of prescription drugs and drugs of abuse—particularly using illicit drugs (e.g., Kaloyanides, McCabe, Cranford, & Teter, 2007; Maier & Schaub, 2015; McCabe, West, Teter, & Boyd, 2014), prevalence estimates for the most common form of neuroenhancement ("soft enhancement" using lifestyle substances) indicate that nearly 90% of university students engage in this form of neuroenhancement (Mache et al., 2012). This statistic reveals that, in contexts like the university, neuroenhancement may be a near-universal phenomenon.

Although the majority of neuroenhancement research has investigated specific modes of neuroenhancement behaviour (e.g., non-medical use of prescription stimulants; Arria et al., 2011; Donaldson, Siegel, & Crano, 2016; Egan, Reboussin, Blocker, Wolfson, & Sutfin, 2013; Gallucci, Usdan, Martin, & Bolland, 2014; Lookatch, Dunne, & Katz, 2012; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2010; Sattler & Schunck, 2016), it has been suggested that neuroenhancement behaviour is united under a shared motive and may thus be best considered a single behavioural construct (Brand & Koch, 2016; Englert & Wolff, 2015; Wolff et al., 2013). In this model, the actual mechanism of action—and whether the mechanism is indeed effective for neuroenhancement—is deemed unimportant. This assumption appears to be supported by the fact that many of these drugs boast only little or mixed evidence of actually enhancing cognition in neurotypical individuals (e.g. Baroni & Castellanos, 2015; Nehlig, 2010).

Importantly, limited evidence of support for the "neuroenhancing effect" among many such substances suggests that the benefit of neuroenhancement fails to outweigh the significant risk associated with reliance on these substances to meet the demands of day-to-day life. Indeed, there is considerable risk of adverse effects associated with misuse even of common, legal neuroenhancement substances. For example, caffeine—commonly consumed with the intent to enhance cognition in the form of coffee, energy drinks, or caffeine tablets—has been associated with insomnia, tachycardia, seizures, and even death in some instances (Clauson et al., 2008). The prospect of addiction and other life-altering medical complications associated with use of other neuroenhancement

compounds likewise highlights the gravity of the issue (Greenhill et al., 2002; Volkow & Swanson, 2003).

Given the weight of this issue, there is great need for studies moving beyond description of the neuroenhancement phenomenon and its correlates into work identifying potential causal mechanisms for neuroenhancement (which may lay the groundwork for intervention and prevention efforts). In support of this aim, the present study builds on emerging research implicating variations in *state levels of self-control* as a potential framework for understanding intent to engage in neuroenhancement behaviour.

Self-Control and Neuroenhancement

The construct of self-control shows promise as a potential mechanism for neuroenhancement behaviour. Self-control may be defined as an essential human capacity to employ higher-order cognitive processes to sublimate or inhibit behavioural, emotional, and cognitive urges. This regulatory process is conducted with the primary goal of moving the individual closer to his or her goal state (de Ridder et al., 2012; Duckworth & Kern, 2011). Variables overlapping with dispositional (i.e., trait) levels of self-control have been frequently found to be inversely related to neuroenhancement behaviour (Dussault & Weyandt, 2011; Lookatch et al., 2012; Maier, Haug, & Schaub, 2015; Rabiner et al., 2010; Sattler & Schunck, 2016). Additionally, similar research regarding doping in sports demonstrated an inverse relation of trait self-control with both athletes' attitudes toward sports-related performance enhancement, and their ratings of intent to engage in the same (Chan et al., 2015). Overall, such findings suggest the importance of the overall ability to regulate one's cognition and behaviour as a factor that protects against engagement in neuroenhancement.

State variation in self-control and its relation to neuroenhancement. Beyond trait-level variation in self-control, it has been suggested that *state* levels of self-control may explain both inter-individual and intra-individual differences in intent to engage in neuroenhancement. Previous authors (Englert & Wolff, 2015; Wolff et al., 2013) have posited that the *self-regulatory strength model of self-control* may be a particularly relevant theoretical framework for conceptualizing neuroenhancement behaviour in terms of state self-control depletion.

The self-regulatory strength model of self-control (also known as the *resource model of self-control* or the *ego strength model of self-control*; e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998; Baumeister, Vohs, & Tice, 2007; Baumeister & Heatherton, 1996) provides a perspective on state variability in self-control that, despite recent controversy surrounding its replicability, has gained status over the past few decades as an influential theory regarding human behaviour. The strength model suggests that exercise of self-control draws on limited resources; much like a muscle, self-control resources (popularly referred to as "willpower") become taxed through repeated or intensive acts of self-control. When an individual has sufficiently "fatigued" his or her capacity for self-control, he or she is said to be in a state of *ego depletion* (or *self-control depletion*), in which self-control failure (and therefore reversion to the individual's dominant behavioural regime) on further tasks requiring self-control is likely (Baumeister et al., 1998).

Importantly, this model posits that all acts of self-control—regardless of the specific behavioural, emotional, or cognitive act involved—draw on the same limited reserve. A wealth of studies has demonstrated that a range of "depleting" acts of self-

control (e.g., choosing a healthy food option over sweets; engaging in a task requiring sustained vigilance and mental effort; filtering out distracting background stimuli during a primary cognitive task; suppressing unwanted thoughts) reduce self-control on subsequent, unrelated acts (Hagger et al., 2010). Thus, an individual may be expected to be incrementally more likely to experience self-control depletion following other acts requiring "willpower".

State self-control depletion and neuroenhancement. Emerging research (Wolff et al., 2013) has experimentally linked state depletion in self-control to neuroenhancement behaviour. Importantly, the strength model posits that when self-control is depleted, individuals revert to their "dominant behavioural response". Thus, individuals with a history of neuroenhancement are more likely to engage in neuroenhancement when they are in a state of self-control depletion. Conversely, individuals who are naïve to neuroenhancement (and therefore have an established dominant behavioural repertoire which does not include neuroenhancement) would be *less* likely to engage in neuroenhancement in a state of self-control depletion (Englert & Wolff, 2015; Wolff et al., 2013). Despite the apparent promise of state self-control depletion in explaining neuroenhancement behaviour, however, there remains a relative paucity of work causally linking depleted self-control to the neuroenhancement construct.

The study conducted by Wolff and colleagues (2013) stands as an exception to the general lack of research in this domain. As the only study to date investigating the effect of state self-control depletion on neuroenhancement behaviour, this work was instrumental in supporting application of the strength model of self-control to neuroenhancement behaviour. It utilized a sample of undergraduate students, all of whom

were neuroenhancement-naïve (i.e., reported that they had never used a substance with the intent to engage in neuroenhancement). Half of these participants were assigned to a control task (not predicted to "deplete" self-control), in which they were asked to quickly and accurately transcribe a passage of text. The other half of the sample was assigned to a self-control depletion condition, in which they were instructed to transcribe the same passage of text (as in the control group), although with the additional instruction to exclude the letters "n" and "e" from their transcription.

Following the experimental manipulation, all participants were told that they would next be asked to engage in a sham concentration task. Participants were then offered a caffeinated product advertised as a means of cognitive enhancement in order to bolster their performance on the upcoming task; their acceptance or refusal of the neuroenhancement product was recorded. In line with the strength model of self-control, the neuroenhancement-naïve participants who had undergone self-control depletion were found to be more likely revert to their dominant behavioural response: abstinence from neuroenhancement (Wolff et al., 2013). Indeed, the depletion group was significantly less likely to accept the opportunity for neuroenhancement when compared to their non-depleted peers. Thus, the strength model of self-control was supported in these neuroenhancement-naïve students' increased likelihood of abstinence from neuroenhancement in a state of ego depletion.

Although Wolff and colleagues' (2013) work constitutes an important first step in implicating state self-control depletion in neuroenhancement, further work is certainly warranted to explore the validity of the strength model in explaining university students' neuroenhancement behaviour. Importantly, Wolff and colleagues' (2013) study did not

yet conclusively demonstrate a causal link between these two constructs. First, the use of only neuroenhancement-naïve participants limits the scope of the authors' conclusions. This aspect of the authors' experimental design was critical for supporting the assumption of the strength model described above: namely, that neuroenhancement-naïve individuals tend to revert to their dominant behavioural response (abstinence) when in a state of self-control depletion. However, additional work is needed to support the application of this assumption to individuals for whom neuroenhancement constitutes a dominant behavioural response--that is, that individuals who have previously engaged in neuroenhancement would be *more* likely to engage in neuroenhancement following self-control depletion. Research into this central assumption is needed in order for self-control depletion to be considered a viable mechanism for neuroenhancement.

Additionally, the dependent measure in the study by Wolff and colleagues (2013)—acceptance or refusal of the caffeinated product for neuroenhancement—constituted a novel, *in vivo* measure of neuroenhancement intent. However, it is important to note that direct assessment of willingness to engage in neuroenhancement may be limited by participants' hesitation to disclose neuroenhancement (particularly in so public a manner as accepting a neuroenhancement substance in a research setting) and social desirability bias (Chan et al., 2015). Indeed, it has been demonstrated that endorsement of neuroenhancement is more likely in studies using a methodology that ensures anonymity of responses (i.e., randomized response technique; Franke, Bagusat, Rust, Engel, & Lieb, 2014). Therefore, though the direct measurement of neuroenhancement intent is valuable—and indeed, Wolff and colleagues (2013) found support for their hypothesis using this methodology—it is feasible that participants may

be more likely to disclose neuroenhancement in a less personal format. Given these limitations, use of computerized assessment of intent to engage in neuroenhancement may be a helpful supplement to the work done by Wolff et al. (2013), as computerized data collection has been demonstrated to produce increased endorsement of risky or stigmatized behaviours (e.g., Booth-Kewley, Larson, & Miyoshi, 2007).

The goal of unobtrusively measuring willingness to engage in neuroenhancement may likewise be accomplished by measuring participants' willingness *indirectly* via measurement of attitudes toward neuroenhancement. Assessment of attitudes constitutes an important secondary avenue for assessment of behaviour; among rigorous studies, attitudes toward a given behaviour tend to overlap considerably with actual instance of the corresponding behaviour and may precede an individual's initial entry into that behaviour (Ajzen & Fishbein, 1977; Wolff & Brand, 2013). In the neuroenhancement literature, attitudes toward neuroenhancement have been shown to predict history of lifestyle neuroenhancement, prescription drug neuroenhancement, and illicit substance neuroenhancement beyond the variance attributable to age and gender (Wolff & Brand, 2013). Moreover, the same study by Wolff and Brand demonstrated that attitudes were a robust predictor of the frequency of lifestyle drug neuroenhancement. These findings highlight the importance of attitudes regarding neuroenhancement and emphasize the need for inclusion of this important variable in future studies of neuroenhancement.

Finally, there is increased need for independent attempts at replication of the self-control depletion effect given current debate regarding its replicability (Blázquez et al., 2017; Friese et al., 2018; Martin S. Hagger & Chatzisarantis, 2016). Thus, further attempts at exploring the self-control depletion effect in the context of neuroenhancement

(using well-validated self-control depletion paradigms) have the potential to speak both to the relation of state self-control variation and neuroenhancement, as well as the *de facto* ability of self-control to be depleted.

The Present Study

Utilizing a quintessential self-control depletion paradigm from the experimental ego depletion literature (Hagger et al., 2010), this study sought to extend the existing work using the strength model of self-control as a conceptual framework for neuroenhancement. Specifically, this study furthers the existing knowledge of neuroenhancement and self-control by investigating the effect of self-control depletion on individuals' *intent to engage in neuroenhancement* and their professed *attitudes toward neuroenhancement.*

In line with demonstrated associations of state self-control variables with neuroenhancement, it was predicted *a priori* that students' (baseline) trait self-control would be significantly associated with neuroenhancement intent and attitudes. Beyond trait self-control, an interaction between self-control depletion condition (i.e., depletion or control task) and baseline history of neuroenhancement was anticipated to predict neuroenhancement intent and attitudes. Specifically, it was expected that individuals with a history of neuroenhancement would be more likely to endorse intent to engage in neuroenhancement and would report more positive attitudes toward neuroenhancement following ego depletion. Conversely, following ego depletion, participants with no history of neuroenhancement would be less likely to endorse intent to engage in neuroenhancement and would report less favorable attitudes toward neuroenhancement. Importantly, the present study aimed to recruit a heterogeneous sample of individuals

with and without history of neuroenhancement, allowing for investigation of the moderating effects of neuroenhancement history on the data relations.

Methods

Participants

Sample size. Based on an *a piori* power analysis conducted using G*Power (Faul et al., 2009, 2007), it was estimated that a sample size of 146 would be required to detect a medium-sized effect. Considering this result—and in order to preserve ability to detect such an effect following removal of any invalid data, a target sample size of 200 (100 participants per experimental condition) was selected for the current investigation.

All undergraduates who were registered in the psychology participant pool were considered eligible to participate; no exclusionary criteria were implemented for study recruitment. However, in order to maintain a balanced distribution of gender and neuroenhancement history in the experimental vs. control groups, data collection was stratified on the basis of gender and neuroenhancement history. This was accomplished as follows: four versions of the study sign-up platform were created in the online participant pool (one for each stratification group; see Table 1) in order to control relative recruitment volume for each stratification group. Participants completed pre-study screening questions (including gender and neuroenhancement history) upon enrolment in the participant pool; on the basis of responses to these questions, only the version of the study for which they qualified was made visible to them on the online participant pool platform. For example, a male who reported no prior history of neuroenhancement would screen into Group B and therefore be eligible to sign up for one of the 32 available

timeslots for participants with those characteristics. Conversely, a female who screened positive for neuroenhancement history would be eligible for one of 68 Group C timeslots.

Balancing sample distribution (gender, neuroenhancement history). Given the experimental design of the present study, it was critical to balance participants across the experimental and control conditions on the basis of characteristics that could potentially influence the study's findings. Specifically, male gender appears to confer greater risk for both neuroenhancement (Franke, Christmann, Fellgiebel, Huss, & Lieb, 2011; Franke, Bonertz, Christmann, Engeser, & Lieb, 2012; McCabe et al., 2014; Wilens et al., 2008) and trait impulsivity/risk-taking behaviours (Cross, Copping, & Campbell, 2011). Although not consistently demonstrated, there has also been some work suggesting a moderating effect of gender on outcomes following ego depletion (e.g., Gailliot & Baumeister, 2007; Lemay, 2013; c.f. Moller, Deci, & Ryan, 2006).

Because of these considerations, it was deemed appropriate to maintain an equal ratio of males to females in the experimental versus control conditions to avoid any confound resulting from greater representation of males or females in one condition. The target ratio (approximately 2.1 females per male) was determined on the basis of distribution of males and females registered in the participant pool at large. It was also considered ideal to maintain equal representation of neuroenhancement history (i.e., participants with history of neuroenhancement vs. neuroenhancement-naïve participants), both across the experimental and control groups and within each gender group. A target sample distribution was constructed along these parameters (i.e., gender X neuroenhancement history) to guide recruitment of the study sample (200 participants).

Experimental group assignment. In order to achieve optimal experimental control, participants were randomly assigned to the experimental and control conditions. Because data were collected in a group format, this was achieved by first scheduling group data collection sessions and then randomly assigning each session to either the experimental or control condition via coin flip. For each session, a pre-determined number of timeslots were opened to participants in each screening group (as outlined in Table 1) in order to retain distribution of screening variables across the experimental and control conditions. For example, a data collection session may include two participants each from screening Group A and Group B, and four participants each from screening Group C and Group D. A coin flip would determine whether these participants would participate in either the experimental or control condition. This method sought to preserve a proportional distribution of participant screening characteristics (gender, neuroenhancement history) across the experimental and control groups, as described in Table 2.

A summary of the demographic characteristics of the final sample (in the overall sample and within each experimental group) is included in Table 3. Participants were approximately two-thirds female (68%) and predominantly Caucasian (55%). Year of university study was relatively evenly represented across participants, with 27% of participants indicating that they were in their first year, 25.5% indicating second year, 21% indicating third year, and 17.5% indicating fourth year of university studies. A small minority indicated that they were in their fifth year and beyond (8.5%).

Materials

State self-control manipulation. The present study utilized a dual-task paradigm for experimental depletion of self-control, whereby participants completed either a depleting (experimental) or non-depleting (control) version of the same task. Although the dual task methodology has appeared in numerous iterations across the ego depletion literature, the specific paradigm selected for use in the current study was originally developed by Baumeister and colleagues in a foundational study of self-control depletion (Baumeister et al., 1998). This method differs slightly from the computerized task used by Wolff and colleagues (2013), as described above. The current task was selected over the computerized letter transcription task because the latter has been criticized as being a poor means of achieving self-control depletion effects (Baumeister & Vohs, 2016) following a failure to replicate a depletion effect using this paradigm in a recent, large-scale pre-registered replication trial. In contrast, the paradigm in the current study has been widely used to produce self-control depletion effects in the published literature. At the time of its publication in 2010, a meta-analysis by Hagger and colleagues identified twenty published studies that had employed this task in order to experimentally manipulate state self-control, with an additional six studies employing similar versions. As such, it is one of the most common and well-studied depletion paradigms in the self-control literature, and has robustly produced the so-called "ego depletion effect" (Hagger et al., 2010).

In this task, participants performed two variants of a letter vigilance task, which entails locating and crossing out all letter *e*'s on a page of printed text. While the specific stimuli utilized in this task vary across studies, stimuli are typically selected from

technical scholarly works (Baumeister et al., 1998; DeWall, Baumeister, Gailliot, & Maner, 2008; DeWall, Baumeister, Stillman, & Gailliot, 2007; Tyler & Burns, 2009). The dense, technical nature of such texts is thought to minimize participant engagement with the content of the text, allowing optimal attention to the task itself. The stimuli for this task were adapted for the current study from a scholarly journal article on statistical methodology that was published in an open-source journal (Tellaroli, Bazzi, Donato, Brazzale, & Drăghici, 2016).

In both the self-control depletion condition and the non-depletion (control) condition, participants completed identical practice tasks. During the practice task, participants were presented with a page of text and were asked to find and cross out all letter *e*'s on the page. Given the high frequency and quantity of responses the task requires from participants, it has been suggested that this practice task successfully establishes a dominant behavioural set (Baumeister et al., 1998).

After completing the practice task, the non-depletion (control) group was presented with a second page of text and was instructed to complete this page in the same manner as was done for the practice task. By contrast, participants in the self-control depletion condition were given a second page of text that, although identical in content to that used by the control group, was printed in a smaller and lighter font and therefore required increased effort to read. Additionally, participants assigned to the self-control depletion condition were asked to complete this second page using a more difficult, effortful set of rules: participants were instructed to cross out the letter *e*'s on the page, except for those *e*'s that met either of two conditions (DeWall et al., 2008, 2007). First, *e*'s were not considered targets if they were directly preceded by a vowel (for example,

the *e* in the word *skies* would not be crossed). Second, *e*'s were not considered targets if they came two letters after a vowel (for example, the *e* in *space* would not be crossed). According to its creators, the letter vigilance task has the advantage of preferentially taxing self-control within the experimental group versus the control group (Baumeister et al., 1998).

As poor comprehension of instructions (or failure to adhere to task instructions) on the letter task could interfere with fidelity of the dual task manipulation, several variables were derived from participants' letter task performance in order to identify potentially invalid responding. These included the total number of omission errors (i.e., target letters which were not crossed by the participant) and commission errors (i.e., non-target letters which were incorrectly crossed by the participant), determined in accordance with the rules for each respective task. Time spent on each page of the task (the practice page and either the experimental or control version of the second page) was also recorded via the online survey platform. Standardized scores (*z* scores) for the variables reflecting practice task performance (practice task omission and commission errors, practice task time on page) were computed relative to all 200 participants, as participants in both the experimental and control conditions completed identical versions of the practice task. In contrast, standardized scores for variables reflecting performance on the second page of the letter task were computed relative only to the other participants in the same experimental condition.

Manipulation checks. Manipulation checks are a critical component of experimental designs, in that they increase researchers' confidence that the desired conditions of the experiment had the intended effect (Kazdin, 2003). Several

manipulation checks were included in the present study, including both self-report questions and a performance-based measure purported to be sensitive to variations in state self-control (handgrip task).

Manipulation check questions. A series of manipulation check questions was adopted from Tyler and Burns (2009) for the present study. First, to ensure participants' comprehension of the instructions for their assigned condition (i.e., letter vigilance depletion vs. control condition), participants were asked to identify the instructions they were asked to follow while competing the letter vigilance task. Second, participants were asked to rate the perceived difficulty of the task on a scale from one ("not at all difficult") to seven ("extremely difficult"). Additionally, participants were asked to rate their motivation to complete the task on a scale from one ("not at all motivated") to seven ("extremely motivated"). This latter check was included in the original experimental examination of the impact of self-control depletion on neuroenhancement (Wolff et al., 2013) as a means of identifying any confound due to differential motivation to complete the respective experimental tasks.

Following completion of the assigned letter vigilance task, participants also completed the Positive/Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). Consistent with previous studies of ego depletion (e.g., Baumeister et al., 1998; DeWall et al., 2008, 2007; Tyler & Burns, 2009), this measure was included in order to probe for any differential effect of the experimental condition on mood in the experimental versus control condition. For the 20 items of the PANAS, participants were asked to rate the degree to which their current affective state matched a given adjective (e.g., "enthusiastic"; "upset"). Responses are on a Likert scale ranging from 1 ("very

slightly or not at all") to 5 ("extremely"). Internal consistency for the PANAS in the current sample ranged from excellent (for the positive affect subscale; $\alpha = .90$) to good (for the negative affect subscale; $\alpha = .80$).

Handgrip persistence task. As a supplement to question-based manipulation checks, the present study also measured participants' stamina in squeezing a handgrip as a measure of state self-control, as described by Muraven and colleagues (Muraven et al., 1998). At each testing point (i.e., both pre- and post-depletion), participants were asked to squeeze a handgrip exerciser, continuously holding a coin between the handles of the handgrip as long as possible. Handgrip persistence was coded as the number of seconds the participant could retain sufficient grip pressure required to keep the coin continuously suspended between the handles of the handgrip apparatus. Inclusion of the coin provided a reliable means of assessing a standardized point of release for the handgrip; when the coin dropped from the handgrip, timing was stopped. Time was recorded inconspicuously (i.e., away from the participant's work station).

Like the letter vigilance task, this task is broadly utilized in the study of self-control depletion (used in 18 studies per the analysis by Hagger et al., 2010). At its face, this task appears to measure bodily strength; however, inter-individual variability on this task has been shown to be nearly completely attributable to self-control, with little variance in handgrip persistence actually relating to body strength (Rethlingshafer, 1942; Thornton, 1939; as cited in Muraven et al., 1998). Indeed, to persist in squeezing the handgrip, individuals must override sensations of discomfort and urges to quit (Muraven et al., 1998). Thus, the handgrip persistence task has the benefit of being a relatively subtle measure of self-control, unlikely to be detected as such by participants (Alberts,

Martijn, Greb, Merckelbach, & Vries, 2007). Evidence for the construct validity of the handgrip task as a measure of self-control (particularly affective self-regulation) was recently demonstrated (Goldberg et al., 2017). Accordingly, several studies have documented decline in handgrip persistence following self-control depletion tasks (e.g., Alberts et al., 2007; Finkel et al., 2006; Muraven et al., 1998; Tyler & Burns, 2009), suggesting that this measure may be sensitive to experimental manipulations targeting self-control depletion (such as that adopted in the present study).

Self-report data. Self-report questionnaires were utilized to measure several variables of interest in the current study: demographic variables, dispositional self-control, history of neuroenhancement, intent for future neuroenhancement, and attitudes toward neuroenhancement.

Demographics. A series of demographic questions was included in the current study (and in the other studies in this project). These questions sample a range of characteristics of potential relevance to self-control and neuroenhancement, including age, gender, academic standing, and history of mental health diagnosis. The demographic questionnaire used in the present study is included in Appendix A.

Dispositional self-control. To examine impact of baseline levels of self-control on the outcome variables of interest, participants were asked to complete the Self-Control Scale (SCS; Tangney, Baumeister, & Boone, 2004). This measure's 36 items (e.g., "I am good at resisting temptation"; "I refuse things that are bad for me") broadly tap individuals' ability to override impulses in favor of long-term goals and values. Responses for this measure are on a five-point scale (1 = "not at all"; 5 = "very much"). In the original validation study for this measure, the authors reported evidence for the

SCS's convergent and discriminant validity, good internal consistency (α = .89), and good test-retest reliability (*r* = .89). Internal consistency in the current sample was good (α = .84).

Neuroenhancement. The design of the current study requires measurement of several variables related to neuroenhancement behaviour: history of neuroenhancement behaviour, intent to engage in future neuroenhancement behaviour, and attitudes toward neuroenhancement behaviour.

History of neuroenhancement behaviour. In line with the behavioural definition of neuroenhancement (Englert & Wolff, 2015), history of neuroenhancement behaviour was coded as a dichotomous variable (i.e., history of neuroenhancement vs. no history of neuroenhancement) and operationalized as endorsement of lifetime history of use of any substance with the intent to enhance cognition. As no appropriate measures were found to measure the broad, behaviourally-defined construct of neuroenhancement history (i.e. neuroenhancement using any substance), a series of questions was assembled for the present study. In the first section, participants were asked to indicate whether they have used a series of common substances for neuroenhancement in three time-frames (i.e., lifetime, past year, past 30 days). Participants were then asked to indicate how frequently they have used these substances during each time period, using a scale used in prior neuroenhancement research (ranging from "never" to "40+ times"; (Gallucci, 2011; Gallucci et al., 2015, 2014). A fictional ADHD drug ("omecetin, e.g., Cognient") was also included as a foil to identify potential over-endorsement of neuroenhancement substance use (and otherwise invalid responding).

Intent to engage in future neuroenhancement behaviour. Future intent to engage in neuroenhancement was measured using a set of four items adapted from a study by Donaldson, Siegel, and Crano (2016). The original items, which were designed to tap future intent to use prescription stimulants non-medically, were broadened to measure neuroenhancement as a global construct for the current study. Internal consistency in the current sample was excellent ($\alpha = .91$).

Attitudes toward neuroenhancement. Participants were asked to complete the Performance Enhancement Attitude Scale (Petróczi & Aidman, 2009), as adapted by Wolff and Brand (2013). The adapted measure consists of nine items tapping attitudes toward neuroenhancement (e.g., "Neuroenhancement is an unavoidable part of learning and working"). Participants are asked to rate their agreement on a scale from one ("strongly disagree") to six ("strongly agree"). Wolff and Brand (2013) report acceptable internal consistency ($\alpha = .79$) and provide evidence (i.e. principal component analysis) for a unidimensional factor structure. Consistent with findings of the scale's authors, internal consistency for the scale was acceptable in the current study ($\alpha = .77$).

Procedure

After obtaining Research Ethics Board clearance for the proposed investigation, the study was registered in the online participant pool. Participants were scheduled for group collection of study data via the participant pool website, as described above. All participants provided informed consent prior to participation in accordance with ethical research principles.

As illustrated in Figure 1, the order of presentation of the tasks was as follows: first, questionnaires measuring neuroenhancement history, demographic and dispositional

constructs (e.g., trait self-control) were completed. Next, participants completed the baseline handgrip task (administered by researcher or trained research assistant), their assigned letter vigilance task (depletion or non-depletion/control), and the post-test handgrip task (administered by researcher or trained research assistant), respectively. Participants then completed other manipulation check measures, as described above, and questionnaires measuring the dependent variables (i.e., neuroenhancement intent; neuroenhancement attitudes). Note that items assessing response validity were embedded in questionnaires (e.g., "Please select '3' for this item") in order to identify any potential cases of random/invalid responding; if invalid responses were detected on any measure, participants were prompted to check each item prior to proceeding with the study.

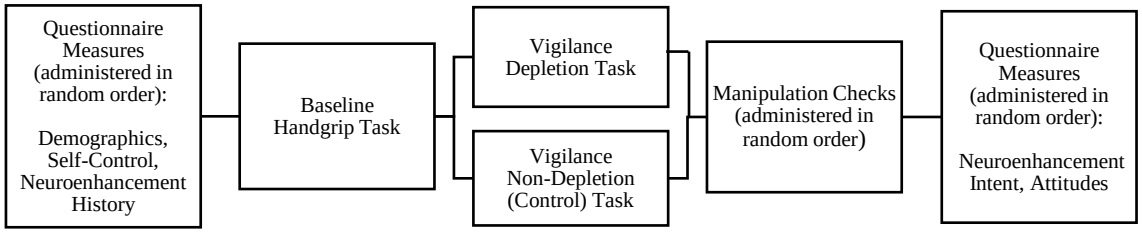

Figure 1. Order of data collection in each timeslot.

Materials were presented in random order within each phase of the data collection, as depicted in Figure 1. For example, at the beginning of data collection, participants were administered the demographic questionnaire, the Self-Control Scale, and the neuroenhancement history question, in random order. Likewise, measures administered within the manipulation check phase and at the end of the study were presented in random order within that phase. Progress through the study was self-paced by participants.

Group size for data collection sessions varied based on participant interest and attendance; on average, sessions included about five participants (M = 4.82) and never more than 12 participants. Each timeslot was run by the author and either one or two highly-trained, directly-supervised research assistant(s). Due to the self-paced nature of the study and availability of multiple research personnel, there was typically minimal delay for researcher-administered tasks (i.e., handgrip pre-test and post-test). When participants incurred a delay, it was brief (no longer than a few minutes).

Data Analysis

Data preparation. Prior to conducting the planned main analyses, the dataset was checked for missing data points. Analysis of missing data points revealed a sparse pattern of missing data, with 1.45% of values missing across the variables of interest. According to Little's (1988) test, these missing data points were missing completely at random (MCAR; χ^2 (152) = 3.54, p = 1.00). Given the negligible quantity and quality of missingness, missing values were imputed using expectation maximization. This analysis – and all subsequent analyses – was conducted using IBM SPSS Statistics for Windows, version 19 (IBM Corp., Armonk, N.Y., USA).

In order to address the statistical assumption of absence of outliers/influential observations in multiple regression analysis (Tabachnik & Fidell, 2001), cases were examined for presence of outliers (z > ±3.27) on one or more of the independent variables to be included in the main analysis. While four cases included outliers on X, none of these data points represented influential observations (Cook's d < 1.0; Stevens, 2002). As a result, these cases were retained for final analyses in order to preserve the

integrity of the regression parameters (Stevens, 2002). There was no evidence of outliers on *Y* (i.e., $z_{residual} > \pm 3.27$; Tabachnik & Fidell, 2001) for either planned regression model.

Additionally, the dataset was examined for indicators of invalid responding and poor engagement in self-control depletion task, as the latter could impact the purported experimental effect. Invalid data and/or letter task performance was operationalized *a priori* as participants' meeting one or more of the following conditions:

1) the participant included incorrect response to a validity check item (i.e., "select 3 for this item") despite prompting as described above ($n = 1$);
2) the participant did not correctly identify the instructions they had been asked to follow while completing the letter task ($n = 8$);
3) the participant endorsed use of the fictional (foil) neuroenhancement substance ($n = 0$);
4) the case contained an outlier ($z > \pm 3.27$) on omission and/or commission errors for either page of the letter task ($n = 5$); or
5) the case contained an outlier ($z > \pm 3.27$) on time to complete either page of the letter task ($n = 2$).

Fifteen cases (ten in the experimental group) met one or more of these criteria and were therefore excluded from final analyses. As such, a final sample size of $N = 185$ was used for subsequent analyses.

Preliminary analyses. Prior to completion of the main multiple regression analyses,

group equivalence was confirmed across the experimental and control conditions on the basis of potentially important variables (e.g., gender, age, history of engagement in

various classes of neuroenhancement behaviour, trait self-control) using chi-square analyses. To ensure that the experimental manipulation had the intended effect, the experimental and control groups were compared using a series of independent samples *t*-tests comparing the two groups' perceived difficulty of the task, their motivation to complete the task, and their self-rated affect following completion of the experimental task. A 2x2 mixed ANOVA with one within-subjects factor (i.e., handgrip duration at baseline and following the depletion task) and one between-subjects factor (experimental vs. control group) was used to probe for changes in state self-control (as measured by the handgrip task) between the experimental groups.

The data were also checked for any potential violation of the assumptions of multiple regression (Field, 2009). In addition to assuming absence of outliers/influential observations (discussed above; Cohen, Cohen, West, & Aiken, 2003; Tabachnik & Fidell, 2001), multiple regression also assumes a sample that is adequately sized, so as to allow generalizability to the population (Cohen et al., 2003). Although the current sample size well exceeds the conventional requirement of fifteen cases per predictor (Stevens, 2002), a *post hoc* power analysis was conducted using G*Power (Faul et al., 2007) in order to verify adequate power based on the specific model parameters and observed effect sizes. For the model predicting neuroenhancement attitudes, observed power exceeded the .80 threshold proposed by Cohen (1992; i.e., $1 - \beta = .86$). Likewise, observed power was adequate for the model predicting neuroenhancement intent ($1 - \beta = .99$). Thus, it is likely that the current analyses were adequately powered to detect the hypothesized effects, if such effects existed.

Multiple regression also assumes lack of perfect collinearity. Derived collinearity diagnostic statistics were all within range (i.e., all tolerance values > .1, all variance inflation factor [VIF] values < 10; Field, 2009; Stevens, 2002). Additionally, visual inspection of histograms and bivariate scatterplots indicated that the residuals adequately approximated the normal distribution, that predictors were linearly related to residuals, and that no heteroscedasticity was present (Field, 2009). Multiple regression also assumes independence of errors. Examination of the Durbin-Watson statistic for the model predicting neuroenhancement attitudes and the model predicting neuroenhancement intent were within acceptable bounds (Durbin-Watson = 2.40 and 2.26, respectively). Cronbach's α values for variables of interest (ranging from good to excellent; reported above for each measure) suggest that the current data adequately address the assumption that variables are measured without error. Finally, multiple regression assumes independence of observations. Given that each variable included in the main analyses reflected a single case, violation of this assumption in the current sample was considered unlikely.

Variable effect coding. Categorical independent variables were transformed into dummy-coded or effect-coded variables, as appropriate, in preparation for use in multiple regression analyses. Given the unequal distribution of gender (i.e., 68% female) and neuroenhancement history (94% endorsed) in the overall sample, these dichotomous variables were transformed into weighted effect-coded variables using the procedure described by te Grotenhuis and colleagues (2017b). An unweighted effect code was used to code experimental condition, as sample size discrepancy between the two groups was minimal (95 vs. 90) and resulted from study characteristics rather than sampling effects

(Cohen et al., 2003). Interaction effects pertaining to these variables were estimated using procedures described by te Grotenhuis and colleagues (2017a).

Multiple regression analyses. A hierarchical multiple regression analysis was conducted for each of the dependent variables (intent to engage in neuroenhancement; attitudes toward neuroenhancement). Demographic variables potentially related to the constructs of interest (gender, age) were entered in the first block of each multiple regression model in order to control for potentially confounding effects of these variables on the outcome. Dispositional self-control scores were entered in the second block. In the third block of each regression model, participants' baseline history of neuroenhancement was entered as an effect-coded variable, and experimental condition (depletion vs. non-depletion/control) was entered as an effect-coded variable in the fourth block. Finally, to assess whether participant history of neuroenhancement moderates the relation between self-control depletion and future neuroenhancement intent / attitudes toward neuroenhancement, the interaction term of participant neuroenhancement history * experimental condition was entered in the fifth block.

Results

Results for the current study are reported below. Variable intercorrelations for variables of interest in the present study are presented in Table 5.

Preliminary Analyses

Check for group equivalence. The experimental and control groups were equivalent with regards to age ($t(183) = -1.08$, $p = .28$) and gender ($\chi^2(1) = 0.01$, $p = .92$). Groups were also equivalent with regards to neuroenhancement history reported at the time of study completion, including history of engagement in any neuroenhancement

($\chi^2(1) = .18$, $p = .67$), legal neuroenhancement ($\chi^2(1) = .25$, $p = .62$), illicit neuroenhancement ($\chi^2(1) = 1.00$, $p = .32$), neuroenhancement via non-medical use of prescription ADHD medication ($\chi^2(1) = .13$, $p = .72$), and neuroenhancement via non-medical use of any medication ($\chi^2(1) = 1.43$, $p = .23$). The groups did not differ on self-rated trait self-control ($t(183) = 1.27$, $p = .21$).

Manipulation checks. Following the depletion task, the groups did not significantly differ on self-rated positive mood ($t(183) = -1.26$, $p = .21$) or negative mood ($t(183) = -1.22$, $p = .23$). Consistent with the intent to provide the experimental group with a more challenging (and therefore depleting) version of the depletion task, participants in the experimental group rated the task as significantly more difficult ($t(183) = -6.68$, $p < .001$). However, there was no significant difference between groups in ratings of motivation to complete the letter vigilance task ($t(183) = 1.50$, $p = .14$).

Descriptive statistics for participants' handgrip task performance are presented in Table 6. Statistical analysis revealed a main effect of handgrip measurement occasion (baseline vs. post-depletion) on handgrip task persistence, with significantly shorter handgrip duration observed following the letter vigilance task in general ($F(1, 183) = 13.177$, $p < .001$). However, there was no main effect of experimental condition on handgrip task persistence ($F(1, 183) = 0.23$, $p = .63$), nor was the interaction between measurement occasion and experimental condition statistically significant ($F(1, 183) = 0.29$, $p = .59$). Thus, in the current sample, the handgrip persistence task was unable to validate the presence of a differential "self-control depletion" effect in the experimental vs. control group.

Multiple Regression Analysis Predicting Neuroenhancement Intent

Results of the regression model predicting *future neuroenhancement intent* are presented in Table 7; variable intercorrelations (including partial correlations, semi-partial correlations, and structure coefficients) for the model are reported in Table 8. Variables entered in the first block (age, gender) did not account for significant variance in neuroenhancement intent scores ($F(2, 181) = 1.51$, $p = .224$). However, addition of SCS total score in the second block resulted in significant improvement in the model ($F_{change}(1,180) = 11.94$, $p = .001$). Addition of the effect-coded neuroenhancement history variable in block three likewise significantly improved the model ($F_{change}(1, 179) = 10.56$, $p = .001$). However, addition of the experimental condition in block four and the interaction term in block five (neuroenhancement history*condition) failed to significantly increase the variance accounted for by the model ($F_{change}(1,178) = 0.46$, $p = .50$ and $F_{change}(1,177) = 0.00$, $p = .97$, respectively). The final model significantly fit the data ($F(1, 177) = 4.46$, $p < .001$), accounting for 13.1% of the variance in future neuroenhancement intent scores.

In the final model, the strongest predictor of higher ratings of neuroenhancement intent was history of neuroenhancement ($\beta = .23$), followed by SCS total score ($\beta = -.21$). Accordingly, examination of the pattern of squared structure coefficients revealed that participants' baseline neuroenhancement history (squared structure coefficient = .53) and the Self-Control Scale total score (squared structure coefficient = .49) drove the model's prediction of neuroenhancement intent.

Exploratory post-hoc analyses. Given previous demonstration of an association of state self-control depletion with intent to engage in neuroenhancement (Wolff et al.,

2013), the failure to demonstrate an association of experimental condition with neuroenhancement intent in the current analysis was surprising (particularly given use of a self-control depletion paradigm that was similar to that employed by Wolff and colleagues and that has been widely used in the strength model literature). It was hypothesized that one factor contributing to this discrepancy may be the use of a summary measure of neuroenhancement intent in the present study (i.e., the derived variable is the sum of items reflecting both immediate and future intent to engage in neuroenhancement). By comparison, the method used in the study by Wolff and colleagues (offering participants an "energy stick") measured immediate intent only. In order to examine evidence for this hypothesis, exploratory analyses were conducted to probe for effect of experimental condition on immediate versus delayed neuroenhancement intent. Independent samples *t*-tests were conducted comparing the experimental to control group on each of the four neuroenhancement intent items (reflecting intent to engage in neuroenhancement now, in the next 6 months, in the next 12 months, and "sometime in the future"). Difference between the groups on ratings of willingness to engage in neuroenhancement *immediately* approached statistical significance at the .05 level ($t(183) = -1.93$, $p = .055$) and was in the predicted direction (i.e., greater willingness among the experimental depletion group), although it was not below threshold required for multiple comparisons ($p < .013$, per Bonferroni correction). There was no significant difference between the groups on items measuring neuroenhancement intent at various *future* intervals ($p = .638$ - $.777$).

Similarly, exploratory replication of the above model using specific item scores (reflecting "immediate" intent and intent to engage in neuroenhancement "sometime in

the future") as the dependent variables was undertaken (as absence of a main effect of experimental condition on the specific intent item scores does not rule out the interaction of condition with neuroenhancement history). These analyses did not produce significant changes in the pattern of predictors. Indeed, in these models, the interaction term again failed to account for significant variance in intent ratings.

Multiple Regression Analysis Predicting Neuroenhancement Attitudes

Results of the regression model predicting participant's *neuroenhancement attitudes* are presented in Table 9; variable intercorrelations for the model are presented in Table 10. Age and gender did not account for significant variance in neuroenhancement attitudes when entered in the first block ($F(2,181) = 1.43$, $p = .242$). Addition of SCS total scores in the second block of the analysis significantly improved the variance accounted for by the model ($F_{change}(1, 180) = 11.36$, $p = .001$). However, addition of neuroenhancement history in block three did not significantly improve the variance accounted for by the model ($F_{change}(1, 179) = 0.54$, $p = .46$), nor did addition of experimental condition in block four ($F_{change}(1, 178) = 0.44$, $p = .51$) or addition of the interaction term (neuroenhancement history*condition) in block five ($F_{change}(1, 177) = 0.27$, $p = .61$). The final model significantly fit the data ($F(6, 177) = 2.58$, $p = .02$), accounting for 8.0% of the variance in neuroenhancement attitudes.

In the final model, the Self-Control Scale total score was the strongest predictor of neuroenhancement attitudes ($\beta = -.23$). No other variables significantly ($p < .05$) contributed to the prediction of neuroenhancement attitudes. As in the model predicting neuroenhancement intent, examination of squared structure coefficients again demonstrated that participants' baseline neuroenhancement history and the Self-Control

Scale total score together accounted for the majority of variance in the model's predicted scores. However, in this model, Self-Control Scale scores accounted for the majority of variance in predicted outcomes (squared structure coefficient = .77), while baseline history of neuroenhancement accounted for a much smaller proportion of the variance in predicted attitudinal outcomes (squared structure coefficient = .14).

Discussion

The current study aimed to extend the scholarly understanding of students' neuroenhancement behaviour by examining the impact of state variation in self-control on neuroenhancement. This work drew upon the strength model of self-control (Baumeister et al., 2007), which posits that state self-control draws from a limited store and, as such, may be depleted following repeated exertion of self-control. Accordingly, the current study examined whether experimental depletion of self-control (using a commonly-implemented self-control depletion paradigm) was associated with alteration in students' intent to engage in neuroenhancement and their attitudes toward neuroenhancement behaviour. In line with previous work in this domain (Wolff et al., 2013), it was hypothesized that participants randomly-assigned to a state self-control depleting task would revert to their dominant behavioural response; that is, students with history of neuroenhancement behaviour would endorse greater intent to engage in neuroenhancement behaviour and more positive attitudes toward neuroenhancement. Conversely, it was anticipated that participants with no baseline history of neuroenhancement would be less likely to endorse neuroenhancement intent and pro-neuroenhancement attitudes. This interaction effect was expected to predict the neuroenhancement-associated outcome variables above and beyond the anticipated

association of demographic variables (age, gender) and trait self-control with neuroenhancement intent and attitudes.

In the final model predicting neuroenhancement intent, students' baseline history of neuroenhancement and their self-rated trait self-control significantly predicted neuroenhancement intent outcomes in the expected direction (i.e., students were more likely to endorse intent to engage in neuroenhancement if they had previously engaged in neuroenhancement and/or if they had lower trait self-control). Contrary to hypotheses, however, neither the experimental condition nor its interaction with baseline neuroenhancement history accounted for significant variance in students' ratings of their intent to engage in neuroenhancement. Exploratory post-hoc analyses replicated this finding with regards to intent to engage in neuroenhancement at different intervals (i.e. immediately or at an undefined future time point); although a trend emerged associating immediate neuroenhancement intent with experimental depletion of self-control, this effect did not survive statistical correction for multiple comparisons.

Results were similar in the model predicting students' attitudes toward neuroenhancement. Here, only trait self-control was a significant predictor of students' attitudes toward neuroenhancement (with lower trait self-control predicting more positive attitudes toward neuroenhancement); unlike the results obtained in the model predicting neuroenhancement *intent*, participants' neuroenhancement history was not a significant predictor of neuroenhancement *attitudes*. Again, neither the experimental condition nor its interaction with baseline neuroenhancement history accounted for significant variance in participants' ratings of their attitudes toward neuroenhancement.

The present study produced several important findings which extend the current understanding of the neuroenhancement phenomenon. First, this study builds upon existing literature that demonstrates an association of students' neuroenhancement history with constructs related to self-control, such as conscientiousness, trait impulsivity, and the symptoms of attention-deficit/hyperactivity disorder (e.g., Dussault & Weyandt, 2011; Lookatch et al., 2012; Maier, Haug, & Schaub, 2015; Rabiner et al., 2010; Sattler & Schunck, 2016). By demonstrating an association of the higher-order trait of self-control with neuroenhancement (both attitudes and intent), the current study may offer a unifying framework for understanding the extant body of work.

Interestingly, these findings mirror those of a similar study conducted to examine sports-related "doping". Using a sample of young athletes, Chan and colleagues (2015) demonstrated that ratings of trait self-control were inversely associated with athletes' pro-doping attitudes and their self-rated intent to engage in athletic performance enhancement. The comparable findings in the current study suggest that those with lower self-control may be more accepting of the broad class of performance-enhancing behaviours and may be more likely to enact these behaviours in day-to-day life.

Perhaps unsurprisingly, participants in the current study who endorsed history of neuroenhancement were more likely to endorse intent to engage in neuroenhancement in the future. However, neuroenhancement history was not a significant predictor of self-rated neuroenhancement attitudes. This finding is unexpected given that attitudes were selected for the current study as a more innocuous metric for neuroenhancement behaviour. The lack of an association between neuroenhancement history and attitudes is also contrary to work by Wolff and Brand (2013) linking history and frequency of

engagement in a range of classes of neuroenhancement (including lifestyle neuroenhancement) to greater pro-neuroenhancement attitudes. Additionally, findings related to this variable must be interpreted with caution due to the grossly unequal cell sizes (i.e., low proportion of sample reporting negative history of neuroenhancement).

Given the association of poor (self-reported) self-control with neuroenhancement outcomes, it is possible that neuroenhancement constitutes an impulsive act which may occur despite possible conflict with the individual's beliefs regarding the acceptability of the behaviour. This perspective is in line with the Theory of Planned Behavior (Ajzen, 1991), which asserts that behaviour is shaped not only by attitudes toward the behaviour and perceived norms, but also by one's perceived control over a given behaviour. Indeed, it has been suggested that the Theory of Planned Behavior (and other social cognitive approaches) may provide a relevant framework for the study of neuroenhancement (Zelli et al., 2015). With regards to neuroenhancement, the current findings suggest a dissociation between attitudinal factors and one's perceived control over their behaviour (i.e., self-rated self-control, which was associated with actual neuroenhancement history). Future work is needed in order to replicate this unexpected result and to better understand differential associations of attitudinal and personality factors with students' neuroenhancement.

Although supporting an association of *trait* self-control with neuroenhancement, the current study was not able to satisfactorily demonstrate the hypothesized association of *state* variation in self-control with neuroenhancement behaviour. This outcome was surprising, given a theoretical expectation that self-control depletion prompts individuals to revert to their established behavioural response (Baumeister et al., 2007; Englert &

Wolff, 2015). In line with theoretical predictions, previous work specific to the topic of neuroenhancement has demonstrated a tendency of students to revert to their established behavioural response to a neuroenhancement opportunity when in a state of depleted self-control (Wolff et al., 2013).

Several possible explanations exist for the current study's failure to produce predicted findings. First, it is possible that a depletion effect did exist in the current study (consistent with ratings of greater task difficulty among the experimental group), but did not relate as predicted to neuroenhancement outcomes and was not captured by the handgrip task. The failure to identify an effect of experimental condition on handgrip task performance was unexpected, as this task is among the most frequently utilized outcome variables in the self-control depletion literature (Hagger et al., 2010). Indeed, it has been utilized in much of the earliest and most foundational work on the subject (e.g. Muraven et al., 1998; Vohs & Heatherton, 2000).

One possible explanation may be that idiosyncratic characteristics of the current sample impacted participants' approach to the handgrip task. Such concerns were initially raised by Murtagh and Todd (2004), who were unable to identify effect of self-control depletion on handgrip task performance. The authors noted that high motivation may impact self-control depletion effect (and indeed, may override it), in accordance with their observation of participants who attempted (successfully) to improve their handgrip performance on post-test. During data collection for the present study, there was likewise frequent subjective observation of strong participant motivation to outperform their baseline handgrip time. Indeed, participants frequently stated that they were trying to "beat their time" despite researcher efforts to mask handgrip duration (e.g., times were

inconspicuously recorded; if participants wished to learn their handgrip duration, they could only see their time following completion of the entire study). It is also possible that the group format for data collection in the current study (although utilized in many other similar studies that did not result in null findings, e.g., Alberts et al., 2007; Finkel et al., 2006; Muraven et al., 1998; Tyler & Burns, 2009) contributed to a desire of participants to "outlast" other participants, despite attempts to provide privacy (i.e., participants worked in cubicles). Future studies may benefit from inclusion of "effort check" items (e.g., "how important was it to you to hold the handgrip as long as possible?"; "how important was it to you to beat your first time?").

While it is possible that the handgrip task failed to capture a depletion effect that truly existed, the possibility that a self-control depletion effect was not successfully produced on the current study (despite use of foundational self-control depletion methods) must also be considered and may indeed more parsimoniously explain the current results. Indeed, discussion of the current null findings within the context of self-control depletion must be situated within recent debate regarding the conceptual underpinnings of the theory and the replicability of the "ego depletion effect". These issues will be summarized here; however, for a full outline of the current status of this debate, the reader is directed to more comprehensive discussions of various perspectives on the topic (Baumeister & Vohs, 2016; Blázquez, Botella, & Suero, 2017; Hagger & Chatzisarantis, 2016; Lurquin et al., 2016).

Briefly, the published literature includes precedent for null findings with regard to the handgrip task. Indeed, a series of studies aimed at replicating the self-control depletion effect in community and student samples failed to identify any effect of

experimental condition on outcome measures (Xu et al., 2014). Of note, the methodology selected in these studies included the letter task (as experimental manipulation of state self-control) and the handgrip task (as a manipulation check measure). A similar failure to demonstrate an effect of self-control depletion on handgrip times was demonstrated by Murtagh and Todd (2004). Other studies have failed to replicate the self-control depletion effect using alternate methodologies (e.g., Lurquin et al., 2016), notably including a large, multi-site pre-registered replication effort (Hagger et al., 2016); however, the methodology of the pre-registered replication has been criticized, and a more recent unpublished pre-registered replication attempt did produce an effect (Baumeister & Vohs, 2016; Garrison, Finley, & Schmeichel, 2018).

Conflicting findings among recent studies of self-control depletion have led to increased concern regarding the validity and replicability of the self-control depletion effect. In conjunction with these results, confidence in the "ego depletion" literature has been eroded through inconsistent meta-analytic results. While some meta-analyses have demonstrated that the depletion effect exists (Blázquez et al., 2017) and is, in fact, large (Hagger et al., 2010), other analyses have indicated that the pooled effect may be smaller or non-significant (Carter et al., 2015; Carter & McCullough, 2014; although notably, these studies producing null findings have also been subject to methodological limitations; Friese et al., 2018). Aside from the replicability of this effect, concerns have been raised regarding the conceptual foundations of the theory; for example, it has been argued that there is not compelling evidence to suggest that the "ego depletion effect" is distinct from more ordinary phenomena (e.g., fatigue; Hagger et al., 2010). In summary, recent investigations of the self-control depletion effect have led to a lack of clarity

regarding the nature and existence of self-control depletion (Friese et al., 2018). Thus, the implications of the current failure to support an impact of self-control depletion on neuroenhancement are not fully clear, although they appear to provide some support for the notion that the ego depletion effect (at least as produced in the laboratory) may not be as ubiquitous and impactful (on attitudes and behaviour) as once thought. Further work is certainly needed to clarify whether self-control is indeed depletable and the nature of its impact (if any) on neuroenhancement susceptibility.

Several limitations of the current investigation must be acknowledged. First, despite extensive attempts to do so, the current sample was unable to achieve equal cell sizes with regards to neuroenhancement history and gender. Indeed, participants were screened for baseline history of neuroenhancement prior to study enrolment and were randomly assigned into the experimental and control groups with intent that each group would be comprised equally of participants with and without prior history of neuroenhancement. However, as detailed in Table 4, a significant majority of participants endorsed history of neuroenhancement upon presentation to the study, even though initial screening should have led to equal distribution of neuroenhancement history. It is unclear what factors contributed to the discrepancy between participants' screening responses and their endorsed neuroenhancement history during study participation. It is possible that some students may be unwilling to endorse neuroenhancement in the screening question format (completed upon registration for the participant pool at large); because answers to screening questions impact the studies for which participants are eligible to participate, they necessarily cannot be anonymous and are tied to participants' pool accounts. In contrast, post-study anonymization of study

data may have encouraged more open reporting of neuroenhancement history upon study participation. Alternately, interim changes in students' neuroenhancement history (between screening and study participation) are likewise plausible.

Although the distribution of the neuroenhancement variable was similar to (albeit slightly higher than) that previously reported by other authors (e.g., Wolff et al., 2014) and therefore allowed for estimation of effects as they exist in the student population (Cohen et al., 2003), recruitment of a group that is balanced with respect to neuroenhancement history (positive vs. negative) may allow for improved power for detection of an effect for this variable (which did not occur for the present study's model predicting neuroenhancement attitudes). Similarly, it was not possible to recruit equal proportions of males and females due to gender distribution within the participant pool. Future studies may attempt to better appreciate the impact of these variables on neuroenhancement attitudes and intent by continued efforts to recruit equal cell sizes with respect to neuroenhancement history and gender.

Additionally, the current study relied heavily on self-report methods for measurement of variables of interest. It must be noted that use of primarily self-report measures may introduce bias due to common method variance (Podsakoff et al., 2003). As such, scholarly understanding of neuroenhancement and its mechanisms may be made more robust through inclusion of both self-report and more objective measures of key constructs in future studies. This may include actual *in vivo* offering of purported neuroenhancement substances in lab-based studies, as was done by Wolff and colleagues (2013), but may also include other objective measures such as urinalysis (which may

sample past use of some neuroenhancement substances, such as prescription stimulants; Burgard, Fuller, Becker, Ferrell, & Dinglasan-Panlilio, 2013).

Finally, the present study examined neuroenhancement history as defined as a broad, behaviourally-based construct (i.e., a macroconstruct encompassing all use of substances for cognitive performance enhancement) to remain consistent with prior work in this area. However, in light of emerging evidence that various categories of neuroenhancement may be conceptually and/or etiologically distinct (i.e., Chapter II, this work), future studies may benefit from fine-grained examination of the impacts of self-control depletion and category-specific neuroenhancement history on attitudes and future neuroenhancement risk.

Conclusions

The current study has extended the existing literature regarding the association of self-control with students' neuroenhancement behaviour. Using a commonly-employed self-control depletion paradigm derived from the model surrounding the strength model of self-control (Baumeister et al., 2007), the current study was unable to clearly produce the predicted *state* self-control depletion effect (as determined by a second task taken from the strength model literature) and was unable to document an association of state self-control variation with neuroenhancement. As such, the present study is unable to add clarity to the current conversation regarding the validity and utility of the strength model of self-control.

However, present findings were able to demonstrate an association of *trait* self-control with neuroenhancement; students with low trait self-control were more likely to endorse both pro-neuroenhancement attitudes and future intent to engage in

neuroenhancement. Additionally, prior history of neuroenhancement behaviour was also shown to prognosticate future intent to engage in neuroenhancement. Thus, the current study stands as an important addition to the neuroenhancement literature by directly highlighting trait self-control and established neuroenhancement behaviour as risk factors for substance use with the intent to enhance cognitive functioning. By providing greater insight into these risk factors, prevention efforts may more effectively target the roots of neuroenhancement behaviour and therefore promote health and wellness for university students.

Table 1

Target Distribution of Sample on the Basis of Gender x Neuroenhancement History

		Neuroenhancement History		Total
		Endorsed	Not Endorsed	
Gender	Male	Group A *N* = 32	Group B *N* = 32	64
	Female	Group C *N* = 68	Group D *N* = 68	136
Total		100	100	200

Note. Selection of participants into groups was accomplished by creating four versions of the study in the online participant pool system, with each version available to only participants meeting criteria for inclusion in either Group A (i.e., males with positive history of neuroenhancement), B (males with no history of neuroenhancement), C (females with positive history of neuroenhancement), or D (females with no history of neuroenhancement). The appropriate study was made available to participants on the basis of responses to participant pool screening questions. In each group data collection timeslot, space was made available to participants in proportion to the target size of the stratified groups (i.e., a timeslot may include 2 participants each from Groups A and B and four participants each from Groups C and D).

Table 2

Timeslot Randomization Procedure

		Experimental Group		Control Group		Sample Total
		Neuroenhancement History		Neuroenhancement History		
		Endorsed	Not Endorsed	Endorsed	Not Endorsed	
Gender	Male	Group A $N = 16$	Group B $N = 16$	Group A $N = 16$	Group B $N = 16$	64
	Female	Group C $N = 34$	Group D $N = 34$	Group C $N = 34$	Group D $N = 34$	136
Total		50	50	50	50	200

Note. Approach to balancing of participants in the experimental and control groups in the final sample as a result of timeslot randomization procedure.

Table 3

Participant Demographic Characteristics

		%		
		Overall Sample	Experimental Group	Control Group
Gender	Female	68	68	68
	Male	32	32	32
Ethnic background	Aboriginal/First Nations	1.5	2	1
	Black/African	11	7	15
	East Asian	7.5	7	6
	South Asian/Indian	8.5	8	9
	Hispanic/Latino	1.5	2	1
	Caucasian or non-Hispanic White/European	55	55	55
	Arab/Middle Eastern	13	12	14
	Biracial/multiethnic	3.5	4	3
	Other	2.5	3	2
	Prefer not to answer	1.5	3	0
Year of study	First	27	23	31
	Second	25.5	27	24
	Third	21	23	19
	Fourth	17.5	15	20
	Fifth	6.5	8	5
	Sixth and beyond	2	3	1
	No response	0.5	1.0	0
		M (SD)		
		Overall Sample	Experimental Group	Control Group
Age		21.5 (4.9)	22 (3.8)	21.1 (5.8)
GPA (%)		75.6 (10.0)	75.8 (9.4)	75.3 (10.5)

Table 4

Descriptive Statistics: Participant Endorsement of Various Modes of Neuroenhancement

Neuroenhancement Category	% Endorsed		
	Total Sample	Experimental Group	Control Group
Legal Neuroenhancement	94	95	93
Coffee	84.5	82	87
Energy Drinks	53	53	53
Caffeine Supplements	16	17	15
Herbal Supplements	23.5	28	19
Probiotics	6	9	3
Alcohol	21.5	17	26
Nicotine	10.5	11	10
Illicit Drug Neuroenhancement	17.5	15	20
Marijuana	16	13	19
Other Illicit Substances	2.5	4	1
Neuroenhancement via Non-Medical Use of Prescription Stimulant / ADHD Medication	10.5	11	10
Methylphenidate (e.g. Ritalin)	1.5	2	1
Amphetamines (e.g., Adderall)	8.5	11	6
Modafinil (e.g. Provigil)	.5	0	1
Omecetin (e.g., Cognient) – Foil	0	0	0
Other/unknown ADHD medication	3	3	3
Neuroenhancement via Non-Medical Use of Any Prescription Medication[1]	14	17	11
Beta-blockers	.5	1	0
Other prescription medication	4	7	1
Any Neuroenhancement	95.5	95	96

Note. [1]Includes neuroenhancement via non-medical use of prescription stimulant/ADHD medications *and* beta-blockers *and* other prescription medications.

Table 5

Study 2 – Variable Intercorrelations (N = 185)

	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	1.00	.01	.08	-.06	.08	-.07	-.11	.18*	.20**	-.01	.18**	-.06
2. Gender		1.00	.02	-.10	-.01	-.10	.08	-.50†	-.50†	.14°	-.22**	.01
3. SCS total score			1.00	-.17*	-.09	-.25**	-.25**	.07	.02	-.08	.23**	-.18**
4. Lifetime neuroenhancement history				1.00	-.03	.11	.26†	-.01	.03	.06	.01	.11
5. Experimental condition					1.00	.07	.06	.04	.02	-.04	.09	.00
6. Neuroenhancement attitudes total score						1.00	.50†	-.02	.06	.10	.00	-.04
7. Neuroenhancement intent total score							1.00	-.01	.04	-.07	.01	.07
8. Handgrip duration – T_1								1.00	.77†	-.58†	.17*	-.13°
9. Handgrip duration – T_2									1.00	.08	.25†	-.17*
10. Handgrip duration – Δ										1.00	.05	-.02
11. PANAS Positive Affect											1.00	.03
12. PANAS Negative Affect												1.00

Note. °p < .10, *p < .05, **p <.01, †p < .001. Abbreviations: SCS = Self-Control Scale; PANAS = Positive Affect / Negative Affect Scale.

Table 6

Handgrip Performance in the Final Sample (N = 185)

	T_1	T_2	Δ
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
Experimental group	55.15 (49.72)	46. 38 (36.71)	-8.77 (29.28)
Control group	51.36 (37.81)	44.82 (35.18)	-6.54 (27.55)
Overall sample	53.21 (43.93)	45.58 (35.84)	-7.63 (28.35)

Note. T_1 = baseline handgrip duration. T_2 = post-depletion handgrip duration. $\Delta = T_2 - T_1$.

Table 7

Hierarchical Regression -- Future Neuroenhancement Intent (N = 185)

	B	*SE B*	β	ΔR^2
Step 1				.016
Constant	23.461	2.363		
Age	-0.166	0.107	-.114	
Gender[1]	0.288	0.368	.058	
Step 2				.061**
Constant	35.736	4.229		
Age	-0.135	0.104	-.093	
Gender[1]	0.313	0.357	.063	
SCS total score	-0.109	0.032	-.248**	
Step 3				.051**
Constant	22.448	4.181		
Age	-0.122	0.101	-.084	
Gender[1]	0.424	0.350	.085	
SCS total score	-0.092	0.031	-.210**	
Neuroenhancement history[1]	0.380	0.117	.231**	
Step 4				.002
Constant	32.965	4.247		
Age	-0.127	0.102	-.088	
Gender[1]	0.429	0.351	.086	
SCS total score	-0.090	0.031	-.205**	
Neuroenhancement history[1]	0.383	0.117	.234**	
Experimental condition[2]	0.698	1.026	.048	
Step 5				.000
Constant	32.9335	4.312		
Age	-0.127	0.103	-.088	
Gender[1]	0.429	0.352	.086	
SCS total score	-0.090	0.032	-.205**	
Neuroenhancement history[1]	0.383	0.117	.234**	
Experimental condition[2]	0.698	1.029	.048	
Condition*Neuroenhancement history	0.089	2.047	.003	

Note. Model R^2 = .131; R^2_{adj} = .102. [1] weighted effect-coded variable. [2]dummy-coded variable. *p < .05; **p < .01; ***p < .001. Abbreviations: SCS = Self-Control Scale.

Table 8

Model Variable Intercorrelations for the Final Regression Model Predicting Neuroenhancement Intent

	r	*pr*	pr^2	*sr*	sr^2	structure coefficient	structure coefficient^2
Age	-.11	-.09	-.01	-.09	-.01	-.32	.10
Gender[1]	.06	.09	.01	.09	.01	.16	.03
SCS total score	-.25**	-.21	.04	-.20	.04	-.70	.49
Neuroenhancement history[1]	.26*	.24	.06	.23	.05	.73	.53
Experimental condition[2]	.05	.05	.00	.05	.00	.14	.02
Neuroenhancement history*Experimental condition	.03	.00	.00	.00	.00	.09	.01

Note. [1] weighted effect-coded variable. [2]dummy-coded variable. Abbreviations: SCS = Self-Control Scale. Abbreviations: *r* = zero-order correlation, *pr* = partial correlation, *sr* = semi-partial correlation. °$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Table 9

Hierarchical Regression – Neuroenhancement Attitudes (N = 185)

	B	*SE B*	β	ΔR^2
Step 1				.073**
Constant	31.621	2.579		
Age	-0.109	0.116	-.069	
Gender[1]	-0.564	0.402	-.104	
Step 2				
Constant	44.705	4.622		
Age	-0.077	0.114	-.049	
Gender[1]	-0.537	0.391	-.099	
SCS total score	-0.116	0.034	-.243**	
Step 3				.003**
Constant	44.124	4.695		
Age	-0.074	0.114	-.047	
Gender[1]	-0.509	0.393	-.093	
SCS total score	-0.112	0.035	-.234**	
Neuroenhancement history[1]	0.096	0.131	.054	
Step 4				.003*
Constant	43.593	4.769		
Age	-0.080	0.115	-.051	
Gender[1]	-0.504	0.394	-.093	
SCS total score	-0.109	0.035	-.229**	
Neuroenhancement history[1]	0.100	0.132	.056	
Experimental condition[2]	0.768	1.152	.048	
Step 5				.001*
Constant	43.984	4.834		
Age	-0.089	0.116	-.056	
Gender[1]	-0.513	0.395	-.094	
SCS total score	-0.111	0.035	-.232**	
Neuroenhancement history[1]	0.098	0.132	.055	
Experimental condition[2]	0.769	1.155	.048	
Condition*Neuroenhancement history	-1.183	2.297	-.038	

Note. Model R^2 = .080; R^2_{adj} = .049. [1]weighted effect-coded variable. [2]dummy-coded variable. *p < .05; **p < .01; ***p < .001. Abbreviations: SCS = Self-Control Scale.

Table 10

Model Variable Intercorrelations for the Final Regression Model Predicting Neuroenhancement Attitudes (N = 185)

	r	*pr*	pr^2	*sr*	sr^2	structure coefficient	structure coefficient[2]
Age	-.07	-.06	.00	-.05	.00	-.25	.06
Gender	-.10	-.10	.01	-.09	.01	-.37	.14
SCS total score	-.25**	-.23	.05	-.23	.05	-.88	.77
Neuroenhancement history	.11	.11	.01	.05	.00	.37	.14
Experimental condition	.07	.07	.00	-.01	.00	.23	.05
Neuroenhancement history*Experimental condition	.07	.07	.00	.04	.00	-.00	.00

Note. [1]dummy-coded variable. [2]effect-coded variable. Abbreviations: *r* = zero-order correlation, *pr* = partial correlation, *sr* = semi-partial correlation. *$p < .05$; **$p < .01$; ***$p < .001$.

IV. THE CONTRIBUTION OF SELF-CONTROL TO THE RELATION BETWEEN ACADEMIC PERFORMANCE AND NON-MEDICAL PRESCRIPTION STIMULANT USE

Prescription stimulant drugs, such as methylphenidate (e.g. Ritalin) and formulations of amphetamine (e.g. Adderall) are among the most commonly-prescribed and efficacious treatments for adults and children experiencing neurocognitive difficulties associated with attention-deficit/hyperactivity disorder (ADHD; Dussault & Weyandt, 2011). This disorder, principally characterized by poorer attention and impulse control compared to same-age peers, is critically related to impaired functioning across life domains (American Psychiatric Association, 2013; Barkley, 2015). For many with ADHD, prescription stimulants may play a critical role in attenuating the impact of attention and impulse control problems on day-to-day functioning (Surman et al., 2013). Thus, the appropriate use of prescription stimulant drugs is a vital component in the evidence-based management of ADHD.

A significant concern surrounding patterns of use for prescription stimulants, however, involves university students' nonmedical use of prescription stimulants (NMUPS). NMUPS is defined by use of prescription stimulant medications without a valid ADHD diagnosis and/or prescription, or for individuals with a valid prescription, taking the medication in excess of prescribed dosage (Arria & Wish, 2006). When individuals engage in NMUPS in order to improve their attention, motivation, wakefulness, or other cognitive faculties, this behaviour fits within the overarching construct of "neuroenhancement" – that is, use of a range of psychoactive substances (i.e., lifestyle drugs, such as caffeine, nicotine, and commercially-available herbal

supplements; drugs of abuse; prescription drugs) with the intent to enhance cognitive functioning (Maier & Schaub, 2015). Lifetime prevalence of NMUPS ranges from 5.3% to 35% (reviewed in Weyandt et al., 2013), with trends toward increasing prevalence over the past decade (McCabe et al., 2014); given the more than 2 million college and university students in Canada (Government of Canada, 2015), this suggests that up to 716,800 young Canadians may have engaged in this problematic behaviour in their lifetimes.

Despite an overall lack of evidence that prescription stimulants effectively enhance cognitive functioning in neurotypical individuals (reviewed in Arria, 2016; Baroni & Castellanos, 2015; Repantis, Schlattmann, Laisney, & Heuser, 2010), enhancement of one or more specific cognitive domains (e.g., improved attention, alertness, or motivation for academic work) is among the most commonly-reported motives for using these drugs non-medically (Clegg-Kraynok, McBean, & Montgomery-Downs, 2011; DeSantis, Noar, & Webb, 2009; Dussault & Weyandt, 2011; Prudhomme White, Becker-Blease, & Grace-Bishop, 2006; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2009; Teter, McCabe, Cranford, Boyd, & Guthrie, 2005; Teter, McCabe, LaGrange, Cranford, & Boyd, 2006; White, Becker-Blease, & Grace-Bishop, 2006). Indeed, perception of academic benefit has been shown to be an important predictor of engagement in NMUPS (Arria et al., 2018), despite evidence that students who engage in NMUPS do not actually demonstrate improved academic performance (Arria et al., 2017). Regardless of the motive driving NMUPS, the potential for adverse effects and addiction due to unmonitored use of these medications (Greenhill et al., 2002;

Volkow & Swanson, 2003) qualifies NMUPS as a major public health concern for university campuses.

Apart from medical risk associated with non-medical use of these drugs, individuals who engage in NMUPS tend to have poorer outcomes across a number of psychosocial domains. For example, NMUPS has been linked to increased likelihood of test anxiety (Sattler & Wiegel, 2013), stress (Wolff & Brand, 2013; Wolff et al., 2014), and dysphoric mood (Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2009). Individuals who engage in NMUPS are also more likely to report increased frequency of—and problems associated with—cannabis, alcohol, and polydrug use (Arria et al., 2013, 2018; Barrett, Darredeau, Bordy, & Pihl, 2005; Lookatch et al., 2012; McCabe et al., 2005a; Rabiner et al., 2010; Teter et al., 2003). In sum, NMUPS constitutes a risk factor for a range of poor outcomes in university students.

The existence of academic difficulties for individuals who engage in NMUPS is well-documented. Individuals who engage in NMUPS self-report a greater number of academic concerns (Rabiner, Anastopoulos, Costello, Hoyle, McCabe, et al., 2009; Rabiner et al., 2010). Most frequently, studies have demonstrated an association between NMUPS and lower GPA (Arria et al., 2013, 2017; Clegg-Kraynok et al., 2011; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2009; Rabiner et al., 2010). Students who engage in NMUPS have been shown to skip class more frequently (Arria et al., 2013), have poorer study habits (Ilieva & Farah, 2015), and admit to "cramming" for exams (DeSantis, Webb, & Noar, 2008). Overall, the literature provides strong support for poor academic outcomes in the presence of NMUPS.

While the occurrence of academic difficulties among individuals who engage in NMUPS is well-documented, little work has examined potential mechanisms or psychological factors that may contribute to this established effect. The present study seeks to further current knowledge of the mechanisms contributing to the above-reviewed academic difficulties frequently observed in university students who engage in NMUPS. Specifically, low overall self-control (both global self-control and self-control as relates to academic tasks) is investigated as a potential contributor to the link between global academic functioning (i.e., GPA) and NMUPS.

Self-Control as a Potential Contributor to the GPA-NMUPS Relation

Self-control, broadly defined, constitutes a collection of top-down cognitive abilities that act to override or modulate impulses, allowing the individual to think, feel, and act in a way that is consistent with his or her goals, beliefs, and moral principles (Duckworth & Kern, 2011). Whereas impulses tend to drive organisms to seek immediate gratification, self-control allows individuals to forgo immediate gratification in pursuit of longer-term gains (de Ridder et al., 2012).

One's level of self-control has been identified as an important source of inter-individual variation; though some argue that self-control is subject to depletion following exertion of self-control resources (Baumeister et al., 2007), individuals appear to differ in terms of their overall "stores" of self-control (i.e., dispositional self-control; Englert & Wolff, 2015). Thus, in this framework, individuals with low dispositional self-control may experience self-control failure (i.e., reversion to one's dominant behavioural response) after relatively few acts of willpower exertion (as posited by the *strength model of self-control*; Baumeister, Vohs, & Tice, 2007). As such, dispositional self-control is a

critical component of success in contexts that require the ability to *consistently* delay gratification in pursuit of one's goals, such as the university setting.

To this author's knowledge, it has not yet been directly tested whether the relation between academic performance and NMUPS may be accounted for on the basis of self-control. However, strong support for this association may be inferred from a recent study by Munro and colleagues (Munro, Weyandt, Marraccini, & Oster, 2017). This study examined associations between academic performance, NMUPS, and executive functioning skills (which serve as an important prerequisite for successful self-control; Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013; Hofmann, Schmeichel, & Baddeley, 2012). Results demonstrated both poorer academic performance (GPA) and greater self-reported difficulties with executive functioning among participants who endorsed NMUPS. In addition to the more direct support provided by this study, indirect support for this hypothesized relation may be gleaned from a wealth of literature on these constructs. This section aims to briefly review the extant work linking academic functioning to self-control and implicating self-control in NMUPS.

Self-control and academic functioning. A substantive body of work has highlighted the importance of self-control to students' ability to successfully function academically. In a landmark study on this construct, Mischel and colleagues found that a preschooler's ability to delay gratification predicted their relative academic achievement in adolescence (Mischel et al., 1988). Self-control in adolescence has been shown to predict a range of academic outcomes, including grade 12 grade point average (GPA), graduation from high school, achievement test scores, and full-time university enrollment at one-year follow-up (Galla et al., 2014). Indeed, self-control has been shown to be a

more robust predictor of academic achievement than even intelligence (Duckworth & Seligman, 2005). Relatedly, low dispositional self-control has repeatedly shown strong relationships with procrastination—a prototypical example of self-control failure (reviewed in Steel, 2007).

A sizeable body of scholarly work has also implicated self-control in university students' academic success. Self-control has been shown to be positively related to GPA (Tangney, Baumeister, & Boone, 2004; Tibbetts & Myers, 1999; Wolfe & Johnson, 1995). Further, low self-control has been shown to be associated with frequency of skipped classes (Gibbs & Giever, 1995), increased likelihood of academic dishonesty, and perceived acceptability of dishonest academic behaviour (Bolin, 2004; Cochran, Wood, Sellers, Wilkerson, & Chamlin, 1998; Tibbetts & Myers, 1999).

The relation between self-control and university students' academic functioning may also be reflected by excessive engagement in a range of behaviours that have the potential to interfere with academic functioning—again reflecting choice of immediate gratification over long-term academic pay-offs. For example, there exists an inverse relation between university students' self-control and problematic drinking behaviour (Gibson, Schreck, & Miller, 2004; Tangney et al., 2004) and other substance use (Tibbetts & Whittimore, 2002). University students who report areas of poorer self-control (i.e., disinhibition) have also been shown to be at increased risk for pathological internet use (Niemz, Griffiths, & Banyard, 2005) and gaming addiction (Mehroof & Griffiths, 2010), increasing the likelihood of academic difficulties (Li, O'Brien, Snyder, & Howard, 2015).

Self-control and non-medical prescription stimulant use. The above-reviewed literature clearly suggests that self-control is critical for university students' academic success. Additionally, an emerging field of research has begun to link NMUPS to low dispositional self-control and related constructs.

With exception of Chapter II (this work), no existing studies have directly investigated the relation between dispositional self-control and NMUPS. Although one previous peer-reviewed study explored the relationship between depleted *state* levels self-control and willingness to engage in "neuroenhancement" (Wolff & Brand, 2013), the use of NMUPS-naïve participants limits the extension of this study to the present investigation. Specifically, as self-control becomes depleted, individuals are thought to revert to their typical patterns of behaviour—which, for non-users, is abstinence (Englert & Wolff, 2015). For individuals who have a history of NMUPS (the group of interest in the present investigation), the opposite may be expected. However, this supposition has not yet been tested in the published literature (although see Chapter III for an investigation of the applicability of the strength model to the broader construct of neuroenhancement).

Despite the relative lack of literature *directly* investigating the relation between self-control and NMUPS, considerable support for this association can be gleaned from studies linking NMUPS to constructs related to self-control. First, an inverse association has been demonstrated between the Big Five personality dimension of conscientiousness and non-medical use of prescription drugs with the intent to enhance cognition (Benotsch et al., 2013; Sattler & Schunck, 2016). Research has revealed that conscientiousness overlaps significantly with self-control (Tangney et al., 2004) to an extent that these

constructs are at times used interchangeably (e.g., Moffitt et al., 2011) or as sub-dimensions of the other (Olson, 2005; Steel, 2007). Thus, studies that have identified low conscientiousness in non-medical prescription stimulant users may have been tapping a relation between NMUPS and the overlapping construct of self-control, as is hypothesized in the current study.

A link between NMUPS and impulsivity has also been demonstrated. For example, in a study utilizing a particularly severe sample (i.e., students who reported frequent engagement in NMUPS; Maier, Wunderli, et al., 2015), NMUPS was found to be associated with elevated scores on the Barratt Impulsiveness Scale, a questionnaire frequently invoked in the measurement of impulsivity (and importantly, also used as a measure of self-control; de Ridder et al., 2012). Similarly, others have found an association between NMUPS and trait impulsivity (Lookatch et al., 2012). Like conscientiousness, impulsivity is a construct intimately related to self-control; indeed, it has been suggested that impulsivity may be conceptualized as the absence or ineffectiveness of the top-down regulatory processes which inhibit impulses in line with longer-term goals (Duckworth & Kern, 2011). In short, individuals who frequently act impulsively lack self-control.

Nonmedical stimulant use has further been associated with elevated self-reported symptoms on both the inattentive and hyperactive/impulsive symptom dimensions of ADHD (Chapter II, this work; Dussault & Weyandt, 2011; Peterkin, Crone, Sheridan, & Wise, 2011; Rabiner et al., 2010). Importantly, a prominent theory of ADHD implicates self-control in the deficits associated with both the inattention and

hyperactivity/impulsivity symptom dimensions (Nigg, 2016), providing additional credence to the hypothesis that self-control may be an important correlate of NMUPS.

Support for the potential link between dispositional self-control and NMUPS may be inferred from a study investigating associations between dispositional self-control and sports-related performance enhancement (Chan et al., 2015). Here, the authors demonstrated that individuals with lower levels of dispositional self-control tended to endorse greater acceptance of, and intent to engage in, sports-related performance enhancement. Though sports-related "doping" and NMUPS are not wholly equivalent—for example, university students view NMUPS as more acceptable than athletic performance enhancement (Dodge, Williams, Marzell, & Turrisi, 2012)—conceptually, these behaviours may both be linked to failure to resist temptation and willingness to transverse legal and ethical norms as a result.

The Current Study

To summarize, much work has indicated an association between low academic achievement and NMUPS, and between academic achievement and self-control. Additionally, research indirectly points to an association between self-control and NMUPS. This study sought to probe the relations between these constructs and to provide a novel hypothesized model explaining these relationships. Specifically, it was hypothesized that the association between academic functioning and NMUPS may be accounted for on the basis of measures representing dispositional self-control (i.e., both a global self-control measure as well as measures which particularly tap aspects of self-control relevant to academic functioning—academic diligence and procrastination). If

empirically supported, this model would highlight importance of self-control as a driving factor for the previously-identified GPA-NMUPS relation.

Methods

Participants

Estimated sample size needed. Sample size determinations were established *a priori* per recommendations of Peduzzi and colleagues (1996). These guidelines (developed on the basis of a series of simulation studies) suggest that the conventional equation for logistic regression sample size determinations ($N = 10k$, where k represents the number of independent variables in the model) should be adjusted for the proportion of positive/negative cases in the sample. Thus, the optimal sample for logistic regression may be derived from the equation $N = 10\frac{k}{p}$, where p reflects the smaller value of either the proportion of positive cases in the sample, or the proportion of negative cases in the sample. According to Long (1997), a minimum sample size of 100 should be used in cases where this equation yields $N < 100$. In the present model, $k = 4$ predictors. In the participant pool portion of the current sample (recruited for co-participation in the study reported in Chapter II and therefore available to guide *a priori* sample determination), 23.5% endorsed lifetime history of NMUPS; thus, $p = .235$. Using Peduzzi's equation, then, a minimum sample size of 170 participants would be needed to adequately power the current analyses. As such, it was expected that the sample reported for Study 1 (Chapter II) possessed adequate power for the proposed logistic regression model, even after removal of any invalid data.

Recruitment strategy. Because the relative proportion of individuals who engage in NMUPS vs. non-users is considerably smaller (see discussion of NMUPS

prevalence above), attempting to recruit equally-sized groups for the present study would inevitably produce results that inaccurately reflect the actual relation between variables in the population (Cohen et al., 2003). As such, no restrictions were placed on the relative size of the NMUPS vs. non-user subgroups.

Following Research Ethics Board approval, (n = 200) participants were recruited through the university's psychology department participant pool in conjunction with recruitment for Study 1 (reported in Chapter II). A small number of additional participants (n = 10) were recruited for the current study through advertisement on campus in an attempt to sample a broader population with regards to academic program and NMUPS patterns/motives. Thus, a total of 210 cases were available for use in the current study.

Demographic/background information for the sample and descriptive statistics on variables of interest (reported for the entire sample and stratified by recruitment source) are reported in Table 1. In the overall sample, slightly more than half of participants identified as female (58.6%). Approximately half identified as Caucasian (52.9%); 12.9% of the entire sample identified their ethnicity as Arab/Middle Eastern, and 11.9% indicated that they identified as Black/African. The majority (67.6%) of the overall sample was enrolled in a program in the university's Faculty of Arts, Humanities, and Social Sciences (67.6%). Participants were approximately evenly distributed across their first year (20.5%), second year (17.6%), third year (30.5%), or fourth year of study (22.9%), although a small number of participants indicated that they were enrolled in their fifth year or beyond (7.2%).

Measures

Demographic information. A series of demographic questions was compiled for use in the three studies comprising the current project (see Appendix A). Questions sample a range of demographic constructs, including participant gender, age, ethnicity, marital status, and history of learning disability or mental health diagnosis.

Academic functioning. The demographic questionnaire also includes information relevant to academic status (e.g., year of study, program of study, fraternity/sorority affiliation) and, of particular importance to the proposed study, academic functioning (operationalized as GPA, consistent with previous research; e.g., Galla et al., 2014; Tangney et al., 2004; see Appendix A). Note that participants were prompted to log into their university academic account to confirm their current GPA when reporting this variable in order to reduce bias associated with estimation and increase validity. Participants were asked to report their GPA for the past semester only and their cumulative GPA. For participants who were in their first semester of university at the time of study participation (n = 35), cumulative GPA at the end of high school was substituted for the latter variable (as this variable is highly correlated with university cumulative GPA; Richardson, Abraham, & Bond, 2012) .

Non-medical use of prescription stimulants. Participants' stimulant use was measured via a series of questions developed by Gallucci (2011). Relevant to the proposed study, this measure includes items tapping individuals' history of NMUPS (either by exceeding prescribed dosage or using stimulant medication without a valid prescription), both in their lifetime and in the past thirty days. To allow for optimum participant experience, five demographic items were deemed redundant with those

included in the demographic form (Appendix A) and were therefore removed from this measure for the current study. For the purpose of coding dichotomous logistic regression outcome variables (reflecting lifetime and past 30 day history of NMUPS), endorsement of any positive history in either one's lifetime or the past 30 days was coded as positive NMUPS for that variable (Gallucci et al., 2015, 2014).

Timeline follow-back assessment of NMUPS. As a supplement to the measure of NMUPS created by Gallucci (2011), a timeline follow-back (TLFB) assessment of NMUPS was administered. TLFB is a common method for measuring substance use frequency, with well-established validity for a range of substances and populations (Hjorthøj, Hjorthøj, & Nordentoft, 2012). The TLFB assessment method (developed by Sobell & Sobell, 1996) utilizes calendar-based prompts in order to facilitate recall of substance use occasions. In the present study, an online TLFB assessment of alcohol and marijuana use described by Pedersen and colleagues (2012) was adapted for measurement of neuroenhancement substance use; in the original study, the online TLFB demonstrated good congruence with more traditional (in person) TLFB administration overall, although there was some indication of more honest responding in the online format (Pedersen et al., 2012). Participants were first asked to indicate which substances they had used in the past 30 days for neuroenhancement as part of a larger measure of neuroenhancement substance use. For each substance participants endorsed using for neuroenhancement in the past 30 days, participants were directed to complete a timeline follow-back assessment of their 30-day neuroenhancement use patterns for that substance; for example, if participants endorsed neuroenhancement via use of caffeine

pills and NMUPS, participants completed a separate 30-day calendar for caffeine pills and prescription stimulants.

Procedures for completing the neuroenhancement TLFB were as follows. Participants were asked to list up to ten marker days for the 30-day timeframe assessed. Examples relevant to the university population (e.g., university course withdrawal deadlines, midterm and final exam dates) and holidays were also provided. After participants provided their marker days, these were auto-populated onto each applicable calendar. On each substance-specific calendar, participants were asked to report on their neuroenhancement substance use for each day. Guidelines (adapted from Pedersen et al., 2012) were provided to indicate substance quantities that were to be considered equivalent to one "use" (Appendix B); for example, participants reported NMUPS with regards to number of pills taken each day (e.g. two Adderall pills = "2"). For days when participants did not engage in neuroenhancement using a given substance, participants entered "0" into the calendar.

A sum was computed for each substance, reflecting the total score across all thirty days. An aggregate score was also derived for classes of substances (i.e., legal neuroenhancement, illicit substance neuroenhancement, NMUPS). This metric is a beneficial complement to dichotomous variables reflecting neuroenhancement history (i.e., history endorsed/denied), as it allows for increased specification of the degree of neuroenhancement that occurred among users (and use of this variable as a continuous outcome in a linear multiple regression model). Given the current study's focus on NMUPS, the thirty-day TLFB aggregate score for NMUPS was utilized.

Self-control. Given the diversity of definitions of the self-control construct (de Ridder et al., 2012), measurement of this important variable is likewise diverse (Duckworth & Kern, 2011). A variety of measures was selected to assess self-control in the present study, including the Self-Control Scale, a general measure of self-control which has seen relatively wide use. Given the focus of the current study on academic functioning, two additional measures of self-control were included that boast enhanced relevance for academic functioning. These include the Tuckman Procrastination Scale and the Academic Diligence Test.

Self-Control Scale. The Self-Control Scale (SCS; Tangney et al., 2004) is a domain-general self-report measure of self-control that broadly assesses individuals' ability to supersede their own immediate emotional state or behavioural drives in favor of longer-term goals. As such, it coincides with generally-accepted definitions of self-control (de Ridder et al., 2012). The measure consists of 36 items assessing self-control behaviours (e.g., "I am good at resisting temptation"; "I refuse things that are bad for me"). Using a five-point Likert scale (1 = "not at all"; 5 = "very much"), participants are asked to rate the degree to which each statement reflects their typical self. The authors report good internal consistency ($\alpha = .89$), good test-retest reliability ($r = .89$), and sufficient convergent and discriminant validity (Tangney et al., 2004). Internal consistency in the current sample was likewise good ($\alpha = .81$).

Tuckman Procrastination Scale. The 16-item Tuckman Procrastination Scale (TPS; Tuckman, 1991) is a self-report questionnaire measuring tendency to procrastinate on tasks. Using a four-point Likert scale (1 = "that's me for sure"; 2 = "that's my tendency"; 3 = "that's not my tendency"; 4 = "that's not me for sure"), participants are

asked to rate the extent to which each item applies to him- or herself (e.g., "I postpone starting things I don't like to do"; "I promise myself I'll do something and then drag my feet"). This measure demonstrated good-to-excellent internal consistency in the original study (α = .89; Tuckman, 1991) and in subsequent studies (e.g., α = .92, Howell & Watson, 2007; .88, Klassen, Krawchuk, & Rajani, 2008). Internal consistency was excellent in the current sample (α = .91). This measure has also demonstrated good convergence with other self-report and behavioural measures of procrastination (e.g. Howell & Watson, 2007; Tuckman, 1991). Following administration, scores on the Procrastination Scale were reversed such that high scores on the measured greater tendency to procrastinate.

Academic Diligence Task. The Academic Diligence Task (ADT; Galla et al., 2014) is a performance-based, domain-specific measure of self-control in the academic setting. Specifically, the ADT taps one's ability to persist in an ostensibly boring task (i.e., arithmetic problems) in pursuit of the long-term benefit of skills improvement. Uniquely, this task allows participants to self-direct between the tedious math practice and activities which are more immediately engaging but have no long-term benefit to the participant (e.g., computer games), such that participants are free to complete as much or as little arithmetic practice as they desire within the 20-minute test phase timeframe. This design parallels many students' experience working on schoolwork; to efficiently study or complete assignments, student must self-direct to prioritize long-term skill development over more immediately-rewarding distractions (e.g., social media, streaming television and movies, parties).

The structure of the ADT is as follows (Galla et al., 2014): first, participants are given brief instructions and complete a one-minute practice block of simple arithmetic problems (with no opportunities to divert attention to a "more engaging" task). Next, participants receive instructions for the full task, accompanied by a prompt describing the personal long-term benefits of arithmetic practice to the student (namely, that arithmetic practice over time improves problem-solving abilities; Royer, Tronsky, Chan, Jackson, & Marchant, 1999, as cited in Galla et al., 2014). During the test phase, participants complete a series of five four-minute, self-directed intervals.

Although a number of scores may be derived from ADT data, the primary metric of interest in measurement of self-control is participants' mean time "on task" (i.e., average time spent solving arithmetic problems" per block). Psychometric data for the ADT are reported by the task's creators (Galla et al., 2014). Although correlations with self-report measures of self-control were generally small (as is generally the case for the relation between self-report and performance-based self-control; Duckworth & Kern, 2011, as cited in Galla et al., 2014), analyses overall demonstrated adequate reliability for ADT time on task scores.

Procedure

Following clearance by the university's Research Ethics Board, participants were recruited through the online participant pool (per procedure reported in Chapter II) and through advertisement on campus. All undergraduate students were deemed eligible to participate. Participants who were recruited through the university's psychology participant pool completed measures for the current study as part of a larger battery (i.e., also including those measures reported in the study described in Chapter II). In exchange

for participation, participants recruited from the university's psychology participant pool received course credit (1 hour = 1 credit) in accordance with participant pool policy. Participants recruited from the university at large completed a smaller battery intended for use in the present study alone. Non-pool participants were awarded a $15 gift card in exchange for their participation.

On presenting at an on-campus computer lab for their appointment, all participants completed the informed consent process. Next, participants completed the battery of measures designated for their recruitment source (i.e., participant pool vs. non-pool), administered on a computer in random order. Validity check items were interspersed throughout the battery (e.g., "select '2' for this item"). As in studies reported in Chapter II and III, participants were prompted to check responses prior to proceeding if invalid responses were detected.

Analyses

Statistical models. Three separate statistical models were constructed in order to assess the role of self-control in the previously-specified relation of GPA with NMUPS. These three models are identical with regards to the array of possible independent variables included (i.e., GPA, Self-Control Scale, ADT average time on task, TPS total score) and differ only with regards to the NMUPS outcome variable, as follows: dichotomous measurement of lifetime history of NMUPS (Gallucci, 2011, Model 1); dichotomous measurement of 30-day history of NMUPS (Gallucci, 2011, Model 2); and continuous measurement of 30-day history of NMUPS (TLFB; Model 3). Independent variables not correlated with the outcome variable (a more liberal cutoff of $p < .10$ was

used to guide variable inclusion decisions) were removed prior to construction of the final model in order to reduce possibility of suppression effects.

As Models 1 and 2 specify categorical NMUPS outcome variables, these models were examined using logistic regression (LR). In contrast, the continuous nature of the NMUPS outcome variable in Model 3 prompted use of multiple regression analysis (MRA). These three models are depicted in Figure 1.

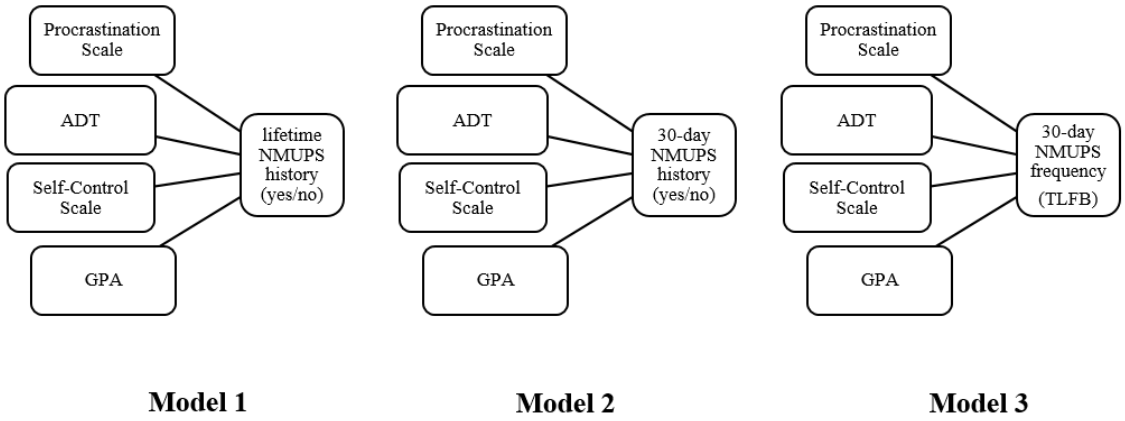

Figure 1. Hypothesized hierarchical models regressing academic performance and self-control-related variables onto non-medical use of prescription stimulants (NMUPS) history, defined dichotomously in Models 1 and 2 (Model 1: lifetime history of NMUPS; Model 2: 30-day history of NMUPS), and continuously in Model 3 (30-day timeline followback frequency of NMUPS). Across the three models, it was anticipated that the array of self-control variables would partially or fully account for variance in NMUPS outcomes associated with GPA. Note that independent variables not correlated with the dependent variable (at $p < .10$ level) were removed prior to final model construction.

A consideration particularly relevant for use of LR in this sample is the issue of data sparseness (i.e., small sample size in each cell). In assessing goodness of fit for the logistic regression analysis, the χ^2 test for goodness-of-fit in logistic regression may be biased by data sparseness (Cohen et al., 2003). Given the likelihood of data sparseness as a result of the relatively low proportion of participants who endorsed NMUPS, supplemental fit indices robust to data sparseness (e.g. Hosmer-Lemeshow Index of Fit)

were calculated for the LR models and were preferentially utilized in interpreting model goodness-of-fit.

Statistical assumptions of LR and MRA. Following data preparation, data were examined for violations of the main statistical assumptions of LR and MRA analyses, per guidelines described by Field (2009). Some statistical assumptions (independence, linearity, absence of multicollinearity) are common to both LR and MRA. First, the assumption of independence was met as a result of the study design (i.e., participants were permitted to provide data for only one case included in analyses). Additionally, both MRA and LR assume linearity, with the former assuming a linear relation between the dependent and independent variables, and the latter assuming a linear relation between the logit and continuous independent variables. For the LR models predicting lifetime and thirty-day history of NMUPS (Models 1 and 2), each continuous independent variable was linearly associated with the log of the outcome variable (i.e., derived variables reflecting the interaction of each independent variable with the log of itself did not contribute statistically-significant variance to the models; Field, 2009). For the MRA model predicting 30-day TLFB NMUPS frequency (Model 3), visual inspection of bivariate scatterplots demonstrated linear relations of the independent variables with the outcome variable. Finally, both LR and MRA assume absence of multicollinearity among independent variables. Examination of collinearity diagnostic values for both LR and MRA models suggested that this assumption was met (i.e., tolerance > 0.1).

Beyond these assumptions shared among both LR and MRA, data were explored for violations of additional assumptions of MRA (Model 3). Visual inspection of bivariate scatterplots suggested adequate homoscedasticity among standardized residuals

and predicted values. MRA also assumes absence of outliers or influential observations. Statistical exploration of the dataset demonstrated 3 cases that represented outliers on *y* ($z > \pm 3.27$). For these cases, the offending value was substituted for the highest non-outlier response on the corresponding variable. No data points represented outliers on *x*. Diagnostic statistics identified one influential observation (Cook's $d > 1.00$), which was removed for main analyses.

Despite these adjustments, histograms and inspection of skewness/kurtosis statistics (of standardized residuals) demonstrated violation of the assumption of multivariate normality. As Williams and colleagues (2013) describe, MRA is robust to violations of this assumption because, as sample size increases, the central limit theorem posits that the sampling distribution will become normalized. Indeed, "normally distributed errors are not required for regression coefficients to be unbiased, consistent, and efficient" (p. 10); however, although the model itself may remain unbiased, significance tests may be subject to bias in smaller samples. Statistical transformation of the data is generally discouraged in such cases, as interpretability tends to be sacrificed (Cohen et al., 2003). As such, in order to address the violation of the assumption of normality in the current sample, statistical tests were supplemented with more robust estimates of effect (e.g., structure coefficients, effect sizes).

Data preparation. Analysis of validity check items indicated that 6.7% of participants (fourteen cases) provided invalid responses to one or more validity check item (3.3% failed one, 1.0% failed two, 1.4% failed three, 0.5% failed four, and 0.5% failed six items). As exclusion of participants who fail validity checks has been shown to improve data validity and statistical power (Oppenheimer, Meyvis, & Davidenko, 2009),

main analyses were conducted after excluding cases which included one or more validity check failures (N = 195).

Data were examined for missing data points prior to execution of planned analyses. Analysis indicated a sparse pattern of missingness overall; data were missing across 1.52% of values, impacting 5 variables (7.69%) and 71 cases (33.81%). Little's (1988) test indicated that data were missing completely at random (MCAR; χ^2 (41) = 53.15, p = .10). Therefore, missing values were imputed using expectation maximization.

Results

Model 1. Variable intercorrelations for the current study are reported in Table 3. All four proposed independent variables were significantly correlated with lifetime NMUPS at the $p < .10$ level and were therefore included in the model.

Results of the hierarchical logistic regression analysis predicting the binary variable reflecting lifetime engagement in NMUPS (yes/no) are reported in Table 4. Entry of GPA in the first block resulted in a statistically-significant improvement in model fit beyond entry of the constant alone ($-2LL_{block0}$ = 206.47, $-2LL_{block1}$ = 191.76); the resultant model demonstrated adequate fit for the data, as demonstrated by the statistically-significant omnibus chi-square test ($p < .001$) and the nonsignificant Hosmer-Lemeshow test (p = .17). The block 1 model correctly classified 76.9% of participants. However, it must be noted that the model correctly classified 0% of participants with positive history of NMUPS.

In the second block, addition of SCS total score resulted in further improvement in the model's fit ($-2LL_{block2}$ = 184.60) and good model-data fit as demonstrated by the omnibus chi-square test (p = .01) and the Hosmer-Lemeshow statistic (p = .36). The

model correctly classified 77.9% of participants overall, and correctly classified 9.3% of participants with history of NMUPS. SCS total scores contributed unique variance above and beyond that accounted for by GPA, but GPA continued to contribute statistically-significant variance to prediction of NMUPS group membership. Thus, GPA and self-reported self-control independently contributed to lifetime NMUPS outcomes in this model.

In the third block, addition of ADT time on task did not lead to substantial change in the model overall ($-2LL_{block3} = 182.76$); model-data fit at this step was moderate per the Hosmer-Lemeshow statistic ($p = .55$), but did not reach statistical significance as measured by the omnibus test ($p = .18$). ADT time on task was not a statistically-significant predictor of lifetime NMUPS outcomes ($p = .17$). The model correctly classified 77.9% of participants overall, and correctly classified 14.0% of participants with history of NMUPS.

In the fourth block, addition of Procrastination Scale total scores likewise did not result in substantial improvement in the model ($-2LL_{block4} = 182.09$). The fit of the model to the data was improved per the Hosmer-Lemeshow statistic ($p = .92$) but did not reach statistical significance when quantified via the omnibus chi-square test ($p = .41$). Procrastination scores were not a statistically-significant predictor of lifetime NMUPS ($p = .42$) beyond variables already accounted for in the model. Consistent with relatively unchanged log likelihood values in this step following addition of procrastination scores, the predictive accuracy of the model was unchanged vs. block 3 (overall accuracy = 77.9, predictive accuracy for participants with positive history of NMUPS = 14.0%). The final model was statistically-significant overall ($\chi^2_{model}(1) = 23.65$, $p < .001$).

In summary, both GPA and Self-Control Scale total score were statistically-significant factors in the model explaining lifetime history of NMUPS. However, these variables contributed unique variance to explanation of lifetime NMUPS, suggesting that they are separate risk factors for lifetime engagement in NMUPS. ADT time on task and Procrastination Scale scores did not account for unique variance in lifetime NMUPS beyond that accounted for by GPA and SCS total scores.

Model 2. Inspection of point-biserial correlations (Table 3) revealed that dichotomously-measured past 30-day history of NMUPS was not correlated ($p < .10$) with ADT time on task ($p = .83$) or Procrastination Scale total scores ($p = .81$); as such, these variables were excluded from final analyses.

Results of the hierarchical logistic regression analysis predicting the binary variable reflecting past-30-day engagement in NMUPS (yes/no) are reported in Table 5. Entry of GPA in the first block of the analysis resulted in minimal improvement in model prediction beyond entry of the constant alone ($-2LL_{block0} = 95.52$, $-2LL_{block1} = 92.29$); the resultant model demonstrated adequate model-data fit according to the Hosmer-Lemeshow test ($p = .15$) and approached statistical significance per the omnibus chi-square test ($\chi^2(1) = 3.23$, $p = .07$). GPA approached significance as a predictor of 30-day NMUPS outcomes ($p = .08$). The block 1 model correctly classified 93.3% of participants overall, although it correctly classified 0% of participants with positive past 30-day history of NMUPS.

In the second block, addition of SCS total score resulted in modest improvement in model prediction overall ($-2LL_{block2} = 89.39$). Model-data fit was marginally improved per the nonsignificant Hosmer-Lemeshow test ($p = .46$), and approached statistical

significance as measured by the omnibus chi-square test (p = .09). Notably, predictive accuracy of the model was unchanged; the model continued to classify 93.3% of participants correctly overall, although it did not correctly classify any participants with past 30-day history of NMUPS. In the final block, SCS total scores alone approached significance as a predictor of 30-day NMUPS history (p = .09); GPA no longer demonstrated marginal statistical significance in the model after entry of SCS scores (p = .25). The final model fit was marginally statistically-significant ($\chi^2(2) = 6.14$, p = .05).

In summary, GPA demonstrated marginal statistical significance in explanation of 30-day NMUPS outcomes, with lower GPA tending to confer greater risk for engagement in NMUPS. However, SCS total scores (which approached statistical significance) tended to predict 30-day NMUPS outcomes above and beyond GPA. Neither ADT time on task nor Procrastination Scale scores was significantly ($p < .10$) associated with 30-day history of NMUPS.

Model 3. Bivariate correlations between hypothesized independent variables and TLFB 30-day NMUPS frequency scores are reported in Table 6. Surprisingly, inspection of bivariate correlations revealed that TLFB frequency of NMUPS was not significantly ($p < .10$) associated with GPA (p = .49), SCS total scores (p = .22), ADT time on task (p = .16), or Procrastination Scale total scores (p = .33). As such, the planned regression model was not executed. Examination of partial and semi-partial correlation coefficients (Table 6) indicated that each of these variables accounted for only negligible variance in TLFB frequency scores. Thus, the array of academic and self-control variables does not appear to drive variance in the frequency with which participants in this sample engaged in NMUPS in a 30-day span.

Post-hoc exploratory analysis of measure equivalency. Due to the discrepancy in models 2 and 3 (ostensibly reflecting multiple levels of analysis of the same behaviour, i.e., dichotomous coding of 30-day NMUPS history vs. continuous coding of 30-day NMUPS history), it was hypothesized that differences in measurement technique (i.e., free recall vs. more specific, calendar-prompted recall) may drive the discrepancy across models 2 and 3. In order to test consistency across the two assessment modalities, a dichotomous categorical variable was derived from the 30-day TLFB data, reflecting positive history of NMUPS (i.e., one or more instances of NMUPS) or negative history (no instances of NMUPS) on the 30-day TLFB assessment. This variable should hypothetically be analogous to the dichotomous 30-day NMUPS variable derived from the Gallucci (2011) questionnaire if the two measurement methods are comparable (i.e., a participant who endorsed past 30-day NMUPS on the Gallucci measure should endorse one or more instances of NMUPS on the past 30-day TLFB assessment of NMUPS). Chi-square analysis demonstrated discordance between the two 30-day history variables ($\chi^2(1) = 138.64$, $p < .001$), suggesting that the TLFB method produced a unique pattern of NMUPS endorsement versus the single-item method derived from Gallucci (2011). As is evident in Table 2, the TLFB assessment resulted in slightly higher rates of past 30-day endorsement of NMUPS compared to the comparable single-item measure (7.7% versus 6.7%, respectively).

Discussion

The current study builds upon prior work demonstrating an association of poorer academic performance among individuals who engage in non-medical use of prescription stimulants (NMUPS) as a means of cognitive and academic performance enhancement.

The current study investigated a novel hypothesis regarding this finding: that the association between academic performance and NMUPS may be accounted for (either wholly or in part) by self-control. In the present study, self-control was quantified both via self-report measures of dispositional self-control (Tangney, Baumeister, & Boone, 2004) and the related construct of procrastination (Tuckman, 1991), and via the Academic Diligence Task, a performance-based measure designed to assess real-world application of self-control that is relevant to the academic setting (Galla et al., 2014). To test this hypothesis, three models were constructed utilizing as outcome indicators three measures of NMUPS history, including dichotomous (yes/no) measurement of lifetime NMUPS history and dichotomous measurement of past 30-day NMUPS history. A novel adaptation of timeline follow-back methodology (widely used and well-validated for measurement of general substance use; Pedersen et al., 2012) was included as a third measure of NMUPS, providing a dimensional measure of 30-day NMUPS history (i.e., reflecting "severity" of NMUPS in past 30 days).

Results partially supported the *a priori* hypothesis, as results were discrepant across the three models (reflecting a differential pattern of associations of self-control and academic achievement with the three NMUPS measurement variables). Specifically, in the logistic regression model differentiating students who had engaged in NMUPS in their lifetime from those who had not, self-ratings of dispositional self-control contributed unique variance to the statistical prediction of NMUPS history beyond that accounted for by students' GPA. However, performance-based self-control measurement and procrastination self-ratings did not contribute additional variance above and beyond that associated with self-control and GPA. In the logistic regression model

differentiating students who had engaged in NMUPS in the past 30 days from those who had not, a non-significant trend ($p < .10$) was identified whereby SCS fully accounted for the variance in NMUPS outcomes initially accounted for by GPA (as demonstrated by reduction in *p* value; it must be noted, however, that the initial association of GPA with NMUPS was of marginal statistical significance).

Although trait self-control (and in the case of lifetime NMUPS history, also GPA) predicted entry into NMUPS and whether participants had engaged in this behaviour in the past 30 days, surprisingly, GPA and the array of self-control variables (self-rated dispositional self-control, performance-based measurement of academic self-control, and self-rated procrastination) were not significantly associated with the frequency with which participants reported that they had engaged in NMUPS (measured via TLFB) in the past 30 days.

The results derived from models predicting categorical measures of NMUPS history in this study unite the extant literature by highlighting both poor dispositional self-control and poor academic performance as risk factors for engagement in NMUPS. Interestingly, these factors appear to confer separate risk for students' entry into NMUPS behaviour (i.e., lifetime engagement in NMUPS), in accordance with prior work demonstrating higher rates of NMUPS among both individuals with lower GPA (Arria et al., 2013; Clegg-Kraynok et al., 2011; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2009; Rabiner et al., 2010) and those who endorse traits related to poor self-control (e.g. Sattler & Schunck, 2016).

However, in the case of past 30-day history of NMUPS, the initial association of GPA and NMUPS appeared to be fully accounted for by self-reported self-control. The

discrepancy between these models (i.e., separate vs. overlapping variance associated with GPA) is relevant, as lifetime history reflects a different pattern of substance use compared to past 30-day use. Indeed, while lifetime history includes single-occasion/experimental substance use patterns, past 30-day history is thought (in aggregate) to reflect more "active" use of a substance (e.g., Wickersham et al., 2016). Thus, although academic underachievement may be an additional distinct motivator for NMUPS experimentation, it can be hypothesized that self-control appears to be a primary driving force among individuals who initiate NMUPS and continue to actively engage in this behaviour.

Taken together, these findings support the prospect that individuals with both poor academic performance and poor self-regulatory skills may engage in NMUPS as a means of propelling themselves toward their academic goals. As proposed by Englert & Wolff (2015), this finding supports the application of Drug Instrumentalization Theory (Müller & Schumann, 2011) to neuroenhancement behaviour broadly and NMUPS more specifically. In this model, individuals engage in substance use (and specifically, neuroenhancement behaviours such as NMUPS for this purpose) in order to reduce discrepancy between their perceived current state and their goal state. Current results suggest that individuals may indeed perceive discrepancy between their current academic performance and their academic goal state, leading to entry into NMUPS. Further, when students perceive discrepancy between their available self-control resources and those required to achieve their academic goals, they may engage in NMUPS with intent to "bridge the gap" and bring them closer to their long-term goals.

The current findings may also be understood within a related framework proposed by Wolff and colleagues (Wolff et al., 2014). This model applies the Job Demands-Resources Theory (JD-R theory; Demerouti, Bakker, Nachreiner, & Schaufeli, 2001) to students' engagement in neuroenhancement behaviour, positing that in circumstances when resources (including both external resources, such as study support, and internal resources, which could include self-control) are inadequate to meet school-related demands, students experience burnout which leads to poor academic performance. Students may turn to neuroenhancement as a means of ameliorating the impact of high academic demands on their school performance (Wolff et al., 2014). Notably, however, the authors found that "such attempts might backfire" (p. 6); in their study, high academic demand was more strongly associated with burnout among students who engaged in prescription drug neuroenhancement. Additionally, students with higher internal resources (which would normally enhance motivation and protect against burnout) who engaged in prescription drug neuroenhancement experienced reduction of these protective effects. Thus, the present demonstration of poorer academic performance and poorer self-control among individuals who have engaged in NMUPS in their lifetime could suggest that individuals at greater risk for burnout may turn to NMUPS as a (possibly unhelpful) strategy to increase available resources in order to meet academic demands.

The failure to demonstrate an association of academic performance and the array of self-control variables with the dimensional variable reflecting NMUPS severity (derived from an adapted TLFB assessment) has key implications for NMUPS research. The preponderance of studies of NMUPS (and of neuroenhancement in general) has

measured these behaviours dichotomously (i.e., lifetime, past year, past 30-day history). While those who have engaged in NMUPS (or other forms of neuroenhancement) appear to be distinct from lifetime abstainers (see Chapters II and III), frequency appears to be a distinct facet of the NMUPS/neuroenhancement construct. In the current study, a pattern of associations of self-control and academic achievement was identified that discriminated participants with and without history (lifetime, past 30-day) of NMUPS. However, these factors did not appear to explain variance in frequency of engagement in NMUPS. Thus, frequency with which individuals engage in NMUPS—and factors which differentiate those who engage rarely vs. frequently – remains an empirical question in need of further exploration. Although not permitted in the current study due to cell sizes, it may be interesting to explore in future work the academic and dispositional factors that differentiate low and high frequency of engagement in NMUPS among users.

Post-hoc analyses suggested that individuals endorsed different patterns of past 30-day use on the TLFB versus single-item assessment methods. This result echoes previous work highlighting subtle differences in substance use endorsement on TLFB versus global measures of substance use. For example, a comparison of TLFB and a global measure of cigarette use among college students who engaged in non-daily smoking (Harris et al., 2009) demonstrated minor (yet statistically-significant) differences in patterns of endorsement across measures. This effect was moderated by overall intensity of smoking; heavier smokers tended to report smoking more cigarettes (overall and per day) on TLFB than on a global measure. Unlike the current study, however, Harris and colleagues found that derived dichotomous variables of past 30-day

smoking history (akin to that derived for NMUPS in the current study) were comparable for TLFB and the global measure. In contrast, the current study demonstrated modest differences in the participants identified by the dichotomous measures of 30-day history derived from the TLFB and global measures.

Factors contributing to the discrepancy between TLFB and single-item measurement of dichotomous, 30-day history in the case of NMUPS require further investigation. Importantly, the illicit nature of NMUPS may introduce additional bias in students' reporting. This prospect is supported by the psychometric properties of the National Survey on Drug Use and Health (Substance Abuse and Mental Health Services Administration, 2010), which demonstrated an overall trend toward lower reliability for measures of illicit drug use compared to legal drug use methods. It should also be noted that, for students recruited through the participant pool, the battery of measures (which included those for both the current study and the study reported in Chapter II) was somewhat lengthy. Although random ordering of measures was implemented in order to alleviate effects of fatigue on any specific measure, participant fatigue may have nonetheless resulted in more inconsistent responding as the study progressed (thus introducing error into study data).

Additional limitations of the current investigation must be acknowledged. First, it must be noted that a heterogeneous measure of cumulative GPA was used in the current study. For the majority of participants, this variable reflected university cumulative GPA; however, for a small subset of the sample who were in their first semester of university study at the time of participation (n = 35), university cumulative GPA data were not available and high school cumulative GPA were instead used. As described

above, there is an extensive literature demonstrating strong correspondence between these variables; indeed, high school GPA has been shown to predict university GPA more strongly than even college entry exam performance (i.e., ACT or SAT; Richardson et al., 2012). Thus, in the interest of including first-semester students and therefore preserving statistical power, high school cumulative GPA was used as a substitute for students for whom no university cumulative GPA data yet existed. Nonetheless, future studies may benefit from comparison of current results to those obtained in of an older sample (i.e., second year and above) for whom university GPA data are available. Notably, older participants may also be in more challenging academic courses and therefore may be at greater risk of engagement in NMUPS (Desantis & Hane, 2010; McCabe, Knight, Teter, & Wechsler, 2005).

Relatedly, there may be limits to the generalizability of current results. Although the sample was representative of the university where data were collected, it is unclear how current results (based on a majority-Caucasian sample) will generalize to university students of other cultural backgrounds and geographic areas. Ethnic background has been shown to be relevant for risk of engagement in neuroenhancement (Weyandt et al., 2008); therefore, it will be important to continue to understand the interplay of self-control and academic functioning as relates to neuroenhancement risk in other groups. Finally, the current sample was somewhat more balanced with regards to gender than is typical for participant pool samples (Dickinson et al., 2012). Although this may improve the generalizability of the current findings with the university student population in general, it may problematize comparisons with studies based on more typical undergraduate samples.

Finally, a limitation inherent to the method of quantifying non-medical prescription drug use via the TLFB assessment must be acknowledged. Drug use quantities provided in the TLFB reflected number of pills used, rather than specific dose (see Appendix B). This method boasted several benefits; first, in other studies in this work, a subset of participants indicated that they were unsure which ADHD medication they had taken (e.g. see Chapter II), suggesting that (at least for some participants) assessment of specific substance/dose used may be unreliable. Additionally, assessing number of pills used enabled creation of a composite variable across ADHD medications. However, as a result, it must be acknowledged that the derived variable quantifies instances/frequency of NMUPS behavior and does not provide data regarding dosage. Thus, future studies utilizing TLFB methodology may benefit from assessment of drug- and dose-specific factors in order to further understand patterns of use and drug-specific effects. Such efforts may be aided by use of aids to enhance participants' accuracy in identifying substances used (e.g., visual pill identification charts).

Despite these limitations, the current study makes important contributions to the academic understanding of students' non-medical use of stimulant drugs. Specifically, the current results highlight poor academic performance as a possible risk factor for lifetime initiation of NMUPS. However, deficient self-control appears to be a critical factor for not only lifetime but also active use of NMUPS. Given the significant risk associated with NMUPS (Urban & Gao, 2017) and indication that it may not actually reduce academic strain (Wolff et al., 2014), the issue of NMUPS remains an important area that needs to be addressed on university campuses. Current results suggest that resources directed at bolstering students' academic performance (e.g., class review

sessions, availability of peer tutoring) may reduce students' perceived need to engage in NMUPS in order to meet the academic demands of the university setting. Moreover, current results highlight individuals with low self-control as a population at particular risk of lifetime and active engagement in NMUPS. As such, systemic efforts to identify these individuals and provide accessible, effective interventions are highlighted as a possible route to decreasing participation in NMUPS.

Table 1

Study 3 Participant Demographic Characteristics and Descriptive Statistics for Model Variables

		% endorsed		
		total sample (N = 210)	psychology pool (n = 200)	university-wide recruitment (n = 10)
Gender	Female	58.6	57.5	80.0
	Male	40.5	41.5	20.0
	No response	0.9	1.0	0.0
Ethnic back-ground[1]	Aboriginal/First Nations	1.0	1.0	0.0
	Black/African	11.9	12.0	10.0
	East Asian	3.3	3.0	10.0
	South Asian/Indian	8.6	7.5	30.0
	Hispanic/Latino	2.4	2.5	0.0
	Caucasian or non-Hispanic White/European	52.9	55.0	10.0
	Arab/Middle Eastern	12.9	12.0	30.0
	Biracial/multiethnic	5.7	5.5	10.0
	Other	0.5	0.5	0.0
	Prefer not to answer	1.0	1.0	0.0
Academic faculty (program of study)	Arts, humanities, and social sciences	67.6	68.0	60.0
	Education	1.0	1.0	0.0
	Engineering	2.9	2.5	10.0
	Kinesiology	4.8	5.0	0.0
	Law	0.5	0.0	10.0
	Nursing	4.3	4.0	10.0
	Business	8.1	8.6	0.0
	Science	9.0	9.0	10.0
	Undecided	0.5	0.5	0.0
	No response	1.4	1.5	0.0
Honors status	Enrolled in honors program	6.7	7.0	0.0
	Not enrolled in honors program	91.9	91.5	100.0
	No response	1.4	1.5	0.0
Year of study	First	20.5	20.0	30.0
	Second	17.6	17.5	20.0
	Third	30.5	32.0	0.0
	Fourth	22.9	21.5	50.0
	Fifth	6.7	7.0	0.0
	Sixth and beyond	0.5	0.5	0.0
	No response	1.4	1.5	0.0

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	M (SD)		
	Total sample (*N* = 210)	Psychology pool (*N* = 200)	Recruited through university advertisement (*N* = 10)
Age	21.61 (4.32)	21.59 (4.37)	22.00 (3.46)
GPA (%) –university cumulative average*	73.73 (8.24)	78.29 (8.16)	78.29 (8.16)
GPA (%) – last semester average**	75.00 (8.80)	79.43 (8.48)	79.43 (8.48)
Self-Control Scale total score	113.07 (15.17)	113.19 (15.29)	110.29 (12.45)
ADT % time on task	75.75 (23.59)	75.86 (21.39)	73.25 (26.44)
Procrastination Scale total score	38.29 (9.30)	38.16 (9.32)	40.80 (8.87)

Note. [1]Categories are not mutually-exclusive. Abbreviations: GPA = grade point average; ADT = Academic Diligence Task. *university cumulative average only available for students in their second semester and beyond. **students in their first semester (*n* = 35) were asked to report last semester of cumulative high school GPA.

Table 2

Non-Medical Use of Prescription Stimulant Endorsement Characteristics

Gallucci (2001) – NMUPS survey	% Endorsed
History of ADHD diagnosis	6.2
Current prescription for a stimulant medication	4.8
History of NMUPS[1]	---
Lifetime	21.9
Past thirty days	6.7
History of using a prescribed stimulant medication in excess/for unintended purposes:	---
Lifetime	4.3
Past thirty days	0.5
History of taking prescription stimulant without a prescription:	---
Lifetime	21.9
Past 30 days	6.2

30-day timeline follow-back for NMUPS	% Endorsed	*M* (SD)
Any history of NMUPS in past 30 days	7.7	---
Number of occasions of NMUPS[2]	---	0.55 (3.07)

Note. [1]Includes both use of prescribed mediation in excess/for unintended purposes and taking prescription stimulant without a prescription. [2]One occasion = one stimulant pill. Abbreviation: NMUPS = non-medical use of prescription stimulants.

Table 4

Study 3 - Results of Model 1: Logistic Regression Model Predicting Lifetime (Yes/No) History of NMUPS (N = 195)

	B (SE)	95% CI for Odds Ratio			R^2		χ^2 (Step)			
		Lower	OR	Upper	Cox & Snell	Nagelkerke	Omnibus χ^2	df	Hosmer-Lemeshow χ^2	df
Block 1	--	--	--	--	.07	.11	13.99†	1	11.56	8
GPA[1]	-0.08 (0.23)**	0.88	0.92	0.97	--	--	--	--	--	--
Constant	4.60 (1.67)**	--	--	--	--	--	--	--	--	--
Block 2	--	--	--	--	.10	.16	7.15**	1	8.76	8
GPA[1]	-0.06 (0.02)**	0.90	0.94	0.99	--	--	--	--	--	--
SCS total score	-0.04 (0.01)**	0.94	0.96	0.99	--	--	--	--	--	--
Constant	7.53 (2.10)†	--	--	--	--	--	--	--	--	--
Block 3	--	--	--	--	.11	.17	1.84	1	6.89	8
GPA[1]	-0.06 (0.02)**	0.90	0.94	0.98	--	--	--	--	--	--
SCS total score	-0.03 (0.15)*	0.94	0.97	1.00	--	--	--	--	--	--
ADT time on task	-1.18 (0.87)	0.06	0.31	1.69	--	--	--	--	--	--
Constant	7.85 (2.12)†	--	--	--	--	--	--	--	--	--
Block 4	--	--	--	--	.11	.18	0.67	1	3.18	8
GPA[1]	-0.06 (0.02)**	0.89	0.94	0.98	--	--	--	--	--	--
SCS total score	-0.04 (0.02)*	0.92	0.96	1.00	--	--	--	--	--	--
ADT time on task	-1.11 (0.88)	0.06	0.33	1.82	--	--	--	--	--	--
TPS total score	-0.22 (0.03)	0.93	0.98	1.03	--	--	--	--	--	--
Constant	9.78 (3.21)**	--	--	--	--	--	--	--	--	--

Note. *$p < .05$, **$p < .01$, †$p < .001$. [1]cumulative GPA. Abbreviations: GPA = grade point average, SCS = Self-Control Scale, ADT = Academic Diligence Task, TPS = Procrastination Scale, NMUPS = non-medical use of prescription stimulants. Final model χ^2 (4) = 23.65, $p < .001$.

Table 5

Study 3 - Results of Model 2: Logistic Regression Model Predicting Past 30 Day (Yes/No) History of NMUPS (N = 195)

	B (SE)	95% CI for Odds Ratio			R^2		χ^2 (Step)			
		Lower	OR	Upper	Cox & Snell	Nagelkerke	Omnibus χ^2	df	Hosmer-Lemeshow χ^2	df
Block 1	--	--	--	--	.02	.04	3.23	1	12.02	1
GPA[1]	-0.06 (0.04)	0.88	0.94	1.01	--	--	--	--	--	--
Constant	1.82 (2.51)	--	--	--	--	--	--	--	--	--
Block 2	--	--	--	--	.03	.08	2.91	1	7.72	8
GPA[1]	-0.04 (0.04)	0.89	0.95	1.03	--	--	--	--	--	--
SCS total score	-0.04 (0.02)	0.92	0.96	1.01	--	--	--	--	--	--
Constant	4.66 (3.10)	--	--	--	--	--	--	--	--	--

Note. *$p < .05$, **$p < .01$, †$p < .001$. [1]cumulative GPA. Abbreviations: GPA = grade point average, SCS = Self-Control Scale, NMUPS = non-medical use of prescription stimulants. Final model $\chi^2(2) = 6.14$, $p = .05$.

Table 6

Study 3 - Variable Intercorrelations for Variables Included in Model 3 (N = 195)

	r	*pr*	pr^2	*sr*	sr^2
GPA[1]	-.06	-.10	.01	-.10	.01
Self-Control Scale total score	.10	.11	.01	.11	.01
ADT time on task	-.05	-.08	.01	-.08	.01
Procrastination Scale total score	-.08	-.01	.00	-.01	.00

Note. $*p < .05$; $**p < .01$; $***p < .001$. [1] Point-biserial correlation. [2]Cumulative GPA at last semester; students in their first semester were asked to report last semester of cumulative high school GPA. Abbreviations: *r* = zero-order correlation, *pr* = partial correlation, *sr* = semi-partial correlation; GPA = grade point average; ADT = Academic Diligence Task; NMUPS = non-medical use of prescription stimulants; TLFB = timeline follow-back assessment.

V. GENERAL DISCUSSION

Primary Aims

Students' use of substances for the purposes of cognitive or academic performance enhancement (often referred to as "neuroenhancement") has attracted increasing research attention in recent years. While the non-medical use of prescription stimulants has been a particularly frequent focus of the neuroenhancement literature, it has been suggested that the use of any substance to enhance or facilitate cognitive/academic performance reflects instrumental behaviour (Müller & Schumann, 2011) and therefore merits research attention under the neuroenhancement construct (Englert & Wolff, 2015).

Until recently, however, the preponderance of work in this area has been limited to epidemiological studies of the prevalence and demographic patterns of use. Although it represents a burgeoning area of interest in the field, less is known regarding the psychological and behavioural correlates of engagement in different classes of neuroenhancement behaviour. Beyond adding to the sparse data regarding neuroenhancement in the Canadian university student population, the studies reported in this work aimed to add to the literature by examining whether low levels of one such psychological factor, self-control, may act as a risk factor for university students' engagement in neuroenhancement behaviour. In doing so, the current investigation harnesses evidence-based assessment of students' self-regulatory skills (which necessitates a multi-method approach; Duckworth & Kern, 2011) and lends insight into the neuroenhancement construct itself.

Under this overarching aim, three studies were executed to investigate specific facets of the self-control/neuroenhancement relation. The first study (Chapter II) sought to examine whether associations of neuroenhancement with a multivariate array of self-control variables differed across three classes of neuroenhancement (i.e., legal neuroenhancement, illicit drug neuroenhancement, prescription drug neuroenhancement). It was anticipated that results would illuminate not only the association of deficient self-control with students' engagement in neuroenhancement, but also attest to the optimal approach to defining the neuroenhancement construct. Indeed, it has been suggested that neuroenhancement can be conceptualized as a unitary construct (united by a single means-end relationship) rather than discrete, substance-specific classes of behaviour (Englert & Wolff, 2015).

In the study reported in Chapter III, the relevance of state variation in self-control was investigated through application of the controversial strength model of self-control (also known as the *ego strength* or *resource model* of self-control*;* Baumeister, 2013) to the neuroenhancement construct. In addition to addressing the limitations of a previous effort in this area (Wolff et al., 2013), it was anticipated that this study could extend the existing literature by moving from description of trait-level correlates of neuroenhancement into discussion of impact of phasic influences on neuroenhancement risk. In the context of ongoing debate regarding the reliability and validity of the so-called "ego depletion effect" (Friese et al., 2018), an ancillary function of this study included an effort to utilize cornerstone methods from the ego strength literature to independently replicate a depletion effect on students' state self-control.

Finally, the third study (Chapter IV) sought to explore contributions of self-control to the previously-demonstrated finding of poorer academic achievement among students who engage in non-medical use of prescription stimulants (NMUPS) for neuroenhancement purposes (Arria et al., 2013; Clegg-Kraynok et al., 2011; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2009; Rabiner et al., 2010). It was anticipated that the association between grade point average (GPA) and NMUPS (defined both dichotomously [over lifetime and past-30-day intervals] and dimensionally [as past 30-day TLFB frequency]) could be accounted for by self-control. Beyond the primary aims of elucidating the role of self-control in the academic underachievement of students who engage in NMUPS, this study addressed critical limitations of extant works in this area (e.g., limited studies differentiating one-time vs. more active/frequent use; lack of studies directly addressing the role of self-control in NMUPS).

Thematic Results

Who Engages in Neuroenhancement?

Associations of neuroenhancement with self-control. This dissertation provided clarity to the psychological and academic correlates of engagement in neuroenhancement behaviour in university students. Across studies, trait self-control emerged as an important factor associated with lifetime engagement in neuroenhancement; however, there were notable nuances to this relation. In Chapter II, results suggested associations of self-control with neuroenhancement, but highlighted a need to refine the notion that neuroenhancement may be conceptualized as a unitary construct (e.g., Englert & Wolff, 2015). ADHD symptoms—which, under one conceptual model of ADHD are reflective of deficient self-control (Nigg, 2016)—

appeared to unify the three classes of neuroenhancement behaviour (consistent with the hypothesis that neuroenhancement constitutes self-medication of sub-clinical or undertreated ADHD symptoms, e.g., Wilens et al., 2008). Additionally, an array of other self-reported variables related to self-control (i.e., trait self-control, non-planning impulsiveness, motor impulsivity) loaded onto variates explaining both legal and illicit drug neuroenhancement, echoing prior work supporting an association of self-control-related variables with neuroenhancement (e.g., Ilieva & Farah, 2015; Lookatch et al., 2012; Peterkin et al., 2011).

In addition to these results, the results reported in Chapter II highlighted an otherwise distinct pattern of associations of self-control across the three modes of neuroenhancement. Interestingly, associations of self-control with illicit drug neuroenhancement (which consisted primarily of cannabis use) were paradoxical, characterized by poor self-ratings of self-control contrasting *less impulsive* performance patterns on one task-based measure of self-control (delay discounting task). This may reflect the *planful* effort of students to use cannabis to reduce negative affectivity (Middendorff et al., 2012) in support of improved academic outcomes. However, given that statistical prediction of cannabis-related neuroenhancement was limited by small cell sizes, future research is needed to replicate and further explore this interesting finding.

In the study reported in Chapter IV, trait self-control was again identified as a correlate of neuroenhancement behaviour – this time, within the specific class of NMUPS. Both self-reported trait self-control and performance on an academically-oriented self-control task were significantly associated with lifetime history of NMUPS (although the latter did not predict unique variance in predicting the dichotomous

outcome variable reflecting lifetime NMUPS history above and beyond the variance accounted for by participants' academic performance and self-control ratings). Similarly, trait self-control ratings marginally predicted the dichotomous outcome variable reflecting 30-day (i.e., "active") history of NMUPS. Interestingly, self-control was *not* associated with past 30-day frequency of engagement in NMUPS (as measured by TLFB), suggesting that although self-control may drive entry into lifetime and active use of NMUPS, other factors may drive high-frequency engagement in this behaviour.

In contrast to the broad demonstration of an association of *trait*-level differences in self-control with students' engagement in neuroenhancement generally (and the specific case of NMUPS), there was not clear support for an association of *state* self-control variation with neuroenhancement in the current work. In Chapter III, an experimental protocol was implemented that has been purported to "deplete" participants' self-control. According to the strength model of self-control and a prior study which demonstrated an impact of self-control depletion on students' neuroenhancement behaviour (Wolff et al., 2013), this would make participants more likely to revert to their established behavioural response (e.g., students who had a history of engaging in neuroenhancement would be more likely to engage in neuroenhancement when state self-control was depleted). However, results did not support this notion; the experimental group (which received the supposedly "depleting" manipulation) did not meaningfully differ from the control group across aggregate measures of both neuroenhancement attitudes and intent, although trait self-control was again a statistically-significant predictor of both more pro-neuroenhancement attitudes and intent to engage in neuroenhancement in the future. There was likewise no significant effect for the

interaction of lifetime neuroenhancement history with experimental group, challenging the notion that depleted students "revert" to previously-established neuroenhancement-related behavioural repertoires. Thus, although trait self-control appears to be one indicator of risk of engagement in neuroenhancement, research investigating a possible role of state variation in neuroenhancement risk (i.e. Wolff et al., 2013 and Chapter III, this work) has produced conflicting results.

Associations of neuroenhancement with other personality variables. Beyond self-control, there is a rich literature suggesting that a range of personality features confer risk of engagement in neuroenhancement. In the study reported in Chapter II, the contributions of neuroticism and conscientiousness (two personality dimensions associated with self-control) to risk of engaging in various modes of neuroenhancement was examined. For the paradoxical effect of self-control on illicit drug neuroenhancement (described above), one candidate explanation may be that highly neurotic students engage in higher-risk classes of neuroenhancement (primarily cannabis use) in order to reduce negative affectivity as they seek to facilitate academic performance. Although this prospect would be supported by literature demonstrating that mood repair constitutes a primary motive for students' use of cannabis (Middendorf et al., 2012), the small loadings of neuroticism onto variates explaining illicit drug neuroenhancement appear to stand in contrast to this finding. Loadings of neuroticism onto the legal neuroenhancement variate were likewise minimal, as were loadings of conscientiousness onto both the legal and illicit neuroenhancement variates. Neither conscientiousness nor neuroticism was robustly associated with prescription drug neuroenhancement. Thus, neuroticism and conscientiousness did not uniquely contribute

to understanding the individual differences that relate to neuroenhancement behaviour beyond the contributions of other self-control-related variables. Although the current study aided significantly in the exploration of self-control as a correlate of neuroenhancement, future research will benefit from examination of the personality facets which drive entry into neuroenhancement and sustainment of various forms of this behaviour beyond those self-control variables specified in the current research effort.

Associations of neuroenhancement with academic functioning. The current project likewise provided additional clarity to academic factors conferring risk for engagement in neuroenhancement behaviour. Specifically, an association of poorer academic performance (operationalized as cumulative GPA) with lifetime and active (past 30-day) history of NMUPS was demonstrated in Chapter IV, consistent with prior literature demonstrating poorer academic outcomes among students who engage in this behaviour (e.g., Arria et al., 2013, 2017; Clegg-Kraynok et al., 2011; Rabiner, Anastopoulos, Costello, Hoyle, & Swartzwelder, 2009; Rabiner et al., 2010). Likewise, students with a lifetime history of NMUPS spent, on average, less time on academic problem-solving in a self-directed, performance-based measure of academic self-control.

Importantly, however, in the model statistically predicting active (past 30-day) NMUPS, the marginal association of GPA with the outcome variable was fully accounted for by ratings of trait self-control. Chapter IV therefore offers further insight into previously-identified associations of academic performance with NMUPS, suggesting that dispositional features (such as self-control) may predispose students to both poor academic outcomes and active engagement in NMUPS (perhaps as a means—albeit an ineffective means—of ameliorating the effects of poor self-control).

Neuroenhancement attitudes and intention as correlates of behaviour. In Chapter III, neuroenhancement attitudes and future neuroenhancement intent were used as outcome variables in the models examining effect of self-control depletion on neuroenhancement. It has been suggested that attitudes and intentions have high correspondence with actual engagement in a behaviour (Ajzen & Fishbein, 1977), although only one study to date has examined congruence of neuroenhancement attitudes/reported intent with behaviour (Wolff & Brand, 2013). Interestingly, this association was only partially replicated in the current work (Chapter III). Although self-control was a robust predictor of both neuroenhancement attitudes and intent, lifetime history of neuroenhancement (using any substance) predicted future neuroenhancement intent above and beyond the effect of trait self-control ratings. However, neuroenhancement history was not associated with neuroenhancement attitudes. Therefore, neuroenhancement attitudes may not maintain strong correspondence with behaviour and thus may not serve as an appropriate substitute for measurement of actual behaviour in the specific case of neuroenhancement.

It must be noted, however, that as these findings were produced using a measure of global neuroenhancement history (i.e., any substance), they may not generalize to substance-specific classes of neuroenhancement behaviour. Given the current evidence supporting a view of neuroenhancement as separate, substance-specific classes of behaviour (Chapter II), it follows that associations of attitude/intent with actual behaviour may vary across substance-specific classes. For example, attitudes toward the specific case of NMUPS may more robustly predict engagement in NMUPS (versus neuroenhancement using other substances). Future examination of the associations of

attitudes/intent with actual behaviour is clearly warranted across modes of neuroenhancement.

Assessment of Neuroenhancement

Definition of neuroenhancement. The current research effort lends additional insight into the definitional basis of the neuroenhancement construct itself, adding to the current conversation regarding whether neuroenhancement is best conceptualized as distinct, substance-specific constructs (e.g., Maier et al., 2015) or as a single class of behaviour reflecting the same means-end relationship (e.g., Englert & Wolff, 2015). Specifically, although associations of self-control were observed across multiple modes of neuroenhancement, demonstration of distinct patterns of association for various modes of neuroenhancement (Chapter II; summarized above) suggests that there exist meaningful differences between legal, illicit, and prescription drug neuroenhancement. Thus, results of the current work suggest that the approach of "collapsing" various modes of neuroenhancement into a single macroconstruct may wash out the unique motives and personality characteristics which differentiate various classes of neuroenhancement behaviour. Further, although illicit drug neuroenhancement and prescription drug neuroenhancement are often unified within a single category of neuroenhancement behaviour ("pharmacological cognitive enhancement"; e.g., Franke et al., 2013), the differences between these two classes of neuroenhancement in the current investigation (and indeed, many students' identified use of cannabis specifically for neuroenhancement purposes) suggest a need to examine neuroenhancement minimally at the level of the drug class (if not at the level of the specific drug compound) used for this purpose.

Differentiation of lifetime vs. active use. Within the literature on neuroenhancement (particularly NMUPS), few studies have directly compared correlates of this behaviour across different assessment time-frames. However, the study described in Chapter IV also highlights a need for differentiation of active neuroenhancement (operationalized as use in the past 30 days; Wickersham et al., 2016) versus lifetime neuroenhancement history. The different pattern of associations elicited by differences in NMUPS assessment time-frame suggest that individuals who actively engage in NMUPS are distinct from those who have engaged in NMUPS in their lifetime, but not necessarily in the past 30 days. The more active users may constitute a more severe group who are differentiated from non-using peers on the basis of poor self-control alone (vs. also poor academic performance, as was found for lifetime users) and are therefore in more urgent need of intervention.

Need for examination of neuroenhancement frequency. There is a general paucity of work investigating frequency of engagement in neuroenhancement (and factors associated with more/less frequent engagement in this behaviour; McCabe, West, Teter, & Boyd, 2014). Chapter IV reinforces need for increased examination of neuroenhancement frequency and use of dimensional approaches to quantifying neuroenhancement. Indeed, the *dimensional* measure of neuroenhancement frequency derived from the TLFB assessment of NMUPS was not associated with any of the academic- or self-control-related variables that were significant factors in the prediction of *categorical* measures of neuroenhancement history (i.e., lifetime and 30-day use histories). As this research effort aimed to explore the specific association of self-control with students' engagement in neuroenhancement behaviour, examination of a broad

range of psychological factors that may *differentially* predispose engagement in various modes and frequencies of neuroenhancement was beyond the scope of the current study. However, given the apparently meaningful distinctions between various modes/frequencies of engagement in neuroenhancement, continued attempts to understand psychological factors predisposing different engagement in various neuroenhancement "subtypes" are needed. Deeper investigation of how measurement method (i.e., single-item vs. TLFB) impacts neuroenhancement endorsement is also warranted.

Overall Limitations

The above-described results must be understood within the context of some limitations. First, the ability to draw causal inferences regarding the nature of the relation between trait self-control and neuroenhancement is limited by the correlational, cross-sectional design utilized in Chapters II and IV. It is plausible that poor self-control both exerts a direct impact on students' engagement in neuroenhancement (e.g., poor estimation of risks associated with neuroenhancement behaviour) and indirectly predisposes students to engagement in neuroenhancement by failure over time to appropriately work toward long-term goals (e.g., favoring recreational activities over studying; putting off projects until just before they are due). However, alternative relations cannot be ruled out, such as the impact of a third variable on both self-control and neuroenhancement behaviour. Although less plausible, it is also possible that neuroenhancement engagement exerts an impact on self-control (or, rather, participants' perceptions of their own self-control, given that the preponderance of effects identified in the current project involved self-report measures). The exact nature of these relations

cannot be fully delineated based on current data. Future research may benefit from adoption of longitudinal approaches to study the evolution of these interrelated constructs throughout the course of students' academic careers.

Although an attempt was made to employ a multi-method approach to the measurement of key variables (particularly those related to self-control in Studies 1 and 3), it also must be emphasized that the majority of effects that emerged nonetheless involved self-report variables. Therefore, the current results may be subject to common limitations associated with use of self-report measures, including bias associated with common-method variance and social desirability in reporting (Podsakoff et al., 2003; Van de Mortel, 2008). It is therefore recommended that ongoing efforts in this area continue to attempt to supplement self-report measures with other approaches that may attenuate bias from these sources (e.g., use of performance-based measurement, informant report).

The current research effort also utilized a relatively homogeneous sample, collected from a single, mid-sized public university in Ontario. On the whole, participants did not endorse participation in competitive academic programs (e.g., the majority of students were not in an honours program) and the majority reported academic majors within the humanities/social sciences. Given that neuroenhancement is more prevalent in academic settings with competitive admissions criteria (e.g., Ivy league universities; McCabe, Knight, Teter, & Wechsler, 2005), it is not clear how current findings would generalize to samples collected from more competitive academic environments or similarly, from other academic disciplines that tend to have competitive retention standards (e.g., pre-med). However, despite these considerations, high rates of endorsement of various modes of neuroenhancement in the current sample reaffirm that

neuroenhancement is a widespread phenomenon within the Canadian academic landscape.

The current project (and the literature surrounding neuroenhancement as a whole) was also limited by the lack of standardized, well-validated measures that assess the full spectrum of neuroenhancement behaviour. Indeed, while several brief measures of NMUPS are described in the literature (including the measure by Gallucci [2011] utilized in Chapter IV), there remains a general paucity of research regarding the utility, reliability, and validity of measures designed to assess other modes/frequencies of neuroenhancement. The neuroenhancement survey (used across studies) and the TLFB assessment (used in Chapter IV) created for the current project are put forth as possible tools for enhancing future measurement of the full spectrum of neuroenhancement-focused substance use. However, further study of these measures is needed, including comparison to more robust measures developed for assessment of other forms of substance use. Methods less subject to retrospective recall bias, such as ecological momentary assessment, have been used successfully in the study of conventional substance use (Shiffman, 2009) and therefore also hold promise as a tool for measurement of neuroenhancement substance use.

Conclusions and Implications

To date, the majority of research investigating neuroenhancement behaviour has been epidemiological in nature. As such, research investigating psychological risk factors for neuroenhancement, as was done in the current dissertation, is in its relative infancy. Adding to the literature demonstrating the importance of appropriate self-regulation for success across functional domains, the three studies contained in this work

highlight poor trait self-control as a potential risk factor for lifetime entry into neuroenhancement and active engagement in this behaviour. Indeed, individuals with poorer self-rated self-control tended to report more favorable views of neuroenhancement and indicated greater intent to engage in this behaviour in the future. Moreover, in the case of active neuroenhancement, previous associations of poor academic functioning with neuroenhancement could be accounted for on the basis of students' self-control skills. Thus, an understanding of the essential cognitive capacity of self-control is vitally important to understanding the likely multifactorial contributions to students' engagement in neuroenhancement behaviour and associated poor academic outcomes.

The current findings have broad policy and clinical implications. First, the current project highlights the widespread nature of neuroenhancement, including as relates to use of illicit substances and non-medical use of prescription drugs. The frequency with which these behaviours occur suggest that university personnel should be prepared to address the issues of fairness, equity, and health/safety that accompany increasing engagement in risky substance use for the purposes of neuroenhancement.

There are also important implications for the demonstrated association of self-control with the spectrum of neuroenhancement behaviour. Specifically, these results suggest that interventions aimed at improving self-control may assist in curbing the so-called "neuroenhancement epidemic", while also equipping students to succeed in other domains (e.g., Tangney, Baumeister, & Boone, 2004). To this end, mindfulness-based interventions hold particular promise as a tool for improving self-control (e.g., Elkins-Brown, Teper, & Inzlicht, 2017); such programming may also reduce risk of neuroenhancement by reducing stress and other risk factors for engagement in

neuroenhancement substance use. Thus, in conjunction with other methods targeting the multifactorial contributions to students' neuroenhancement behaviour (e.g., students' perceptions regarding high pressure academic environments; misperceptions regarding enhancing effects of common neuroenhancement substances), mindfulness-based interventions and other programming targeting improved self-control may assist in reducing health-related risk on university campuses.

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APPENDICES

Appendix A

Demographic Questionnaire

Personal information:

1. Your current age: _____ years old

2. Gender: _____

3. How do you describe your ethnicity (circle all that apply)?
   a. Aboriginal/First Nations
   b. Black/African descent
   c. East Asian descent
   d. South Asian/Indian descent
   e. Hispanic/Latino
   f. Caucasian or non-Hispanic White/European descent
   g. Arab/Middle Eastern descent
   h. Biracial/Multiethnic
   i. Other (please describe): _____
   j. Prefer not to answer

4. Your native (first) language:
5. Other languages spoken (if applicable):

6. Relationship status (circle one):
   a. Single
   b. In a relationship
   c. Married / in a civil union
   d. Cohabitating
   e. Divorced
   f. Widowed
   g. Prefer not to answer

7. Are you a member of a fraternity, sorority, or other similar group?
   a. Yes (please describe): _____
   b. No

8. Are you a member of any organized sports teams? **(if NO, skip to item #10)**
   a. Yes, varsity-level sports at the university (describe): _____
   b. Yes, club sports (describe): _____
   c. Yes, intramural sports (describe): _____
   d. Yes, community recreational team (describe): _____
   e. Other: _____
   f. No, I am not involved in any sports teams

9. On average, how many hours per week do you estimate that you spend on activities related to your sports team (e.g., training, practicing, in games/matches)?
   _____ hours per week

10. Current living situation (please circle one):
    a. Living in residence
    b. Living in a fraternity / sorority house
    c. Living off-campus with family
    d. Living off-campus with friends
    e. Living off-campus with acquaintances
    f. Living off-campus with spouse/partner/significant other
    g. Other: _____

11. Are you employed outside of the home?
    a. yes (please describe position): _____
    b. no
    c. prefer not to answer

Academic information:

1. Current year of study (please circle one): 1 2 3 4 5 6+

2. Current major: _____

3. Grades: (note: you can find this information on http://my.uwindsor.ca/web/uw/transcripts → click on the current and previous semester to expand)
   a. Current cumulative grade average (overall): _____
   b. Current cumulative grade average (major): _____
   c. Sessional average for last full semester: _____

4. Have you ever been diagnosed with a learning disability (circle one):
   a. yes (describe) _____
   b. no

5. Have you ever been diagnosed with a mental health condition (e.g., depression, anxiety, attention-deficit/hyperactivity disorder [ADHD])?
   a. yes (describe) _____
   b. no

6. Please indicate whether a doctor has ever prescribed you each of the following medications. If you have had a prescription for any of the medications, please indicate the name/type and approximate dates taken (MM/YYYY – MM/YYYY). If you are unsure, it's okay to estimate.

	No, I have NOT had a prescription for this medication	**Yes, I HAVE had a prescription for this medication**	**Medication name/ description**	**Dates Taken**
Methylphenidate (e.g. Ritalin)				
Amphetamine (e.g. Adderall)				
Modafinil (e.g. Provigil)				
Omecetin (e.g. Cognient)				
Other ADHD medication				
Beta blockers				
Other antidepressant medication				
Other anxiety medication				
Other mental health medication				

7. Have you **ever** received educational accommodations (e.g. Individual Education Plan [IEP], extra time to take tests, etc.)? Please include time before you entered the University of Windsor.
   a. yes (describe) _____
   b. no

8. Are you **currently** receiving educational accommodations or services through the Student Disabilities Office (e.g. Individual Education Plan [IEP], extra time to take tests, etc.)?
   a. yes (describe)_____
   b. no

For the following questions, please circle the response that best applies to you:

1 very false for me **2 somewhat false for me** **3 somewhat true for me** **4 very true for me**

	very false for me	**somewhat false for me**	**somewhat true for me**	**very true for me**
1. I enjoy school.	1	2	3	4
2. I am excited by my program of study.	1	2	3	4
3. School is difficult.	1	2	3	4
4. I feel pressure to succeed.	1	2	3	4
5. The academic atmosphere at this university is competitive.	1	2	3	4
6. I have what it takes to succeed academically.	1	2	3	4

Appendix B

Quantity Guidelines for Timeline Follow-Back Reporting of NMUPS

Substance	**Amount represented by "1"**
Coffee	One average-sized cup
Energy Drinks	One standard energy drink or packaged "energy shot" (e.g. Five Hour Energy)
Caffeine pills	One 100mg tablet
Herbal supplement	One dose as indicated on packaging (if multiple types of supplements, count each; e.g. if one vitamin and one omega-3, this counts as 2)
Probiotics	One dose as indicated on packaging (if multiple types of probiotics, count each; e.g. if one supplement and one serving of yogurt for cognitive enhancement, this counts as 2)
Alcohol	12 oz. beer 10 oz. wine cooler 4 oz. wine 1 oz./1 shot 100 proof liquor 1 ¼ oz. (one shot) 80 proof liquor 1 cocktail with one shot as described above
Nicotine	1 average-sized cigarette Approx. 15 puffs on an e-cigarette One piece of nicotine chewing gum One pouch of chewing tobacco
Cannabis	Number of "times" used cannabis on given day – one occasion where smoked one joint/bowl/pipe/bong/vaporizer etc. within one time period. For example, if split one bowl with a friend, that would be one "time"; if repacked it and smoked it again, that would be two "times" so would record 2 for that day
Other illicit substances	Used an illicit substance on that day
Methylphenidate	Number of pills per day
Amphetamine	Number of pills per day
Modafinil	Number of pills per day
Other ADHD	Number of pills per day
Beta blockers	Number of pills per day
Other prescription medication	Number of pills per day

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