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Inhibition Tasks Are Not Associated with a Variety of Behaviours in College Students

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Abstract: Executive functions are (EF) top-down control processes involved in regulating thoughts, ignoring distractions, and inhibiting impulses. It is widely believed that these processes are critical to self-control and, therefore, that performance on behavioural task measures of EF should be associated with individual differences in everyday life outcomes. The purpose of the present study was to test this assumption, focusing on the core executive function facet of inhibition. A sample of 463 undergraduates completed five laboratory inhibition tasks, along with three self-report measures of self-control and 28 self-report measures of life outcomes. Results showed that although most of the life outcome measures were associated with self-reported self-control, only one of the outcomes was associated with inhibition task performance at the latent-variable level, and this association was in the unexpected direction. Furthermore, few associations were found at the individual task level. These findings challenge the criterion validity of lab-based inhibition tasks. More generally, when considered alongside the known lack of convergent validity between inhibition tasks and self-report measures of self-control, the findings cast doubt on the task's construct validity as measures of self-control processes. Potential methodological and theoretical reasons for the poor performance of laboratory-based inhibition tasks are discussed. © 2020 European Association of Personality Psychology

Key words: inhibition; executive function; self-control; self-regulation; conscientiousness

INTRODUCTION

The construct of self-control has been depicted in both psychological theory (e.g. Akers, 1991; Nigg, 2017; Vohs & Baumeister, 2016) and the lay self-help industry (Hollins, 2017; McGonigal, 2011) as key to achieving positive outcomes across a wide range of domains, including physical, mental, and financial health; school and work achievement; substance abuse; criminal behaviour; relationship quality; and numerous others (Berg, Latzman, Bliwise, & Lilienfeld, 2015; De Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012; Tangney, Baumeister, & Boone, 2004). Prospective work has established that, after controlling for a number of covariates, such as IQ and socio-economic status (SES), self-control in childhood predicts a host of positive outcomes later in life, including better health, increased wealth, and decreased criminality (Moffitt et al., 2011).

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Despite its common colloquial usage, self-control has been conceptualized in many ways within psychology. Some of these include acting in the service of personally relevant and valued goals (Duckworth & Kern, 2011), as the capacity to inhibit dominant response tendencies or temptations (De Ridder et al., 2012), as a limited volitional capability available to the self (Baumeister, Bratslavsky, Muraven, & Tice, 1998), and as the antithesis of acting impulsively (Evenden, 1999). Furthermore, a large cluster of similar terms and concepts exists across subdomains of psychology (Nigg, 2017; Duckworth, Taxer, Eskreis-Winkler, Galla, & Gross, 2019) and other social science fields (Frey, Pedroni, Mata, Rieskamp, & Hertwig, 2017). These include self-regulation, impulsivity, conscientiousness, disinhibition, emotion regulation, grit, risk-taking, and others. Researchers often want a broad superordinate term that encapsulates the similarities between these concepts. Common terms for this purpose include self-regulation (Enkavi et al., 2019; Fujita, 2011; Nigg, 2017), self-control (De Ridder et al., 2012; Moffitt et al., 2011; Tangney et al., 2004), and impulsivity (Sharma, Kohl, Morgan, & Clark, 2013; Sharma, Markon, & Clark, 2014). For the present paper, we will use the term 'self-control'.

There are pros and cons of lumping self-control constructs together (Duckworth & Seligman, 2017; Nigg, 2017; Sharma et al., 2013). For example, there is strong evidence for multidimensionality across (Sharma et al., 2013) and within (Whiteside & Lynam, 2001) these constructs. Furthermore, lumping foregoes important nuance that may matter when concentrating on different outcomes (Duckworth &

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Seligman, 2017; Sharma et al., 2013) or levels of analysis (Nigg, 2017). However, when considered at a higher level of abstraction, there exists a large degree of conceptual and empirical overlap. Duckworth and Kern (2011) found that the average correlation between various self-report measures of self-control constructs (47 studies and 57 effects sizes) was large at $r = .50$.[1]

A notable exception to this convergent validity is executive function (EF)—the construct within neuroscience and cognitive psychology that most closely aligns with self-control (Baddeley, 1986, 1996; Stuss & Benson, 1986; Teuber, 1972). Across three meta-analyses and three comprehensive tests, the average correlation between report measures of self-control broadly construed and measures of EF ranged from $r = -.01$ to $r = .14$ (Cyders & Coskunpinar, 2012; De Ridder et al., 2012; Duckworth & Kern, 2011; Nęcka, Gruszka, Orzechowski, Nowak, & Wójcik, 2018; Saunders, Milyavskaya, Etz, Randles, & Inzlicht, 2018; Sharma et al., 2014). Consequently, the discrepancy between EF and these report measures of self-control is more conspicuous than the discrepancy that characterizes the multidimensionality among these self-control measures.

Executive function is commonly understood as goal-directed, higher-level cognitive processing that is crucial for, regulating thoughts, ignoring distractions, and inhibiting temptations (Diamond, 2013; Jurado & Rosselli, 2007; Miyake et al., 2000; Williams & Thayer, 2009). Thus, EF, like other self-control constructs, is thought to play a critical role in real-word control and goal achievement (e.g. physical health, psychological adjustment, and general life success; Bari & Robbins, 2013; Blair & Ursache, 2011; Diamond, 2013, 2014; Enkavi et al., 2019; Hofmann, Schmeichel, & Baddeley, 2012; Miyake & Friedman, 2012; Nigg, 2017; Rueda, Posner, & Rothbart, 2005). Consistent with this understanding, researchers commonly use EF tasks (particularly inhibition tasks) as faithful operationalizations of self-control exertion in experimental studies examining self-control fatigue (Hagger, Wood, Stiff, & Chatzisarantis, 2010; Richeson & Shelton, 2003). Additionally, within the context of dual-process models of self-control, EF is often construed as an enabler of controlled, deliberative processing thought to regulate impulses and desires (Deutsch & Strack, 2006; Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008).

Yet as reported above, research has shown very little empirical association between EF and self-control, despite this extensive theoretical and conceptual overlap (Blair & Ursache, 2011; Duckworth & Seligman, 2017; Hall & Fong, 2013; Hofmann, Schmeichel, & Baddeley, 2012; Williams & Thayer, 2009). This is perplexing. However, one way forward may be to focus on criterion validity. It is possible that although there is little to no association between the two, self-control and EF measures could assess disparate aspects of the processes that enable healthy and adaptive behaviours in important life domains (Cyders & Coskunpinar, 2012; Leshem & Glicksohn, 2007; Nęcka, Lech, Sobczyk, & Śmieja, 2012). If this is indeed the case, then measures of self-control and EF should incrementally predict such behaviours.

DOES EXECUTIVE FUNCTIONING MATTER FOR REAL-WORLD LIFE OUTCOMES?

Several meta-analyses and comprehensive studies have been conducted to examine the influence of individual differences in self-control on a wide range of life outcomes (Berg et al., 2015; De Ridder et al., 2012; Duckworth, Weir, Tsukayama, & Kwok, 2012; Sharma et al., 2014; Tangney et al., 2004). In contrast, although there are meta-analyses dedicated to a single outcome domain (school achievement: Jacob & Parkinson, 2015; attention-deficit hyperactivity disorder, ADHD: Oosterlaan, Logan, & Sergeant, 1998), only one meta-analysis to date (Sharma et al., 2014) has examined associations between EF task performance and several disparate outcome domains. Sharma et al. examined 40 studies that included at least one self-report measure of self-control *or* at least one EF measure, and at least one outcome (primarily externalizing behaviours, such as drug use and delinquency). The results from this meta-analysis revealed considerable variability in the relations between EF measures and externalizing behaviours, with correlations ranging from $r = .00$ to $r = .40$. Unfortunately, Sharma et al. did not indicate the number of studies in their analysis that included a laboratory EF measure or the number of studies that contributed information to the correlation between each laboratory task and outcome. Moreover, only 10 of the 40 studies included in the meta-analysis involved a non-clinical, healthy adult sample.

In her comprehensive review of EF, Diamond (2013) cites evidence for the hypothesis that EF is positively related to life outcomes. However, close inspection of the 21 studies cited in this review suggests only minimal support for this hypothesis. Five of the studies in the review used self-report measures of self-control rather than (behavioural) EF measures (Broidy et al., 2003; Duncan et al., 2007; Miller, Greene, Montalvo, Ravindran, & Nichols, 1996; Riggs, Spruijt-Metz, Sakuma, Chou, & Pentz, 2010; Will Crescioni et al., 2011). In another case, a laboratory EF measure was used not as an index of individual differences in self-control but rather as an outcome for measuring effects of an ego-depletion manipulation (Denson, Pedersen, Friese, Hahm, & Roberts, 2011). Two additional studies treated individual differences in ADHD as a proxy for EF performance (Brown & Landgraf, 2010; Eakin et al., 2004). In the end, only six of the 21 studies in Diamond's review (also see Diamond, 2014) provide empirical evidence for an association between individual differences in EF task performance and various life outcomes (Blair & Razza, 2007; Borella, Carretti, & Pelegrina, 2010; Davis, Marra, Najafzadeh, & Liu-Ambrose, 2010; Gathercole, Pickering, Knight, & Stegmann, 2004; Penades et al., 2007; Tavares et al., 2007). Three of these studies failed to find an association between one or more EF tasks and the life outcome(s) of interest. On the basis of these reviews (Diamond, 2013, 2014; Sharma et al., 2014), it would appear that the question of whether

[1]This was for self-report measures. The correlation between informant reports (44 studies and 142 effect sizes) was $r = .54$.

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EF tasks are related to real-world life outcomes is less resolved than it often is portrayed to be (Hofmann, Schmeichel, & Baddeley, 2012; Rueda et al., 2005).

Moreover, recent research has emphasized the distinct methods commonly used to assess self-control and EF (Hedge, Powell, & Sumner, 2018). In particular, whereas self-control is commonly measured with self-report or informant report, EF is almost always measured with a host of laboratory-based behavioural tasks, such as the Stroop (1935) task. It has been argued that cognitive tasks, such as some EF tasks, are unsuitable for correlational research designs involving the examination of individual differences (Enkavi et al., 2019; Hedge et al., 2018). This is because between-subjects variance (and the reliability scores that partly depend on such variability) is not large enough to consistently preserve the rank ordering of participant's scores. In contrast to this, it is argued that for significance testing in experimental designs testing group differences, low between-subjects variance is an asset. This argument suggests that EF tasks could perform well in some research contexts while performing poorly in others. Thus, in addition to the shortfall of positive evidence in favour of EF tasks, there are also psychometric reasons for doubting their influence on outcomes.

INHIBITION AS AN INTEGRAL FACET OF EXECUTIVE FUNCTIONING

Executive functioning (EF) is assessed with a dizzying array of cognitive tasks, which are only modestly correlated with one another (Duckworth & Kern, 2011; Sharma et al., 2013). Numerous explanations have been offered for these lacklustre associations, including mediocre internal reliabilities (Miyake et al., 2000, but see, e.g. Friedman et al., 2006), potentially problematic test–retest reliabilities (Hedge, Powell, & Sumner, 2017, but see, Wöstmann et al., 2013), task impurity (Miyake et al., 2000), and multidimensionality (Miyake et al., 2000; Miyake & Friedman, 2012). Given these concerns, instead of attempting to capture the sprawling EF construct in its entirety (Miyake & Friedman, 2012) and to facilitate the validity and precision of our measurement, we chose to focus our assessment on inhibition. Inhibition involves overriding internal predispositions or prepotent behavioural responses in order to make goal-appropriate responses (Diamond, 2013; Miyake et al., 2000) and therefore is the facet of EF most commonly assumed to be of theoretical importance for self-control and life outcomes (Barkley, 1997; Diamond, 2013; Hall & Fong, 2013).

Empirical work indicates that the construct of inhibition might represent a core, unifying component of a multidimensional EF construct (Miyake & Friedman, 2012). Quantitative modelling of EF task data consistently shows that performance on a variety of EF tasks, including inhibition tasks, loads on a 'common EF' latent factor. Once variability associated with this common factor has been accounted for, there is insufficient residual variance in inhibition task performance to form a separate 'inhibition-specific' factor (for a review, see Friedman & Miyake, 2017). This is not the case with two other facets of EF (i.e. working memory updating and task switching), each of which form an additional, separate factor represented by performance on updating and switching tasks, respectively. In other words, it appears that the underlying construct measured by inhibition tasks (e.g. overriding prepotent responses) is common to virtually all EF measures, but other kinds of EF tasks assess additional specific constructs beyond inhibition.[2]

THE PRESENT STUDY

The present study sought to provide the most comprehensive test to date of the commonly assumed association between inhibition—one representative facet of EF—and life outcomes. To ensure comprehensiveness in measurement of inhibition and to overcome the task impurity problem (Bollen, 1989), five of the most commonly used behavioural inhibition tasks were administered, and a latent variable comprising performance across these tasks was extracted. To ensure comprehensive coverage of important life outcomes (Tangney et al., 2004), 28 outcomes were measured. These measures represent primary aspects of life where people report experiencing temptation, goal conflict, and self-control failure (Hofmann, Vohs, & Baumeister, 2012), and overlap with outcomes commonly examined in the self-control and EF literature, as reviewed previously. The current study also included three self-report measures of self-control to test whether inhibition and self-control measures account for incremental variance in life outcomes, despite their overall lack of association with each other (e.g. Sharma et al., 2014). Additionally, a number of common variables known to be associated with life outcomes were measured (sex, SES, and fluid intelligence), in order to control for their influence. Finally, social desirability was measured in order to account for potential method-based third variables that could inflate the associations between the self-reports of self-control and the self-reports of life outcomes. The study was not preregistered. For full transparency, the data analytic strategy was planned in advance, but part of the strategy changed at the request of reviewers (clarified below). This did not alter the results.

METHOD

Participants and statistical power

Participants were 463 undergraduates enrolled in an introductory psychology course for partial course credit at a large, public, midwestern university [276 male (60%); *M* age = 18.81 years, *SD* = 1.54, range: 17–33 years]. Given the dependence of one of the inhibition tasks on colour vision, colour-blind individuals were not eligible for the study. Data collection was planned to begin in the fall semester and to continue unconditionally until the end of February in the spring semester. The minimum target *N* was 300, with a desired *N* of 400 or greater. The primary test was whether

[2]Some research suggests that inhibition is not a unitary construct (Friedman & Miyake, 2004; Rey-Mermet, Gade, & Oberauer, 2018). The tasks used in the current study fall into the prepotent response inhibition category.

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inhibition would incrementally predict real-world outcomes after controlling for four covariates (sex, SES, IQ, and social desirability) and self-control (which we expected to be uncorrelated with inhibition). Four-hundred and twenty-six participants were included in these tests after data quality checks. With this *N*, and assuming $\beta \geq .15$ (i.e. incremental $R^2 \geq .02$), the power of the tests was 84% (G Power, 3.19.2, Faul, Erdfelder, Buchner, & Lang, 2009).

Procedure

Participation involved one laboratory session. During this session, a battery of laboratory-based tasks (inhibition and fluid intelligence) was administered. This was followed by a battery of questionnaires programmed in Qualtrics (Qualtrics, Inc., Seattle, WA) that assessed self-control and a diverse spectrum of outcomes. On average, the study lasted 1.75 h. The task order was as follows: stop signal, antisaccade, go/no-go, Stroop, Simon, and Raven's Progressive Matrices. Each task lasted roughly 10 min (range: 8–11 min). There was a 3-min break between the Simon task and the Raven's Progressive Matrices. These procedures had university internal review board approval, and informed consent was obtained from all participants.

Measures

Self-reported self-control measures and covariates

Descriptive statistics for each measure in this study, including means and *SD*s, distributional properties, and reliability estimates are provided in Table 1.

Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency impulsive behaviour scale. The Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency (UPPS-P) scale is a 59-item questionnaire designed to assess five dimensions of impulsivity (Cyders & Smith, 2007; Whiteside & Lynam, 2001): lack of planning ('My thinking is usually careful and purposeful' [reversed]), lack of perseverance ('I generally like to see things through to the end' reversed)], negative urgency ['I have trouble controlling my impulses' [reversed]), positive urgency ('I tend to lose control when I am in a great mood'), and sensation seeking ('I'll try anything once'). Responses are made on a Likert-type scale ranging from 1 (*agree strongly*) to 4 (*disagree strongly*). Reliability estimates in previous studies range from .80 to .90 (Cyders & Smith, 2008).

The Brief Self-Control Scale. The Brief Self-Control Scale is a 13-item short-form version of the 36-item Self-Control Scale (Tangney et al., 2004). The scale assesses respondents' ability to override or change inner responses (e.g. 'I get carried away by my feelings') and to interrupt undesired behavioural tendencies and refrain from acting on them (e.g. 'I am good at resisting temptations'). Responses are made on a Likert-type scale ranging from 1 (*Not at all like me strongly*) to 5 (*Very much like me*). Tangney et al. (2004) demonstrated that the full scale version has good reliability (Cronbach's $\alpha = .89$) and good test–retest reliability ($r = .89$ over 3 weeks). The short-form version showed a correlation of $r = .93$ with the full scale (Tangney et al., 2004).

Conscientiousness. Conscientiousness was assessed using two items from the Ten-Item Personality Inventory (NEO short form; Gosling, Rentfrow, & Swann, 2003), which is a very brief measure of the Big Five personality dimensions. The two items ask whether the participant sees himself as 'dependable, self-disciplined' and 'disorganized, careless'. Responses are made on a Likert-type scale ranging from 1 (*Disagree strongly*) to 7 (*Agree strongly*). The remaining four factors were assessed but not analysed. Ten-Item Personality Inventory has demonstrated good psychometric properties (e.g. mean $r = .77$ with the five factors of the Big Five Inventory; John & Srivastava, 1999) and good test–retest reliability (Gosling et al., 2003).

Socio-economic status. Socio-economic status (SES) was measured with four items. Two items pertained to the highest degree or level of school that the participant's father (first item) and mother (second item) completed. These items were on a 9-point scale ranging from *eighth grade or less* to *doctoral degree*. Another item assessed family annual income on a 14-point scale ranging from 'under $19,999' to 'over $200,000'. The final item assessed subjective SES. Participants were asked to place themselves on a ladder, depicted by a stack of coins, that represented where people stand compared to other persons in the USA in terms of income, education, and occupation (Adler et al., 1994). A vertical slider scale ranged from 1 (*lowest rung*) to 9 (*highest rung*). The slider started on 5. Items were standardized prior to creation of a mean across the four items.

Socially desirable responding. Given that self-control and life outcomes share the same self-report measurement method, it is possible that associations between them will be inflated due to shared method variance resulting from method-based third variables. One possible third variable that could confound these associations is the degree to which a participant provides answers that impress others. The Marlowe–Crowne Social Desirability Scale (Crowne & Marlowe, 1960) is a widely used, well-validated measure of social desirability response bias. It contains 33 items to which participants respond using a dichotomous 'true' or 'false' scale.

Fluid intelligence. Fluid intelligence involves abstract reasoning, problem solving, and pattern recognition (Ackerman, Beier, & Boyle, 2005; Kane, Hambrick, & Conway, 2005). A computerized version of the Raven's Advanced Progressive Matrices (Raven & Raven, 1998) was used as a measure of fluid intelligence. The task consists of 24 matrix reasoning items presented in ascending order of difficulty. For each item, participants were presented with a 3 × 3 matrix of abstract shapes, where the bottom-right panel of the matrix is omitted. Participants were asked to select from among eight response alternatives the one that completes the overall pattern of the matrix. A participant's total number of correct responses determined their score on the test. The present study administered only 24 items from the Raven's item pool (sets D and E) with a maximum time limit of 10 min, consistent with past research (Kane et al., 2005; Oswald, McAbee, Redick, & Hambrick, 2015). The sum of

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Table 1. Descriptive statistics for all study variabes

Domain	Measure	*N*	# of items	Item scale	Min–max	Mean	*SD*	Skewness	Kurtosis	*α*
Self-control scales										
	UPPS-P	432	59	1–4	1.64–3.78	2.78	.35	−.15	−.03	.93
	Brief Self-Control Scale	431	13	1–5	1.46–5	3.26	.72	−.01	−.55	.87
	Conscientiousness	425	2	1–7	1–7	5.32	1.14	−.71	.38	.58
Inhibition tasks										
	Latent factor scores	443	—	—	−76.49-55.09	.55	21.06	−.52	.26	—
	Stop signal	283	48	—	126.67–434.54	308.63	59.56	−.95	1.14	.97[b]
	Go/no-go	433	320	—	0.21–0.94	.58	.15	−.08	−.59	.89[b]
	Antisaccade	445	80	—	0.28–1.00	.67	.15	−.33	−.27	.88[b]
	Stroop	420	288	—	−494.92–66.61	−185.87	98.44	−.58	.45	.92[b]
	Simon	454	320	—	−106.19–22.99	−40.10	21.00	−.44	.79	.73[b]
Covariates										
	Sex	432	1	—	—	—	—	—	—	—
	SES	431	4	—[a]	−2.37–1.55	.00	.70	−.38	−.03	.65
	Fluid intelligence	459	24	—	1–22	14.92	4.22	−.95	1.14	—
	Social desirability	432	33	1–2	.09–.87	.48	.15	.15	−.12	.73
Life outcomes										
Finance										
	Compulsive spending	432	6	1–7	1–7	5.03	1.37	−.64	−.10	.87
	Monetary prudence	432	6	1–7	1–7	4.04	1.18	.08	−.20	.80
	Financial well-being	432	8	1–5	1.88–5	3.94	.76	−.46	−.56	.78
Health										
	Exercise	432	2	—[a]	−2.19–1.41	.00	.95	−.09	−1.01	.87
	Fat intake	432	13	1–8	3.08–6.85	4.76	.56	.13	.56	.70
	Diet quality	432	1	1–5	1–5	2.98	.96	−.24	−.51	—
	BMI[c]	428	2	Open	15.66–42.57	23.50	3.90	1.47	3.08	—
	Hygiene	432	7	—[a]	−1.96–1.4	.00	.53	−.26	.13	.58
	Risky sexual behaviour	429	20	Open	0–12.83	1.97	2.26	1.67	2.96	.92
	Sleep procrastination	432	9	1–5	1.11–4.78	2.52	.78	.42	−.36	.86
Media										
	Game duration	209	1	1–11	1–10	3.67	2.15	.93	.34	—
	TV duration	432	1	1–9	1–9	4.41	2.13	.51	−.49	—
	Video game pathology	137	9	1–3	1.22–3	2.47	.41	−.56	−.31	.78
	Phone duration	431	1	Open	0–17	5.61	3.69	1.22	.99	—
	Phone pathology	432	20	1–5	2–5.55	3.30	.69	.17	−.41	.90
Psychological adjustment										
	Life satisfaction	431	5	1–7	1–7	4.97	1.26	−.60	.07	.91
	Meaning in life	429	5	1–7	1–7	4.93	1.38	−.68	.14	.94
	Leisure orientation	432	15	1–7	2.80–6.67	4.75	.72	.03	−.51	.75
	Depression	432	8	1–4	1–4	3.19	.64	−.87	.53	.88
	Anxiety	432	7	1–4	1–4	3.20	.71	−1.04	.63	.90
	Aggression	432	12	1–5	1.75–5	3.87	.74	−.45	−.49	.87
	Dysregulated eating	432	8	1–6	1–6	2.97	1.24	.34	.60	.91
Relationship										
	Rel. satisfaction	308	5	9.00	1–9	6.71	1.95	−.84	.26	.95
	Rel. accommodation	308	12	1–9	2.67–7.67	5.41	1.03	−.23	−.50	.80
School										
	School engagement	432	12	1–5	1.58–4.83	3.63	.58	−.55	.37	.83
	Study habits	432	9	1–5	1.22–5	3.52	.77	−.35	−.06	.86
	High school GPA	429	1	Open	2.5–5[d]	3.67	.40	.12	.88	—

(Continues)

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Table 1. (Continued)

Domain	Measure	N	# of items	Item scale	Min–max	Mean	SD	Skewness	Kurtosis	α
	ACT	413	1	Open	17–35	25.66	3.44	.24	−.42	—
Work										
	Work quality	405	6	1–5	1.67–5	3.76	.52	−.18	.84	.62, .74[e]

[a]Designates measures that included items with different scales and that were therefore standardized before computing mean composites.
[b]For tasks that did not depend on difference scores (antisaccade and go/no-go), Cronbach's alpha was used to calculate internal reliability. For tasks that did (Stroop, Simon, and stop signal), Spearman-Brown corrected split-half reliability was used (see the method section for the scoring of each task).
[c]This measure was reversed for analyses but is presented here in its original form for ease of interpretation.
[d]This item did not clarify whether to report weighted or unweighted GPA.
[e]Alpha values for past job performance and present job performance are reported here.

correct responses on the 24 items was used as the dependent measure.

Inhibition tasks

Descriptive statistics for each inhibition task are given in Table 1.

Antisaccade task. In this version of the antisaccade task (adapted from Miyake et al., 2000), each trial consisted of a black fixation cross that appeared on a white background for a random duration between 1000 and 2750 ms in increments of 250 ms on a white background. During an initial prosaccade block, the fixation point was followed by a cue (black square) appearing on one side of the screen for 200 ms, which was then replaced by a target stimulus (an arrow pointing up, down, left, or right, enclosed in an open 0.63-in. square) shown for 115 ms. The target was then masked with a four-pointed star, which remained on the screen until the participant indicated the target's direction with an arrow key press. The structure of trials in the subsequent antisaccade block was similar, except that the target stimulus appeared on the side opposite the cue. The task began with the 40-trial prosaccade block, followed by an eight-trial antisaccade practice block and then two 40-trial antisaccade blocks. The viewing distance was 16 in. The dependent measure in this task was the proportion of errors made in the antisaccade bock.

Stroop task. In this version of the Stroop task (adapted from Stroop, 1935), each trial consisted of a letter string or word that appeared on the computer screen in one of four colours (red, blue, green, and yellow) on a black background. On each trial, participants were instructed to identify the colour of the stimulus as quickly as possible by pressing one of four keys on a standard QWERTY keyboard ('v', 'b', 'n', and 'm'). Trials were separated by a 75-ms inter-trial interval following the response. The task began with 24 *neutral* trials, in which participants were to identify the colour of a letter string ('XXXXX'). This enabled participants to learn the color and response key mappings. Next, participants completed two blocks of 48 *congruent trials*, in which colour words were presented in corresponding colours. Finally, participants completed a brief practice block of 16 trials followed by four blocks of 48 *incongruent trials*, in which colour words were presented in non-corresponding colours (e.g. 'red' printed in green). The dependent measure for this task was the Stroop interference effect, calculated as the difference in mean reaction time (RT) between the incongruent and congruent trials (for discussion of alternative control methods, see Laird et al., 2005).

Go/no-go task. In this version of the go/no-go task (adapted from Newman & Kosson, 1986; Nieuwenhuis, Yeung, Van Den Wildenberg, & Ridderinkhof, 2003), each trial consisted of a white numeral ranging from 1 to 8 that appeared randomly for 200 ms on a black background. Participants were instructed to press the space bar as quickly as possible whenever the number was not a 3 or 8 (*go trials*) and to refrain from pressing the space bar if the number was a 3 or 8 (*no-go trials*). Each of the eight numerals appeared equally often resulting in 80% go trials and 20% no-go trials. The inter-trial interval varied randomly between 500, 750, 1000, and 1250 ms. The task began with a practice block of 15 trials followed by four blocks of 80 trials each. The dependent measure was the proportion of errors made on the no-go trials.

Simon task. In this version of the Simon task (adapted from Lu & Proctor, 1995; Simon & Rudell, 1967), each trial consisted of a white fixation cross that appeared for 500 ms on a black background. The fixation point was followed by the word 'Left' or the word 'Right' that appeared at random on the left or right side of the screen for 200 ms. Participants were instructed to identify the word as quickly as possible (within 750 ms) by pressing a left-hand key (Caps Lock) if the word was 'Left' and a right-hand key (Enter) if the word was 'Right'. *Non-conflict* trials are those in which the word corresponds to its location (and, hence, the correct response is mapped to the word's location), whereas *conflict trials* are those in which the word and its location correspond to opposing responses (e.g. 'Right' on the left side of the screen). Trials were separated by a 300-ms inter-trial interval. The task began with a practice block of eight trials, followed by four blocks of 80 trials each. The dependent measure for this task was the RT difference between the conflict and non-conflict blocks.

Stop signal task. This version of the stop signal task was taken from an open source program called Stop-It (Verbruggen, Logan, & Stevens, 2008). Each trial consisted

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of a white square or circle that appeared at random in the centre of the computer screen on a black background. Participants were instructed to press the 'z' key if the object was a square and the '/' key if the object was a circle (stickers of the shapes were placed on these keys). On 25% of the trials, the shape was followed by a beep via headphones. When this occurred, participants were instructed to withhold pressing any buttons until the next shape appeared. Shapes remained on the screen for up to 1250 ms. The amount of time between the beep and the presentation of the shape (stop signal delay; SSD) began at 250 ms. If a participant got a beep trial incorrect, the SSD was decreased by 50 ms, making the next beep trial easier. If a participant got a beep trial correct, the SSD was increased by 50 ms, making the next beep trial harder. The adaptive nature of the task is intended to keep accuracy rates close to 50%. The task began with 16 practice trials and was then followed by three blocks of 64 trials (16 signal trials per block).

The dependent measure for the Stop signal task was the stop signal reaction time (SSRT). SSRT can be understood as the length of time required for a participant to react to the stop stimulus (Logan & Cowan, 1984). SSRT was calculated using the block integration method (Logan & Cowan, 1984; Verbruggen, Chambers, & Logan, 2013). Participants often strategically slow their responses throughout this task, resulting in positive skew of RTs and accuracy rates above 50%, even though the adaptive nature of the task is meant to keep accuracy rates around this level. In these cases, the mean method will overestimate SSRT. The block-based integration method gives a more accurate inhibition measure when gradual slowing and positive skew are present in the data (Verbruggen et al., 2013).

Life outcome measures. See Table 1 for a list of the life outcomes measured and the Supporting Information for a description of these measures.

Quality control and data cleaning

Quality checks, participant removal, and task data truncation and winsorizing were carried out according to standard conventions. Full details are available in the Supporting Information.

Data analytic plan

Inhibition measurement model

To create a latent inhibition variable, confirmatory factor analysis (CFA) was conducted treating performance on the five inhibition tasks as indicators on a single latent variable. An effect indicator model was fit using SSRT, Stroop RT difference score, Simon RT difference score, antisaccade trial accuracy, and no-go trial accuracy (Figure 1). The mean and variance of the model was constrained to 0 and 1, respectively. The model was estimated using the robust maximum likelihood estimator, a full information maximum likelihood estimation method featuring robust standard errors using Mplus, Version 7.4. Multiple fit indices were used (Hu & Bentler, 1999): χ^2 test, standardized root-mean-square residual (<.08), root-mean-square error of approximation (RMSEA < .06), comparative fit index (>.95), and Tucker–Lewis index (>.95).

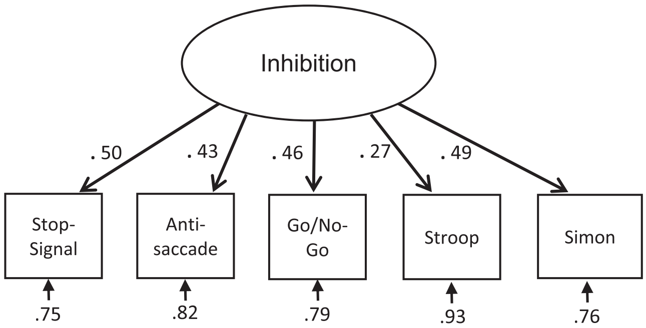

Figure 1. One-factor measurement model of inhibition. All paths were significant at $p < .001$. Factor loadings are standardized.

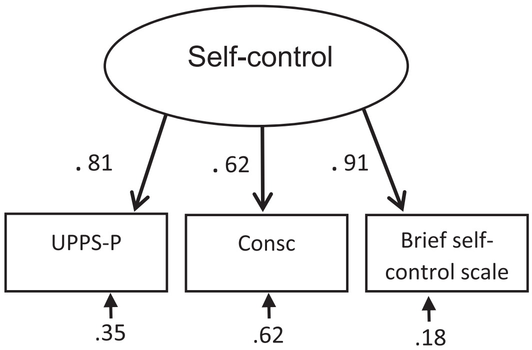

Figure 2. One-factor measurement model of self-control. All paths were significant at $p < .001$. Factor loadings are standardized. Consc, conscientiousness (two-item).

Self-control measurement model

A saturated effect indicator model was fit using three indicators: Brief Self-control Scale, total UPPS-P score, and two-item conscientiousness (Figure 2).

Structural models testing the association between inhibition and life outcomes

Structural equation models were used to estimate the association between inhibition and life outcomes (Mplus, Version 7.4. A separate model was tested for each of the 28 life outcomes, resulting in 28 structural equation models. Each model contained the following (Figure 3): four observed covariate variables (sex, SES, fluid intelligence, and social desirability) and two latent variables (a five-indicator inhibition latent variable and a three-indicator self-control latent variable). Each of these six variables werepredictors of a single life outcome, which was unique for each of the 28 models. The correlation between the two latent variables was also modelled. The preplanned analytic strategy used multiple regression models containing factor scores derived from the measurement models rather than structural equation models. The change was made based on reviewer feedback. Both methods produced similar results.

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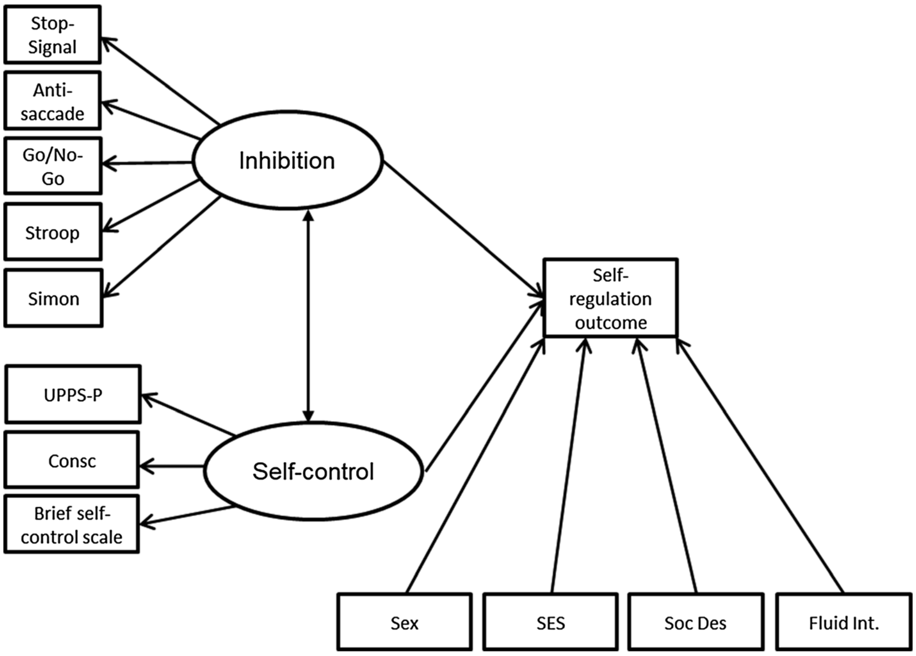

Figure 3. Configuration of the structural equation models reported in Table 3. Each model was individuated by a different self-regulation life outcome (28 outcomes total). Each outcome was regressed on the inhibition and self-control latent variables, as well as on four covariates. SES, socio-economic status; UPPS-P, Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency Scale.

RESULTS

Inhibition measurement model

The inhibition CFA model fit the observed data well, $\chi^2(5) = 6.06$, $p = .309$, comparative fit index = .988, Tucker–Lewis index = .977, RMSEA = .021, RMSEA 90% confidence interval [.000, .071], standardized root-mean-square residual = .027. As indicated in Figure 1, all tasks yielded statistically significant factor loadings on the hypothesized latent construct, with magnitudes ranging from .27 to .50.

Self-control measurement model

The self-control CFA model had three indicators, making it a saturated model (Figure 2). For this reason, the fit indices were uninformative. As indicated in Figure 2, all three measures yielded statistically significant factor loadings on the hypothesized latent construct, with magnitudes ranging from .62 to .91.

Association between inhibition and self-control latent variables

Consistent with previous research (Duckworth & Kern, 2011), the average Pearson correlation between the five inhibition tasks (stop signal, antisaccade, go/no-no, Stroop, and Simon) was $r = .18$ (range: .10 to .28; see Table 2). Also, consistent with previous research (Duckworth & Kern, 2011), the average Pearson correlation between the three self-control measures (UPPS-P, Brief Self-Control Scale, and Conscientiousness) was $r = .59$ (range: .49 to .73). The test for a difference in fit between the model that allowed the latent variable of inhibition to correlate with the latent variable of self-control (comparison model) versus the model that restricted this correlation to 0 (nested model)

Table 2. Correlations between inhibition tasks and self-control measures

Measure	1	2	3	4	5	6	7
1. Stop signal	—						
2. Antisaccade	.26***	—					
3. Stroop	.10	.16***	—				
4. Go/no-go	.20***	.19***	.13*	—			
5. Simon	.28***	.16***	.13*	.24***	—		
6. UPPS-P	−.03	.07	−.02	.10*	.05	—	
7. Conscientiousness	−.07	.05	−.07	.05	.04	.49***	—
8. Brief Self-control	.03	.05	−.05	.07	.08	.73***	.56***

*$p < .05$. **$p < .01$. ***$p < .001$.

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indicated that there was no difference in fit between the two models, χ^2 (1) = 1.12, p = .293. The association between the two latent variables in the model that estimated the association was r = .12, p = .111. Furthermore, the average Pearson correlation between the five inhibition tasks and the three self-report measures was r = .02 (range: −.07 to .10). Despite the evidence for no association between the lab tasks of inhibition and the self-report measures of self-control, we decided to allow the two latent variables to correlate in our structural models. The results of sensitivity analyses that did not allow for this association indicated no change in the results of the structural models.

Associations with life outcomes

Covariates

All of the following tests for association were conducted at α = .05 and make no experiment-wise correction across the large number of tests. As can be seen from Table 3, the four covariates were associated with a large portion of the

Table 3. Structural models regressing each life outcome on covariates, self-control, and inhibition

	Covariates				Latent variables	
Dependent variable	Sex	SES	Soc. Des.	Fluid Int.	Self-control	Inhibition
Finances						
Compulsive spending	−.37***	−.04	.07	.07	.31***	−.01
Monetary prudence	−.06	.09*	.00	.01	.39***	−.04
Financial well-being	−.12**	.27***	.04	.04	.27***	.09
Health						
Exercise	−.13**	.14**	.19***	.03	.07	−.01
Fat intake	.19***	.07	.07	.03	.04	−.03
Diet quality	.04	.09*	.12*	.12*	.21**	.01
BMI	.17***	.18***	−.08	−.01	.07	.06
Hygiene	.00	−.07	.08	−.12*	.31***	−.08
Risky sexual behaviour	−.14*	.06	−.25***	−.03	.49	−1.13
Sleep procrastination	−.07	.10*	.06	−.06	.36***	.01
Media						
TV duration	−.01	.14**	.04	.05	.07	−.04
Video game pathology	.20	.01	.20*	−.17*	.12	.04
Phone duration	−.33***	.12**	.06	.12*	.10	.07
Phone pathology	−.27***	−.03	.27***	.03	.31***	.03
Psychological adjustment						
Life satisfaction	.00	.18***	.01	.04	.42***	−.04
Meaning in life	.00	.07	.03	−.04	.45***	.06
Leisure orientation	−.04	.10*	.11*	.04	.19**	.00
Depression	−.18***	.09*	.07	−.01	.51***	−.02
Anxiety	−.20***	.08	.11*	.10*	.32***	−.01
Aggression	.12**	.11*	.37***	.01	.35***	−.04
Dysregulated eating	−.39***	.00	−.08	.04	.34***	−.13
Relationship						
Rel. satisfaction	.08	.14**	−.01	.07	.24**	.04
Rel. accommodation	−.07	.00	.19**	.14**	.34***	.03
School						
School engagement	.06	.06	.09	.08	.51***	.02
Study habits	.15***	.15**	−.04	.05	.49***	−.12*
GPA	.11*	.12**	−.04	.19**	.27***	.04
ACT	−.21***	.24***	−.12*	.33***	.12*	.05
Work						
Work quality	.10*	.01	.20***	.14*	.34***	−.01

Note. Each row designates a separate structural equation model that is individuated by the dependent variable on the left. Values are standardized coefficient estimates, except risky sexual behaviour, which involved Poisson regression. All variables except risky sexual behaviour are scored such that greater self-control and inhibition scores are expected to result in positive associations. Fluid Int., fluid intelligence; Soc. Des., social desirability. *p < .05. **p < .01. ***p < .001.

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Table 4. Pearson correlations between inhibition tasks and life outcomes

	Inhibition measures					
Dependent variable	Factor score[a]	Stop signal	Antisaccade	Go/no-go	Stroop	Simon
Finances						
Compulsive spending	−.01	−.05	.14**	.01	.05	−.10*
Monetary prudence	−.02	−.04	−.02	.00	.06	.03
Financial well-being	.06	.07	.05	.05	.04	.04
Health						
Exercise	−.03	−.01	−.01	.03	.07	−.05
Fat intake	−.01	.02	−.10*	.04	−.12*	.08
Diet quality	.05	−.02	.08	.04	.00	.03
BMI	.07	.11	−.03	.10	−.05	.03
Hygiene	−.05	−.12*	−.05	.01	.00	−.01
Risky sexual behaviour	.00	.00	−.04	.06	.01	−.08
Sleep procrastination	.01	−.06	.02	.06	.04	−.02
Media						
TV duration	−.01	−.03	−.03	.04	−.01	−.02
Video game pathology	.02	−.04	−.11	.18*	−.02	.03
Phone duration	.04	−.03	.10*	.01	.11*	.02
Phone pathology	.03	−.06	.14**	−.03	.01	.04
Psychological adjustment						
Life satisfaction	.01	.00	.00	.05	−.01	−.01
Meaning in life	.04	.06	.03	.03	−.01	.08
Leisure orientation	.02	−.05	.03	.05	−.04	.03
Depression	.02	−.03	.06	.05	.00	−.03
Anxiety	.02	.00	.07	.02	−.01	.00
Aggression	.02	.03	.08	.02	−.07	−.01
Dysregulated eating	−.07	−.11	.06	−.04	−.04	−.10*
Relationship						
Rel. satisfaction	.09	.12	.04	−.03	.04	.07
Rel. accommodation	.09	.05	.18**	−.05	.12	.03
School						
School engagement	.06	−.01	.09	.03	−.02	.08
Study habits	−.03	−.02	−.07	.03	−.09	.02
GPA	.09	.04	.16***	.04	−.11*	.07
ACT	.11*	−.03	.21***	−.01	.11*	.05
Work						
Work quality	.04	−.02	.04	.07	−.11*	.08

Note. All variables except risky sexual behaviour are scored such that greater inhibition scores are expected to result in positive associations.
*$p < .05$. **$p < .01$. ***$p < .001$. [a]Factor scores resulting from the inhibition measurement model.

outcome variables. SES had 16 statistically significant associations (SSAs; 16 out of the 28 tests; SSA β = .14, all β = .09, range: −.07 to .27).[3] All of the SSAs were in the expected (positive) direction. Sex (male = 1 and female = 0) had 16 SSAs (SSA β = −.09, all β = .05, range: −.39 to .20). Social desirability had 11 SSAs (SSA β = .16, all β = .07, range: −.12 to .37), with one in the opposing direction (ACT score). Fluid intelligence had nine SSAs (SSA β = .10, all β = .05, range: −.17 to .33), two of which were in the opposing direction. Notably, the largest associations were with GPA and ACT—two cognitive outcomes with which IQ would be expected to be associated. This provides some assurance of the validity of the measure, even if it displayed less association with outcomes than is typically observed with IQ measures (Moffitt et al., 2011).

[3]'SSA β' designates the average β for statistically significant associations. 'All β' designates the average β for all associations, excluding the unstandardized risky sex variable. The range includes all associations. Unlike the other dependent variables, risky sex analyses involved Poisson regression, and the coefficients reported in Table 3 are unstandardized estimates. For these reasons, all reports of mean β and β ranges do not include this variable.

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Inhibition tasks

Only one of the outcomes was associated with the inhibition latent variable, and this association was in the unexpected (negative) direction (Table 3). The average β across the tests was .00, range: −.13 to .09. Given this surprising lack of association, less conservative tests for association were conducted without the covariates by calculating the Pearson correlation coefficients between each life outcome and each individual inhibition task measure (Table 4). Moreover, the correlations between each outcome and the factor scores from the inhibition latent variable were also calculated. Results were similar to the structural models containing the covariates. The inhibition factor score variable was associated with only one outcome (ACT), $r = .11$, $p = .031$. Correlation coefficients between the individual tasks and each outcome also indicated limited association. Stop signal performance was associated with one outcome, but in the unexpected direction (all $\beta = -.01$, range: −.12 to .12). Go/no-go performance was associated with one outcome in the expected direction (all $\beta = .03$, range: −.05 to .18). Stroop task performance was associated with five outcomes; three were in the unexpected direction (all $\beta = .00$, range: −.12 to .12). Simon task performance was associated with two outcomes (all $\beta = .01$, range: −.10 to .08); both were in the unexpected direction. Antisaccade task performance was associated with seven outcomes, only one of which was in the unexpected direction (SSA $\beta = .12$, all $\beta = .04$, range: −.11 to .21).

Self-control

The self-report, self-control latent variable exhibited 21 SSAs (SSA $\beta = .34$, all $\beta = .28$, range: .04 to .51). None of these associations were in the unexpected direction. To see associations with the life outcomes for each of the three self-report measures separately and for each of the five UPPS-P facets, see Table S3.

DISCUSSION

Self-control, along with a cluster of related constructs such as impulsivity and conscientiousness, is associated with successful regulation in a broad range of life domains (Berg et al., 2015; De Ridder et al., 2012; Moffitt et al., 2011; Tangney et al., 2004). There is extensive theoretical and conceptual overlap between these constructs and executive functions (Blair & Ursache, 2011; Hall & Fong, 2013; Hofmann, Schmeichel, & Baddeley, 2012; Williams & Thayer, 2009). This, and empirical support, has led to the persistent belief that EF is critical for real-world regulation success (Diamond, 2013; Hofmann et al., 2012). However, given the lack of comprehensive investigation of the issue, the state of the empirical evidence linking EF task performance to regulatory success is difficult to discern. Additionally, research has consistently documented poor convergent validity between behavioural task measures of EF and self-report and informant report measures of self-control (e.g. Saunders et al., 2018) which raises concerns regarding EF's criterion validity (i.e. its influence on self-control-relevant life outcomes) and by extension, its construct validity. Furthermore, the viability of using cognitive tasks like inhibition tasks for individual difference research has been challenged on the grounds of low individual difference variation and low test–retest reliability (Enkavi et al., 2019; Hedge et al., 2018). For these reasons, coupled with growing interest in the replicability and robustness of effects often 'taken for granted' in psychology (Collaboration, O. S, 2015; Franco, Malhotra, & Simonovits, 2014; Simmons, Nelson, & Simonsohn, 2011), the purpose of the current study was to provide a comprehensive assessment of the association between the core EF facet of inhibition and 28 domains of daily life functioning. To our knowledge, this represents the most thorough single-study investigation to date of the hypothesis that inhibition, as measured using standard laboratory-based behavioural measures, is associated with real-life outcomes that characterize healthy and happy living.

Contrary to this hypothesis, after entering sex, SES, fluid intelligence, and social desirability as covariates, an inhibition latent variable composed of performance across five commonly used behavioural task measures exhibited no incremental value in predicting life outcomes (average $\beta = .00$). Of the 28 outcomes, only one association was statistically significant, and that association was in the unexpected direction (i.e. better task performance associated with poorer outcomes). Even after removing the covariates and simply examining the Pearson correlations between the inhibition factor scores and each individual outcome, only one, very modest association emerged ($r = .11$). To ensure that these results were not due to an unsatisfactory latent variable (loadings were similar to or larger than those in the existing literature), correlations between performance on each of the five tasks and each outcome were examined. Using this approach also yielded a limited number of associations. Three of the tasks demonstrated a small number of SSAs with outcome variables—roughly within the range expected by type I error—and roughly half of these associations were in the unexpected direction. Performance on the Stroop task demonstrated five associations, but three were in the unexpected direction. Performance on the antisaccade task was most consistently associated with life outcomes, with seven SSAs small to moderate in magnitude. In contrast to these results, the latent variable composed of three self-control measures demonstrated 21 associations out of the 28 tests.

Potential methodological and psychometric reasons for inhibition's poor performance

The lack of association between inhibition and life outcomes could be attributed to many factors. An obvious question in the face of null findings is whether the study was adequately powered to detect predicted effects. The current analyses were based on a rather large sample—nearly twice as large as those in previous studies (Diamond, 2013)—and was powered at 84% to detect a small-to-medium sized effect. Thus, lack of statistical power does not seem to provide an explanation for the current findings. Potential lack of convergent validity between the tasks and task impurity (Miyake

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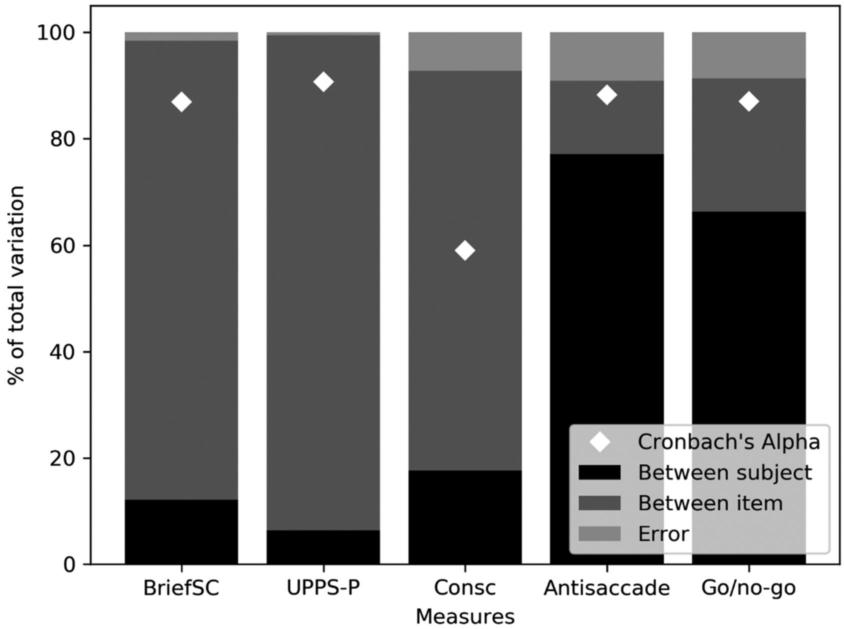

Figure 4. Variance decomposition for the self-report measures of self-control and for the two inhibition tasks that do not rely on difference scores. Variance is normalized by the total amount of variance in each measure. Cronbach's alpha values are depicted in non-decimal form. BriefSC, Brief Self-Control Scale; Consc, conscientiousness (two-item); UPPS-P, Urgency, Premeditation (lack of), Perseverance (lack of), Sensation Seeking, Positive Urgency Scale.

et al., 2000) were addressed by extracting a latent variable containing variance common across all five tasks (Bollen, 1989). Despite some relatively modest correlations across some of the tasks (especially the Stroop task), the fit indices for the latent variable were excellent, even if the factor loadings were not great, which is typical for these tasks (Friedman, Miyake, Robinson, & Hewitt, 2011; Friedman & Miyake, 2004). Furthermore, the inhibition tasks used in the study were selected based on their common use in the literature as measures of inhibition (Bialystok, Craik, Klein, & Viswanathan, 2004; Friedman & Miyake, 2004; Logan & Cowan, 1984; Wright, Lipszyc, Dupuis, Thayapararajah, & Schachar, 2014) and on their face validity as the inhibition tasks that are most likely to be related to one another in terms of assessing a similar underlying inhibition ability.

It has recently been argued that cognitive tasks, such as inhibition tasks, are unsuitable for correlational research designs involving the examination of individual differences (Enkavi et al., 2019; Hedge et al., 2018). The basis for this claim is that the reliability of these tasks is purportedly not large enough to consistently preserve the rank ordering of participant's scores. Nevertheless, four of the tasks achieved good-to-excellent internal reliability, ranging from .88 to .97, with the lowest being .73 (Table 1). The reliability of the self-report measures of self-control ranged from .58 (two-item conscientiousness) to .93. Given the high reliability of most of the inhibition tasks along with most of the outcome measures and given the almost perfect non-association between inhibition tasks and outcomes (average $\beta = .00$), the null findings are unlikely due to reliability levels (e.g. Bobko, 1983; Sackett & Yang, 2000; Spearman, 1904). For instance, the dissatenuated correlation coefficient using Spearman's (1904) formula, for an observed correlation of $\beta = .02$ and for reliabilities of .75 for both measures, is $\beta = .03$.

It has also been claimed that the purportedly low reliability of these tasks is due to low between-subjects variance relative to self-report measures of self-control (Enkavi et al., 2019; Hedge et al., 2017). We used the present data to examine this claim. Figure 4 shows variance decomposed into three components for the two inhibition tasks that do not rely on difference scores and for the three self-report measures of self-control. Cronbach's alpha can be computed from variance components simply by subtracting the ratio of MSerror over MSsubjects from one. Thus, Cronbach's alpha depends only on the relative relationship between these two variance components. It is clear that the variance structure between the laboratory and self-report measures is quite different, even though both achieve acceptable reliability. Compared to the inhibition tasks, the self-report tasks possess much less between-subject variance relative to the between-item variance, but this lower between-subject variance is compensated for by very low error variance (see Von Gunten & Bartholow, 2019, for an understanding of what we are calling between-subject variance).

It is important to stress that the current study examines internal (within session) reliability whereas the papers under discussion (Enkavi et al., 2019; Hedge et al., 2018) examine test–retest (across session) reliability. The extent to which number of trials contributes to test–retest reliability, and whether estimated internal reliability during a single task administration is a good proxy for test–retest reliability, remains an open question. Enkavi et al. (2019) and Hedge et al. (2018) provide some insight into this question by reporting internal reliabilities in their supplemental materials. With the exception of the stop signal, which had very high

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internal reliability in both the current study and in Hedge et al. (2018), the tasks in the current study (Stroop, go/no-go) reached higher internal reliabilities. Hedge et al., (2018) note that suboptimal test–retest reliability could be due to substantial changes in performances over time or contexts, or to problematic task construction and measurement. If the former, one might expect higher within-session reliabilities (i.e. internal reliability) than test–retest reliabilities. They do not find evidence for this, because both reliabilities were low. However, the internal reliability found in the present paper was good for four of the five tasks, suggesting either that genuine change in performance over time would result in lower test–retest reliability or that the tasks used in the present study would result in higher test–retest reliability. Future research could examine the relationship between internal reliability and test–retest reliability, given the discrepancy between the tasks used in the present paper and those used in Enkavi et al. (2019) and Hedge et al. (2018).

It should further be noted that data from the inhibition tasks used in this paper feature in a methods paper examining reliability and power (Von Gunten & Bartholow, 2019). The psychometrics of the inhibition tasks (particularly the relationship between number of trials, variance, reliability, and power) are examined in detail there, along with time-on-task descriptive statistics. In the context of the present paper, the primary point is that the null associations between inhibition tasks and outcomes measures found in the current study do not appear to be due to problematic reliability and between-subjects variability found within session.

The current null findings also could be attributed to the sample used. One such concern is that the ranges of the scores are restricted because the average college student is likely to be above average in many cognitive abilities and outcomes. The reduced reliability that would accompany the reduced individual difference variation was treated in detail earlier and is not a major concern. However, another concern is that inhibition tasks may provide more diagnostic individual difference information for certain clinical populations or during certain developmental periods. For instance, psychopathologies that are partly characterized by cognitive deficits, such as ADHD and addiction, may reliability show deficits in EF (Barkley, 1997; Day, Kahler, Ahern, & Clark, 2015; Oosterlaan et al., 1998). Additionally, much developmental work has focused on the association between EF abilities and math and reading achievement in children and adolescents (Jacob & Parkinson, 2015). Thus, it could be that EF tasks convey less useful individual difference information in healthy emerging adults than in adolescence or once cognitive abilities begin to decline later in adulthood (Belleville, Rouleau, & Van der Linden, 2006; Hasher & Zacks, 1988).

Finally, another potential concern is common method bias (Conway & Lance, 2010; Podsakoff, MacKenzie, Lee, & Podsakoff, 2003; Reio, 2010). Both the self-control and life outcome variables were assessed with self-report, while inhibition was measured with behavioural task performance. In order to account for potential method-based third variables that could inflate the associations between the self-reports of self-control and the self-reports of life outcomes (but see Podsakoff et al., 2003), social desirability was added as a covariate to the models. This concern, however, should not distract from the aim of the present study which was to examine the laboratory-based inhibition tasks that are commonly enlisted in the literature. Among the large variety of self-report measures of constructs and facets related to self-control, there do exist measures that possess the semantic label of 'inhibition' or 'disinhibition' (Sharma et al., 2013, 2014). And as described in the introduction, report measures tend to correlate strongly with each other and not with inhibition tasks (e.g. Duckworth & Kern, 2011; also replicated in the present paper). Furthermore, we would expect that report measures of 'inhibition' exhibit degrees of criterion validity similar to that of other report measures of self-control (Table S3). But because report measures do not correlate much at all with many laboratory-based inhibition tasks, we expect low-to-no correlation as well between inhibition reports and inhibition tasks. Thus, regardless of whether report measures of 'inhibition' demonstrate convergent and criterion validity, the question remains as to whether the commonly used task measures of inhibition possess these properties. It should also be pointed out that fluid intelligence, which was measured by a cognitive performance task (Raven's Progressive Matrices), did show some success in predicting the life outcomes (nine associations and two in the unexpected direction), suggesting that the null associations between inhibition tasks and outcomes go beyond their cognitive performance nature. In the succeeding texts, we discuss some modified inhibition tasks and alternative measurement approaches for self-control and outcomes.

Potential theoretical reasons for inhibition's poor performance

In addition to methodological concerns, there are also substantive theoretical reasons related to the processes that enable successful regulation that can explain why inhibition task performance might be unrelated to life outcomes. One such reason is that maintaining consistent success across multiple domains might not depend heavily on the inhibition of impulses and may instead depend on circumventing impulses in the first place.

Self-control is regularly understood as an effortful struggle between temptations that are highly desirable in the moment and long-term goal pursuit (De Ridder et al., 2012; Duckworth et al., 2019; Heatherton & Wagner, 2011; Hofmann et al., 2008, 2009; Milyavskaya, Inzlicht, Hope, & Koestner, 2015). This conceptualization of self-control as a real-time competition suggests that high trait self-control depends on being able to successfully override impulses when they occur. However, individuals can employ a number of other strategies, besides effortful impulse inhibition, in order to attain their goals and maintain high trait self-control (Magen & Gross, 2010). Recent research exploring these alternatives has focused on several self-control strategies that may be loosely considered, to some extent, proactive in nature (De Ridder et al., 2012; Duckworth, Gendler, & Gross, 2016; Fujita, 2011; Fujita, Trope, Cunningham, & Liberman, 2014). This research suggests that a large portion of self-control success is less about being

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able to reactively restrain temptations once they occur and more about proactively decreasing the likelihood of experiencing temptation in the first place. These strategies include habit formation and situation selection (Adriaanse, Kroese, Gillebaart, & De Ridder, 2014; Galla & Duckworth, 2015; Wood & Rünger, 2016), and possibly automatic forms of control (Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trötschel, 2001; Gollwitzer, 1999; Mc Culloch, Aarts, Fujita, & Bargh, 2008).

Support for this perspective comes from research demonstrating that habits mediate the relationship between trait self-control and various outcomes (Galla & Duckworth, 2015), that greater goal attainment is associated with *fewer* reports of temptations (Milyavskaya & Inzlicht, 2017), and that individuals with greater self-control report attempting to inhibit temptation *less* than individuals with lower self-control (Hofmann, Baumeister, Förster, & Vohs, 2012). Taken together, these studies suggest that the experience of temptation and/or goal conflict is already a bad sign for a person who is trying to achieve their long-term goals.

The possibilities just considered are levelled at the construct of inhibition. Yet even if the ability to inhibit impulses in the moment turns out to be a major component of regulation success, there are still reasons why laboratory inhibition tasks may not be good operationalizations of state impulse control as it occurs in everyday contexts. One difference is the time scale and consecutive nature of inhibition tasks. Each trial in a task normally lasts less than a second, and trial numbers range from the tens to the hundreds. Conceptually, this means that the tasks are assessing up to hundreds of sequential bouts of self-control exertion. How this conceptualization generalizes to the temporal nature of real-world behaviours (Duckworth et al., 2016) is unknown. Some opportunities for control, such as the urge to respond aggressively to an insult, may be quick but may not require repeated instances of suppression. Such scenarios are unlike inhibition tasks in that they lack repeated encounters with discreet stimuli that require response suppression. Other self-control scenarios involve decisions that play out over longer periods of time, in which the stakes are much higher than in a typical EF task (e.g. whether to act on the desire to pursue an extramarital affair with a co-worker or to purchase a desired but unnecessary luxury item). Such scenarios also do not resemble inhibition tasks in that a single failure to suppress can have dramatic and far-reaching consequences. This contrasts greatly with the typical approach to scoring inhibition task performance (i.e. computing means across dozens or hundreds of trials), which represents an index of a large number of small-scale inhibitions.

There is also arguably less motivational urgency in inhibition tasks (such as suppressing an eye movement in response to peripheral visual stimulation) relative to ecologically valid contexts (such as those involving money, food, sex, and anger). Other behavioural lab measures of self-control exist that attempt to rectify this apparent dissimilarity by matching urges found in everyday life. The classic marshmallow test is such an example (Mischel & Baker, 1975; Watts, Duncan, & Quan, 2018). Other measures involve modified EF and inhibition tasks that use stimuli specific to a self-control domain of interest (e.g. images of food, school, or alcohol; Fillmore, Ostling, Martin, & Kelly, 2009). Still, others use subjective reports of craving and neural assessments after cue exposure to a particular regulatory domain (e.g. smoking; Heatherton & Wagner, 2011; Kober et al., 2010).

Research examining neural activations during inhibition task performance may be able to address the generalizability of traditional tasks to real-world contexts. Work on traditional inhibition tasks has emphasized the importance of the interplay between the dorsal anterior cingulate cortex and dorsolateral prefrontal cortex (dlPFC) for control regulation (e.g. Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick & Cohen, 2014). Work examining inhibition tasks that use domain-specific stimuli have implicated similar dlPFC regions, while placing less emphasis on the dorsal anterior cingulate cortex (e.g. Heatherton & Wagner, 2011). Therefore, there is some support that dlPFC activation evinced during inhibition tasks does translate to salient, domain-specific self-control. However, this work also suggests that the types of impulses in play during real-world control are often represented in neural regions related to reward (e.g. Delgado, Gillis, & Phelps, 2008), emotion (Ochsner & Gross, 2005), and memory (Depue, Curran, & Banich, 2007) that are not normally implicated in traditional inhibition measures. Thus, although standard inhibition tasks may be able to inform how self-control is achieved in everyday contexts, measuring inhibition in the presence of domain-specific temptations may be more valid and diagnostic of individual differences related to self-control outcomes (Kazén, Kaschel, & Kuhl, 2008).

In summary, we have discussed two broad ways in which inhibition can fail to be associated with real-world outcomes. The first pertains to the construct and maintains that the inhibition of everyday impulses may play a limited role in real-world self-control success. The second pertains to measurement (not to be confused with the methodological and psychometric reasons discussed previously) and questions whether the mechanisms that underlie the inhibition of dominant responses in laboratory inhibition tasks are generalizable to the time-course and motivationally salient nature of impulse suppression in real-world contexts.

Limitations and future directions

One limitation of the study was the use of a convenience sample of college students. As mentioned previously, the current results may not hold for clinical, adolescent, or senior populations. Additionally, the present study emphasized quantity over quality when it came to measuring the life outcomes. That said, the majority of the measures have confirmed construct validity, sound psychometric standing, and see regular use in this literature. Even so, other procedures and methods, such as informant reports, ecological momentary assessment, and experience sampling (Stone, 2018) may be able to improve not only the measurement of some domains but also the external validity of the findings.

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Ecological momentary assessment (which usually involves self-report) may better capture performance by shortening the interval between behaviour and report (e.g. how many times today did you eat more than you planned) than general self-reports (e.g. how good are you at resisting food temptations; but see Finnigan & Vazire, 2017).

Additionally, the present paper includes measures from many different life domains in order to provide a more exhaustive test for the relevance of inhibition tasks. Although the inhibitions tasks showed no success regardless of domain, the performance of the self-control latent variable did vary across domains. In particular, it exhibited less association with the health and media domains. Further work could explore differences across domains (Krueger, McGue, & Iacono, 2001; Sharma et al., 2013) and whether specific measures can be developed for making better domain-specific predictions. This may be particularly important since the life outcomes generally displayed a low degree of association with one another (Table S4).

Finally, the present study only examined inhibition—one facet of EF. Although inhibition appears to play a central role in EF (Friedman et al., 2008, 2011), other facets of EF, such as shifting and working memory updating, also should be examined in the context of self-control outcomes (Hofmann et al., 2012). This is a pressing issue as our results may incline one to think that the issue has less to do with inhibition tasks and more to do with behavioural, laboratory, and/or cognitive tasks more generally. Yet IQ is regularly found to be associated with important domains of life functioning (e.g. Moffitt et al., 2011), such as those measured in the current study. Regarding the EF facet of working memory updating, given its association with fluid and crystallized intelligence (Friedman et al., 2006), it may hold the most promise as an EF facet that matters for behavioural concomitants of self-control. Regarding the facet of shifting (and cognitive flexibility more generally), its role in real-life control remains at issue, both at a theoretical (Dreisbach & Haider, 2008, 2009) and empirical level (Herd, Hazy, Chatham, Brant, & Friedman, 2014; Martins, Bartholow, Cooper, Von Gunten, & Wood, 2018).

One further category of tasks of interest are those commonly used in the decision-making literature, such as delay-discounting and risk-preference measures. These tasks are regularly construed as laboratory measures of the self-control construct, are not speed based or performance based, and are not often discussed in the EF literature (Jurado & Rosselli, 2007; Miyake & Friedman, 2012; but see Diamond, 2013, who groups these tasks with inhibitory control functioning). The risk-preference literature differentiates report versus behavioural measures (Frey et al., 2017). The findings mimic those of the self-control literature: behavioural measures lack convergence with one another; demonstrate low test–retest reliability; and have low convergence with report measures, which converge with one another (Frey et al., 2017; Pedroni et al., 2017). Further work should examine the association between behavioural measures of risk-preference and life outcomes (see Table S1 for some data).

CONCLUSION

The state of evidence linking EF tasks to regulatory success in everyday life is difficult to determine because there is a lack of comprehensive coverage of the issue. The present study sought to comprehensively assess whether inhibition, a representative facet of EF, is associated with a broad array of life outcomes relevant to self-control. Contrary to prevailing attitudes in the literature, the current study did not find evidence for an association between inhibition measures and life outcomes. This lack of criterion validity, when considered alongside the failed convergent validity between inhibition tasks and self-report measures of self-control, challenges the construct validity of inhibition more generally. More specifically, although the simple nature of inhibition tasks may make them useful for the examination of lower-ordered attentional processes and motor control (Nigg, 2000) and for understanding specific forms of psychopathology (e.g. ADHD; Barkley, 1997), this may make them unsuitable for the study of person-level regulation success in more externally and ecologically valid contexts. Of course, replication of the current results is needed before any conclusions can be stated with confidence.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Data S1 Supporting Information

Supporting info item

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