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BRIEF REPORT

The relation between fluid intelligence and self-regulatory depletion

Noah A. Shamosh and Jeremy R. Gray
Yale University, New Haven, CT, USA

Self-regulation depends on a limited resource that can be depleted temporarily, but little is known about how this resource relates to individual differences in cognitive ability. We investigated whether self-regulatory depletion would vary with individual differences in fluid intelligence (*g*F), a stable index of cognitive ability with ties to executive function. Participants performed an emotion regulation task varying in self-regulatory demand, followed by the Multi-Source Interference Task to assess depletion. On a separate day, participants completed Raven's Advanced Progressive Matrices to assess *g*F. Emotion suppression led to impairment on the interference task, indicating self-regulatory depletion. Critically, higher *g*F was associated with greater depletion. Controlling for variables reflecting susceptibility to task demands and trait motivation did not influence this effect. The results have implications for theories of the relation between self-regulatory and cognitive abilities, and the mechanisms supporting the control of behaviour.

The ability to exercise voluntary control over one's own thoughts, feelings, and actions is an essential component of daily life. The importance of self-regulation becomes especially clear when considering some potential consequences of not exercising enough of it. Chronic or repeated failures of self-regulation relate to a host of personal and social problems (see Tangney, Baumeister, & Boone, 2004, for a review) and characterise numerous

Correspondence should be addressed to: Noah A. Shamosh or Jeremy R. Gray, Department of Psychology, Yale University, Box 208205, New Haven, CT 06520–8205, USA.
E-mail: noah.shamosh@yale.edu or jeremy.gray@yale.edu

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psychological disorders, such as drug addiction, binge eating disorder, generalised anxiety disorder, and attention-deficit hyperactivity disorder (Baumeister & Vohs, 2004). Yet, despite the significance of self-regulation to myriad behaviours across many domains, little is known about how individual differences can influence how this capacity functions.

According to a prevailing model, self-regulation taps a limited resource that can be temporarily depleted (see Muraven & Baumeister, 2000, for a review). The ability to self-regulate is hypothesised to fatigue the way that a muscle does after exercise, such that performing tasks requiring self-regulation will impair self-regulation on subsequent tasks, even when these tasks are unrelated. The range of behaviours that can induce self-regulatory depletion (or become impaired by it) is broad and diverse; virtually any act of self-regulation will consume the limited resource. This model is thus both parsimonious and comprehensive.

Some studies have investigated individual differences in depletion, showing that particular self-regulatory challenges are more depleting for certain people. For example, interacting with an experimenter of the opposite race is more depleting for those with stronger implicit racial bias (Richeson & Trawalter, 2005), and avoiding tempting snacks depletes chronic dieters (Vohs & Heatherton, 2000). Despite having implications for how particular phenomena relate to self-regulatory depletion, these studies do not address whether depletion effects can vary with individual differences related to self-regulation itself, rather than to the demands of a particular self-regulatory task.

One important variable to examine in relation to self-regulatory depletion is general fluid intelligence (*g*F), which reflects the ability to reason and to solve novel problems (Cattell, 1971). Intelligence is a major dimension of human individual differences. In particular, *g*F can be assessed reliably and is becoming understood in terms of the cognitive and neural mechanisms that support it (e.g., Duncan, Emslie, Williams, Johnson, & Freer, 1996; Gray, Chabris, & Braver, 2003; Gray & Thompson, 2004; Kane & Engle, 2002). These mechanisms are often associated with those involved in aspects of executive function, including brain regions that have been implicated as partial mediators of self-regulatory depletion (Richeson et al., 2003). Furthermore, *g*F typically has a very high loading on general intelligence (as identified in factor analyses; see Jensen, 1998), and evidence suggests that self-regulatory depletion selectively impairs performance on tasks with high *g*F loadings (Schmeichel, Vohs, & Baumeister, 2003). Thus, given that self-regulation and *g*F are both associated with executive function and intellectual performance, a relation between *g*F and depletion seems likely. To our knowledge, however, no study has tested directly for this association.

Our key objective was to investigate whether *g*F is associated with differences in self-regulatory depletion. There are plausible reasons for a relation in either direction. One possibility is that higher *g*F is associated with resistance to self-regulatory depletion. For example, *g*F could indicate the effectiveness of a mechanism that it shares with self-regulation, e.g., a component of executive function. In this case, individuals with higher *g*F would have a more effective mechanism and show increased resistance to depletion. The other possibility is that higher *g*F is associated with increased susceptibility to self-regulatory depletion. For instance, *g*F could influence the extent to which limited resources are mobilised on self-regulatory tasks. Given evidence that higher *g*F correlates with greater brain activity during demanding tasks (e.g., Gray et al., 2003, 2005; Lee et al., 2006), higher *g*F may indicate greater utilisation of this resource, leaving less available for subsequent self-regulation. By providing the first test of association between *g*F and self-regulatory depletion, our aim was to constrain future investigations of specific mechanistic hypotheses.

METHOD

Fifty-eight undergraduates (40 female; age range 18–23) were recruited from introductory psychology courses at Yale University and were compensated with course credit and $10 for their participation. One participant was excluded from all analyses for sleeping, leaving 57 participants (39 female) for analyses of depletion effects. Six participants who did not return for day two, and one participant who scored improbably low on the measure of *g*F (score 10, 4.04 *SD*s below the mean, completed in under 10 minutes), were also excluded from moderator analyses, leaving 50 participants (39 female).

On day one, participants underwent a standard self-regulatory depletion paradigm (cf. Baumeister, Bratslavsky, Muraven, & Tice, 1998). Before and after a self-regulatory challenge, participants completed 96 trials (over approximately six minutes) of the Multi-Source Interference Task (MSIT; Bush & Shin, 2006), a Stroop-like interference task that places even greater demands on executive attention than the classic Stroop. Like the classic Stroop, the MSIT involves both incongruent and congruent trials, and the difference in RT between the two trial types is the interference effect. Change scores (interference after video minus interference before video) provided within-subject measurements of depletion. The self-regulatory challenge involved watching a sad video clip (from *Terms of Endearment*), with instructions serving as the key manipulation of self-regulatory demand. Participants in the control condition were told that their task was simply to watch the video clip. Those in the emotion suppression condition were told to conceal and suppress any emotional reaction. The video task was presented as an optional pilot task for a separate study, and all participants voluntarily agreed to do it. Participants' facial expressions were digitally recorded (with their prior consent) using an iSight digital video camera. To assess group differences in effort during the task, participants also responded to one 7-point item asking them how effortful they found it to perform the task with the video clip. The Brief Mood Introspection Scale (BMIS; Mayer & Gaschke, 1988) was also given before and after the video to detect any between-group differences in mood change.

On day two, participants completed Raven's Advanced Progressive Matrices (APM; Raven, Raven, & Court, 1998), a standard measure of *g*F. The total score consisted of the number of items from Set II completed correctly within the 40-minute time limit. Three items from Set I were provided for practice. Participants also completed the Berkeley Expressivity Questionnaire (BEQ; Gross & John, 1995), which assesses tendencies to express emotions outwardly, and the Behavioural Approach Sensitivity and Behavioural Inhibition Sensitivity scales (BIS/BAS; Carver & White, 1994), which measure sensitivity to threat (BIS) and to appetitive (i.e., reward) cues (BAS). These scales were administered as control measures that would allow us to disentangle the influence of *g*F from differing task demands (participants with higher BEQ scores would have to work harder to suppress their emotional expressions) and trait motivation (those higher in BAS may have greater motivation to overcome depletion).

Following the questionnaires, the experimenter administered a funnelled debriefing to assess participants' knowledge of the study's true aims and any potential awareness of the key manipulation's effects. Finally, participants were debriefed about the aims of the study and compensated.

RESULTS

Manipulation checks

The emotion regulation manipulation successfully induced self-regulatory depletion. That is, whether a participant was instructed to suppress his or her emotions significantly influenced how much his or her MSIT interference effect changed after watching the video. We conducted a one-way ANCOVA with the increase in MSIT interference as the DV and suppression/no suppression condition as the grouping variable. Sex was included as a covariate based on pilot data ($N = 48$) and published research showing sex differences in emotion regulation (e.g., Gross & John, 1995). Participants who were told to suppress their emotions during the video showed a significantly greater increase in MSIT interference from before to after the video than did participants who received no instructions,

$F(1, 54) = 6.46$, $p = .014$; $\eta_p^2 = 0.11$. Specifically, suppression participants' interference effect increased (marginal mean = 18.28; 95% CI = −1.15, 44.71) while control participants' decreased (marginal mean = −29.00; 95% CI = −54.98, −3.04). Thus, consistent with self-regulatory depletion, participants who received no suppression instructions during the video demonstrated a significant improvement on the MSIT, whereas participants who suppressed during the video showed no improvement (and did worse, though not significantly so). Moreover, a one-way ANCOVA (sex covariate) showed that MSIT interference did not differ between groups before watching the video, $F(1, 54) = 2.16$, $p > .05$.

Effort and mood. As expected, participants in the emotion suppression condition found the video clip task more effortful than did controls, mean rating of 4.00 vs. 2.79; $t(55) = 3.00$, $p = .004$. Also, the depletion effect cannot be attributed to a change in mood. There was no difference between conditions in the change on the four BMIS subscales from before to after the video (all ts < 1, ps > .80). Furthermore, for each of the four BMIS subscales, a separate one-way ANCOVA was performed with the increase in MSIT interference as the DV, suppression/no suppression condition as the grouping variable, and the subscale's change score as a covariate (in addition to sex). None of the mood subscales' change scores had a main effect on the change in MSIT interference or showed a significant interaction with condition (Fs < 1.49, ps > .23).

Facial expression. To verify that emotional expressiveness varied between groups, two independent judges who were blind to the experimental hypotheses scored a segment from each subject's video ($n = 47$) using the FACES coding scheme (Kring & Sloan, in press). The mean judges' ratings of overall expressiveness, which achieved acceptable inter-judge agreement, $r(45) = .76$, $p < .001$, confirmed that individuals in the non-suppression condition were more expressive than those in the suppression condition, $\bar{x} = 1.86$ vs. 1.32 out of 5, respectively; $t(45) = 2.68$, $p = .01$.

Fluid intelligence and depletion

Of main interest, higher fluid intelligence was associated with a larger depletion effect. To test whether APM scores (*range* = 19–36, $\bar{x} = 27.56$, $SD = 4.35$) moderated depletion, a hierarchical linear regression was conducted with change in interference effect as the DV, sex, condition, and APM score as IVs in the first step, and the condition × APM interaction as an IV in the second step (see Table 1). There was no main effect of APM score on MSIT performance, but the critical APM × condition interaction was significant.

TABLE 1
Summary of hierarchical regression for variables predicting the change in MSIT interference ($n = 50$)

Variable	*B (SE B)*	*β*
Step 1		
Sex (0 = female, 1 = male)	−56.98 (22.42)	−.34*
Condition (0 = no instructions, 1 = suppression)	37.50 (21.96)	.25
Raven's APM score (grand mean centred)	2.22 (2.53)	.13
Step 2		
Sex (0 = female, 1 = male)	−68.07 (21.65)	−.40*
Condition (0 = no instructions, 1 = suppression)	33.16 (20.84)	.22
Raven's APM score (grand mean centred)	−3.25 (3.22)	−.19
Condition × APM interaction	12.45 (4.91)	.46*

Note: $R^2 = .44$ for Step 1; $\Delta R^2 = .10$ for Step 2 ($ps < .018$); *$p < .015$.

Simple-effects analyses revealed that APM scores varied with decline in MSIT performance when people faced an emotion regulation challenge, but not when they merely watched the film clip. That is, higher APM scores predicted a greater increase (or less of a decrease) in interference for participants in the emotion suppression condition but were unrelated to the change in interference for participants in the control condition (see Figure 1).

Other analyses suggested that the APM × condition interaction reflected neither individual differences in sensitivity to the demands of the emotion regulation task nor differences in trait motivation. People with higher APM scores did not show more depletion because they were differentially

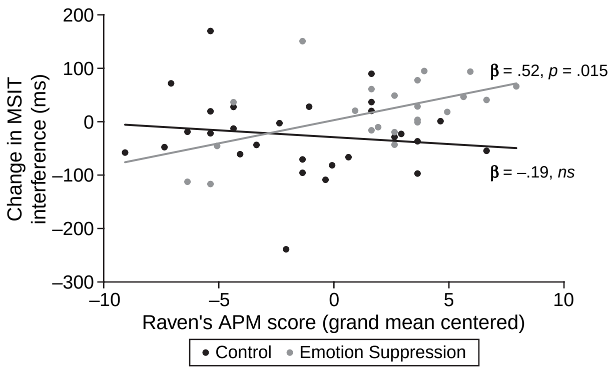

Figure 1. Fluid intelligence, as assessed using Raven's Advanced Progressive Matrices (APM), is associated with greater self-regulatory depletion: Interaction of depletion condition and APM on change in interference (controlling for sex; $n = 50$).

expressive (and hence likely to find the suppression task more difficult): adding BEQ and the BEQ × condition interaction to the regression did not eliminate the APM × condition interaction ($\beta = .42$, $p = .027$). Furthermore, APM scores did not influence depletion through differences in trait motivation: adding BAS and the BAS × condition interaction did not attenuate the APM × condition interaction ($\beta = .48$, $p = .012$), nor did adding BIS and the BIS × condition interaction ($\beta = .47$, $p = .015$).

Finally, APM scores did not vary with the subjective effort experienced during the emotion regulation task, controlling for sex, $pr(47) = .11$, $p = .44$, or ratings of the overall expressiveness shown during that task, $pr(44) = -.18$, $p = .24$, even for the emotion suppression condition exclusively, $pr(19) = .24$, $p = .29$ and $pr(19) = -.16$, $p = .50$, respectively. APM scores were correlated with MSIT RTs before the video, congruent: $pr(47) = -.42$; incongruent: $pr(47) = -.44$; ps $= .002$, and were marginally associated with the interference effect, $pr(47) = -.27$, $p = .065$. The pattern of results was similar after the video as well, though the relation between APM scores and the interference effect was weaker, $pr(47) = -.10$, $p = .48$.

DISCUSSION

Individual differences in *g*F were associated with individuals' susceptibility to self-regulatory depletion. Specifically, people with higher *g*F showed more depletion when they had to regulate their emotions. This effect not only demonstrates an association between cognitive individual differences and self-regulatory abilities but also constrains potential bases for that relation. If *g*F reflected the effectiveness of a mechanism that it shares with self-regulation, higher *g*F would have been associated with resistance to depletion. Instead, the data suggest that *g*F reflects the extent to which self-regulatory resources are mobilised, such that higher *g*F indicates a greater susceptibility to depletion.

The data argue against two less interesting explanations of the effect: differences in expressivity and differences in trait motivation. Participants higher in *g*F were no more susceptible to depletion by emotion regulation per se, as controlling for emotional expressivity did not eliminate moderation by *g*F. Moreover, *g*F did not correlate with subjective effort on the emotion regulation task or with ratings of emotional expressivity. It is also unlikely that differences in motivation to perform the emotion regulation task well or to overcome depletion influenced the result, as controlling for BAS and BIS did not attenuate the moderation by *g*F.

A more interesting possibility is that people with higher *g*F consume more of an actual resource involved in both cognitive control and self-regulation. Recent findings suggest that glucose is the resource on which self-regulation depends, and that self-regulatory depletion results from a decrease in available glucose due to prior self-regulation (Gailliot et al., in press). As noted above, during effortful task performance, people with higher *g*F show greater recruitment of certain brain regions (e.g., Gray et al., 2003, 2005; Lee et al., 2006; but for an exception, see Haier et al., 1988). To the extent that this increased cortical activity entails greater glucose consumption (see Raichle, 1994), people with higher *g*F may consume more glucose during effortful tasks—which, ironically, would leave them more prone to self-regulatory depletion.

To speculate, a possible reason why individuals with higher *g*F would expend more glucose during self-regulatory tasks is that they tend to use strategies on these tasks that place greater metabolic demands on neural substrates. Indeed, some evidence suggests that people with higher working memory capacity, which correlates strongly with *g*F, tend to use more cognitively demanding strategies on tasks that can be solved in a less-demanding way (Barrett, Tugade, & Engle, 2004; Beilock & Carr, 2005). To the extent that these more demanding strategies place greater demands on brain circuitry, they could also consume more glucose. Another possibility is that participants with higher *g*F engage cognitive systems more extensively, independent of which strategy they use. For instance, these individuals may show greater activation of working memory networks because they have more capacity available (see Just & Carpenter, 1992), which may lead to greater neural activity and, therefore, greater glucose consumption.

One potential point of concern is that our sample represents a limited range of APM scores focused on the high end. We submit, however, that our sample showed an acceptable range, as evidenced both by the range statistic itself and by our attainment of sufficient power to detect an interaction effect in a moderately-sized sample. Moreover, our observed mean was less than one standard deviation higher than that of nearly all reported undergraduate comparison groups (see Raven et al., 1998), so there is little reason to suspect that our population is significantly different from college students in general. Nonetheless, as with many laboratory studies involving college students, replication in more diverse samples will be an important next step.

Another interesting question that our results raise is whether any self-regulatory task would reveal the same relation of depletion to intelligence, or whether this relation is specific to depletion as induced by emotion regulation. On one hand, suppression of emotion has been demonstrated to have specific cognitive and physiological consequences (e.g., Gross, 2002). On the other hand, previous studies have shown that emotion suppression consistently induces depletion in ways effectively indistinguishable from other depletion manipulations that require effortful control unrelated to emotion (see Muraven & Baumeister, 2000). Thus, although the specific effects of emotion regulation on depletion may be of interest to future investigations, we think that our results likely would generalise to a wide array of self-regulatory behaviours.

Our findings run counter to the vast body of work highlighting the benefits of high intelligence (e.g., Jensen, 1998), but add to a nascent literature showing that higher cognitive ability can actually impair performance under certain circumstances (e.g., Beilock & Carr, 2005). It is notable that higher *g*F led to greater depletion even though *g*F was unrelated to performance on the emotion suppression task. This result suggests that more intelligent individuals were less efficient on that task, consuming more valuable resources without any apparent benefit. Although a potential ceiling effect on suppression performance may have obscured a relation to *g*F, the implication remains that higher intelligence can sometimes be detrimental to performance. Yet this potential cost to having high intelligence ostensibly does not negate its benefits. Perhaps more intelligent individuals learn, through repeated exposures, to cope with self-regulatory demands in a less resource-intensive way, thereby mitigating depletion effects. It is also plausible that long-term optimisation of resource allocation profits from a greater initial investment of resources during relatively novel self-regulatory challenges. Clearly, future research is required to clarify how the boons and banes of high intelligence might jointly influence behaviour.

The ability to self-regulate can become fatigued over time, as if it depends on a limited resource. The present study suggests that having higher fluid intelligence can tax this resource further, ironically undermining the ability to sustain self-regulatory efforts. The results suggest that cognitive abilities do not index the amount of self-regulatory resources a person has, but rather his or her tendency to consume them. More work is needed to ascertain the mechanisms underlying the relationship between intelligence and self-regulation and the scope of the resource on which they both critically depend.

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