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No effects of executive control depletion on prospective memory retrieval processes

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ABSTRACT

Research has suggested that prospective memory retrieval is reliant on executive control processes, and the degree to which these processes are necessary for intention fulfillment is dependent on a host of variables related to the prospective memory task. Based on results suggesting that aspects of the prospective memory task vary in their need for executive control, the current study examined the possibility that executive control depletion from the Stroop task would negatively transfer to prospective memory performance. Depletion of executive control, measured objectively in a Stroop task, did not impair prospective memory performance in either low or high cue-target association conditions. However, participants' subjective assessments of their own cognitive fatigue correlated significantly with their prospective memory performance, regardless of the association between cues and target responses.

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1. Introduction

Prospective memory refers to the process of remembering to perform an intended action at the appropriate time in the future (McDaniel & Einstein, 2007). The scope of these actions ranges from everyday tasks, such as remembering to go to the grocery store, to activities with potential life-altering consequences, such as remembering to monitor a child's safety. Prospective memory often blends demands on attention and retrospective memory processes in any given memory task (Smith & Bayen, 2004). To assess these demands, prospective memory failures are typically studied in the laboratory by having participants busily engage in some ongoing activity in which prospective memory cues are presented that should stimulate retrieval of previously established intentions. The current research explored the hypothesis that placing demands on executive control processes after establishing an intention but prior to beginning the ongoing activity where cues are to be detected will interfere with subsequent prospective memory performance (i.e., executive-control depletion).

1.1. Prospective memory retrieval processes: cue-intention association

McDaniel and Einstein (2000) hypothesized that if a prospective memory cue has a high degree of association with a target action (e.g., the intention is to buy milk and the cue is passing the grocery store), then reflexive episodic memory retrieval processes will promote retrieval of the intention upon encountering the cue, contrasted with a situation where there was a lesser degree of association between cue and intended action. To test this hypothesis, McDaniel, Guynn,

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Einstein, and Breneiser (2004) asked participants to remember to write down a specific word in response to the occurrence of a set of specific target words. To hold detection processes constant, the target words remained the same across conditions, but the response words varied; in the high-association condition, the cue (e.g., spaghetti) had a strong associative relation to the target response (e.g., say "sauce") and in the low-association condition the cue (e.g., spaghetti) was weakly associated to the target response (e.g., say "steeple"). Additionally, half of the participants in each condition concurrently completed a secondary task that limited the availability of executive-control processes for the prospective memory task. The data showed that for participants in the high-association condition, prospective memory performance was unaffected by the executive-control demands of the secondary task, but for participants in the low-association condition, prospective memory performance was significantly impaired by the secondary task. These results suggest that executive control is necessary for successful prospective memory fulfillment only when the use of controlled retrieval processes (i.e., inhibition of competitors, temporal-contextual search, etc.) is necessary for successful prospective memory performance. Therefore, under conditions of low cue-intention associations, executive control demands intervening between intention establishment and the opportunity to fulfill the intention should lead to prospective memory impairments.

1.2. Depletion

Depletion refers to the idea that performing tasks related to controlling or modifying thoughts or behavior requires the use of cognitive resources and that by performing these activities, the availability of these resources can be diminished, thereby negatively transferring to performance on subsequent tasks that utilize the same resource pool.

Ego depletion refers to a temporary reduction in one's capacity or willingness to engage in volitional acts (e.g., self-control, making choices, initiating action) due to previous engagement of volition (Baumeister, Bratslavsky, Muraven, & Tice, 1998). Baumeister et al.'s use of ego as a concept stemmed from Freud's definition of the ego as "the part of the psyche that must deal with the reality of the external world by mediating between conflicting inner and outer pressures" and Freud's assumption that the ego required energy to make these choices (p. 1253). Baumeister et al. (1998) conducted a series of experiments to test his theory of ego depletion by using a variety of volitional acts to attempt to deplete ego resources and then measuring performance on subsequent volitional acts to determine whether a detrimental effect had occurred.

For example, in one experiment Baumeister and colleagues used self-control as the volitional act, instructing a group of participants to eat radishes while tempted with the appealing presence of chocolates, which they were specifically instructed not to eat. A second group had the instructions reversed (eat chocolates, not radishes), and a control group did not eat any food. Following this exercise participants were asked to try and solve a puzzle that, unbeknownst to them, was unsolvable; the researchers, working under the assumption that persistence is a function of self-control, measured how long participants focused on solving the puzzle before giving up. The participants in the radish-eating group worked on the puzzle for significantly less time than either the chocolate-eating or control groups; the chocolate-eating group (who presumably did not have to exercise much self-regulation) did not differ significantly from the control group in terms of persistence. These results provided support for the hypothesis that varying forms of volitional acts draw from the same limited resource pool.

1.3. Executive control depletion

Schmeichel (2007) extended the concept of ego depletion to apply to any task that falls under the label of an executive control function, which broadly refers to the ability to modify one's thoughts and actions (Baddeley, 1986; Norman & Shallice, 1986 in Schmeichel (2007), p. 241). These executive control functions can include controlling attention, updating memory, and inhibiting or exaggerating automatic responses (Schmeichel, 2007). For example, in the classic Stroop task (1932) participants are presented with a series of words denoting a color that are also presented in a colorful font. Participants are instructed to name the color of the font and to avoid reading the word. In this task, words and font color can either match (congruent trials) or mismatch (incongruent trials). Across many published studies in experimental psychology, participants are slower on incongruent trials than congruent trials indicating that executive control processes are necessary for avoiding the automatic response to read the word in favor of naming the color (i.e., the Stroop Effect; for a review, see MacLeod, 1991). Of course, participants could complete a version of the Stroop task under the instruction to simply read the color words thereby removing any executive control demands inherent in avoiding automatic reading responses.

Of particular interest to the current study is Schmeichel's (2007) research concerning the impact of executive control depletion on memory updating and maintenance. Schmeichel's first experiment examined the effects of depleting attention control on the ability to update working memory. Participants in the experiment were asked to watch a short video with unrelated words clearly visible at the bottom of the screen appearing for 15 s each. The attention control group was asked to watch the clip but avoid looking at or reading the words appearing on the screen (similar to the demands of a standard Stroop task), whereas the control group was merely asked to watch the clip (they were provided with no further instructions). After watching the video, participants engaged in either an operation span task or a sentence span task, both of which served to measure working memory performance. The operation span task consisted of evaluating the correctness of math equations and later recalling a set of target words given after each equation; the sentence span task consisted of answering a multiple-choice question about a sentence and later recalling the last word of each sentence. Results provided support for the executive control depletion hypothesis; participants in the attention control condition performed significantly worse

on the recall task than participants in the control condition. However, the scores on the equation evaluations and multiple-choice questions did not differ, suggesting that the resources used in completing those tasks do not stem from the same pool as those used by attention control and working memory recall. Given these results, it seems not all executive control functions are similarly impacted by executive control depletion.

Recent neuroimaging evidence has supported the domain specificity view of depletion (Persson, Larsson, & Reuter-Lorenz, 2013). This neuroimaging work brings clarity to the notion of "resource depletion" by showing that neural fatigue was predictive of behavioral decrements on transfer tasks when the depletion task was "process specific". Therefore, executive control depletion can be conceptualized as continued demand placed on neural circuitry (Persson et al., 2013). Accordingly, negative transfer from depletion should be expected in situations where two tasks (the depletion and transfer task) rely on similar neural networks. In other research it has been suggested that one process that executive-control depletion might affect is future-oriented behavior, namely prospective memory.

1.4. Depletion and prospective memory

Only two published studies have examined the effects of executive control depletion on prospective memory abilities with equivocal results (Shelton et al., 2010, 2013). In the Shelton et al. (2010) study younger and older adults completed either a standard Stroop task (name color) or a control task (name word) and subsequently completed a prospective memory task that varied in the demands on attentional control processes necessary for cue detection. More specifically, in the prospective memory task participants completed a lexical decision task (LDT) in which they either had to detect focal (i.e., a single word; *tortoise*) or nonfocal (i.e., a syllable; *tor*) event-based prospective memory cues. Previous individual differences research has supported the hypothesis that executive control processes supporting working memory capacity are necessary for nonfocal but not focal cue detection (Brewer, Knight, Unsworth, & Marsh, 2010). Shelton et al. (2010) replicated previous research showing that nonfocal cues are detected less frequently than focal cues and that this effect is especially pronounced for older adults. With regard to the current study, there was also a three-way interaction between depletion, aging, and focality, with older adults in the sample showing pronounced depletion effects only in the nonfocal condition. Essentially, executive control depletion in the Stroop task negatively transferred to a prospective memory task that theoretically demanded more executive control for older adults in the sample. Importantly, in a more recent study Shelton et al. (2013) failed to find effects of executive-control depletion on prospective memory. Therefore, the degree to which executive-control depletion from the Stroop task will negatively transfer to prospective memory abilities is currently unclear.

The Stroop task places similar cognitive and neurophysiological demands on individuals as a standard prospective memory task. These demands reflect the need for active maintenance and inhibitory processes inherent in successful Stroop and prospective memory performance. Both the Stroop task and prospective memory are susceptible to lapses of attention (Brewer, 2011; West, Murphy, Armilio, Craik, & Stuss, 2002). Accordingly, previous individual differences research has shown a positive relation between Stroop performance and prospective memory (Kliegel, McDaniel, & Einstein, 2000; see Schnitzspahn et al., 2013 for relations between prospective memory and other inhibitory control tasks). Okuda et al. (1998) suggested that similar neural areas are recruited for attention control in Stroop tasks and prospective memory. For these reasons we decided to explore the dynamics of negative transfer from Stroop performance onto prospective memory abilities.

2. The current study

In the current study we placed retrieval demands on prospective memory processes by manipulating the association between cues and target behaviors. Our reasoning was that continued performance of the Stroop task would interfere with (i.e., deplete) inhibitory processes necessary for suppressing inappropriate associative information to the cue in order to retrieve the relatively weaker, but appropriate, target action (e.g., when detecting the cue spaghetti, the participant must inhibit the word "sauce" to facilitate retrieval of the appropriate target word "Steeple").

McDaniel and Einstein (2000) suggest that prospective memory (event-based in particular) relies on multiple cognitive processes to function (a multiprocess model). In some cases attentional control must be committed to monitoring of the environment for the prospective memory cue (see also Smith, 2003); in other cases the association between the cue and the intended action may be strong enough in one's memory to lessen the demands on attentional control because exposure to the cue can automatically retrieve or activate the intended action. In the current study we sought to extend the depletion results found by Shelton et al. (2010) to a college-aged sample under varying cue-intention associations. We expected that depleting executive control would not impair prospective memory generally, but rather impairment should occur only when the prospective memory cue and intention had a low association.

3. Methods

3.1. Participants

Participants consisted of 106 students from Introduction to Psychology classes at Arizona State University. For their participation, students received research credit that served as part of their class grade. All participants progressed through

Table 1
Prospective memory cues and targets.

	Condition	
	High association	Low association
Cue	Target	Target
Spaghetti	Sauce	Needle
Church	Steeple	Pencil
Eraser	Pencil	Steeple
Thread	Needle	Plane
Pilot	Plane	Sauce

the experiment in the following order, the specifics of which will be detailed below: participants learned the appropriate prospective memory cues and intentions, performed a version of the Stroop task, provided a subjective assessment of their own cognitive fatigue levels, performed a LDT with the embedded prospective memory task, made two more subjective assessments of fatigue, and completed a final recognition task concerning the prospective memory cues and intentions. Three participants who failed to achieve perfect performance in the post-experimental recognition test were replaced (McDaniel et al., 2004).

3.2. Depletion task

Participants were randomly assigned to one of four between subject conditions: depletion – low association, depletion – high association, control – low association, or control – high association. Participants were given instructions for the prospective memory task (discussed below) and were required to learn the prospective memory cue and intention pairs before moving on the depletion or control task, allowing them to form the prospective memory intention before the intervening depletion/control task occurred.

Participants in both the depletion and control conditions performed a Stroop task on a Dell Inspiron 560 computer (Intel® Pentium® dual-core E6700 3.20 GHz, 2 MB L2, 1066 MHz, 4 GB RAM) with a screen refresh rate of 60hz. All participants were presented with a color word (red, green, blue, or yellow) presented in one of four different font colors (red, green, blue or yellow). In the depletion conditions, the participants' task was to indicate the font color via key press (red = 1, green = 2, blue = 3, yellow = 4), whereas participants in the control condition were instructed to respond to the name of the word rather than the color. Participants were told to press the corresponding key as quickly and accurately as possible. During the task, approximately 80% of the trials were incongruent such that the word and font color did not match (e.g., "red" printed in green) and the remaining trials were congruent (e.g., "red" printed in red). We chose this congruency level to remain consistent with literature on the interaction between depletion and prospective memory (i.e., Shelton et al., 2010). The Stroop task lasted ten minutes in both the depletion and control conditions. Following the Stroop task, participants were asked to provide a subjective assessment of their level of cognitive fatigue on a scale of 1–6, with 6 meaning extremely fatigued.

3.3. Prospective memory task

Following the Stroop task, all participants performed a computerized LDT that involves determining whether strings of letters were valid English words or not. The letter strings were presented one at a time in the center of the screen and participants responded to each by pressing either the "F" key for nonwords or the "J" key for words. After each response, there was a screen with a message reading "waiting" and participants needed to press the space bar to move to the next trial in the task. As discussed previously, before the Stroop task participants were told that we were interested in their ability to perform an action in the future. Participants in both the high and low association conditions were told that whenever specific target words appeared, they should type in specified response words during the "waiting" message (after they have made the word or nonword judgment). The cues and target response words used for each condition are presented in Table 1.

Participants were also told that if they recognized a target word but could not remember the response word, they should type "x" during the waiting message instead. The prospective memory task was not mentioned again once the depletion tasks began. The LDT consisted of 210 trials, and 8 evenly spaced trials consisted of prospective memory cues (see McDaniel et al., 2004 for more information). Following the completion of the LDT participants were asked to make two more assessments of their subjective fatigue including fatigue while completing the prospective memory task and fatigue after completing the prospective memory task. Finally, participants completed a recognition task requiring matching the prospective memory cues and intentions they had been asked to respond to throughout the experiment. The three participants who were unable to correctly identify the appropriate word pairings were replaced in the final analysis.

4. Results

Our experimental design was a 2 (depletion versus control) × 2 (low versus high association) between-subjects ANOVA and the dependent measures were the proportion of correct prospective memory responses (prospective memory

performance), the speed of ongoing task responses (task interference), and the speed of responses to the prospective memory cues (cue interference). Participants rarely made "x" responses and therefore this dependent measure was excluded from the following analyses.

4.1. Stroop task performance

To determine whether our executive control depletion manipulation was successful, we fist examined performance on the Stroop task. Accuracy in all conditions was at ceiling and did not differ between conditions. Thus, the Stroop Effect was calculated for each participant as the difference between their average response times on incongruent trials (where the word and color are different) and congruent trials (where the word and color are the same). A larger Stroop Effect was detected in the depletion conditions ($M = 111.67$, SD = 80.60) than in the control conditions ($M = 49.95$, SD = 141.48), $F(1,104) = 7.62$, $p < .01$, $\eta^2 = .07$. There were no differences in the Stroop Effect between high and low association conditions and no interaction. These effects indicate that differential demands for executive control were present between the depletion and control conditions.

4.2. Prospective memory performance

The results for prospective memory performance are reported in Table 2. Replicating previous research, participants in the high association condition detected and correctly responded to more cues than participants in the low association condition, $F(3,102) = 12.47$, $p < .01$, $\eta^2 = .11$. However, there was neither a main effect of depletion nor an interaction between depletion and association conditions. Furthermore, Bayesian Odd Ratios are reported in Table 2 and can be interpreted in terms of the relative odds in favor of the null (Rouder, Speckman, Sun, Morey, & Iverson, 2009). The evidence favored the null hypothesis that executive control depletion had no effect in either the low cue-target (Bayes Factor = 5.12-to-1) or the high cue-target conditions (Bayes Factor = 1.19-to-1). Thus, completing the Stroop task for 10 min failed to negatively transfer to the attention and retrieval processes necessary for detecting prospective memory cues and retrieving appropriate target actions regardless of cue and target associations.

4.3. Task interference and cue interference

Task interference is a measurement of the average speed of correct word decisions during the LDT falling within 2.5 standard deviations of a participant's mean (Brewer, 2011). There was neither an effect of depletion, nor association, nor an interaction between the two. The evidence favored the null hypothesis that executive control depletion had no effect in either the low cue-target (Bayes Factor = 5.22-to-1) or the high cue-target conditions (Bayes Factor = 2.05-to-1). However, this might be expected given that the cues (spaghetti, church, eraser, thread, pilot) to be noticed did not differ between conditions. Importantly, however, depleting executive control by completing the Stroop task failed to negatively transfer to lexical decision performance or task interference.

Cue interference is a measurement of the speed of correct word decisions during the LDT on cue trials only (Marsh, Hicks, Cook, Hansen, & Pallos, 2003). Replicating Marsh et al. (2003), participants in the high association condition made their lexical decision response to cue words more quickly than participants in the low association condition, $F(3,63) = 7.19$, $p < .01$, $\eta^2 = .10$. It should be noted that the reduction of degrees of freedom in this result is due to elimination from the analysis of those participants who did not respond correctly to at least one cue. Neither a main effect of depletion nor an interaction between depletion and association conditions was detected. The evidence favored the null hypothesis that executive control depletion had no effect in either the low cue-target (Bayes Factor = 2.86-to-1) or the high cue-target conditions (Bayes

Table 2
Descriptive statistics and Bayesian odds ratios.

	Control ($n = 27$)	Depletion ($n = 25$)	Bayes Factor
Low cue-target association			
PMP	.33 (.07)	.30 (.07)	5.12
It	774.43 (31.18)	770.66 (30.74)	5.22
Ic	1296.95 (369.23)	756.71 (302.40)	2.86
	Control ($n = 26$)	Depletion ($n = 28$)	Bayes factor
High cue-target association			
PMP	.48 (.07)	.65 (.07)	1.19
It	770.00 (26.63)	831.93 (34.77)	2.05
Ic	782.74 (139.45)	820.77 (100.77)	5.12

Note: Mean (Standard Error) reported for prospective memory performance (PMP), task interference (It), and cue interference (Ic). Bayes Factor represents odds in favor of the null hypothesis (Scale r on effect size = 1.0; Rouder, Speckman, Sun, Morey & Iverson, 2009).

Factor = 5.12-to-1). Thus, participants exhibited slowing on cue trials when attempting to retrieve target responses with minimal associative relation with prospective memory cues. However, cue interference does not differ as a function of depleting executive control.

4.4. Prospective memory and Stroop Effect

One possible reason that performance was not affected by our depletion manipulation is that perhaps not all participants in the depletion conditions suffered from performing the Stroop task. Thus, to further explore this hypothesis we correlated the Stroop Effect with the three prospective memory variables reported earlier. The first column of the correlations found in Table 3 shows that the magnitude of each participant's Stroop Effect was not related to prospective memory abilities generally, and these correlations did not differ between the high-association and low-association condition. Interestingly, for the depletion conditions, correlations between the Stroop Effect and prospective memory abilities was consistently negative indicating that individuals with larger Stroop Effects performed nonsignificantly poorer on all aspects of the prospective memory task. However, this is the exact opposite prediction one would make from an executive control depletion framework. That is, participants with *smaller* Stroop Effects should exhibit *larger* prospective memory deficits because they were more consistently maintaining executive control over the course of the task.

We report two additional analyses to examine the time course of executive control depletion and its effect on prospective memory. First, we binned the Stroop Effect into blocks of 20 trials each and averaged the second, third, and fourth block together to compare with the averaged ninth, tenth, and eleventh blocks. The first block of 20 trials was removed because participants were gaining familiarity with the Stroop task. The difference between the Stroop Effect in the last 60 trials of the task minus the Stroop Effect in the first 60 trials after 20 trials of practice was used as our primary individual differences measure of executive control fatigue. In the depletion conditions, this measure was not correlated with any of the prospective memory ability measures at the individual differences level (all r's < −.22, *n.s.*). Second, we created a grouping variable where participants with negative binned difference scores were placed in a "depletion group" and participants with positive values were placed in a "facilitation group". Roughly 50% of participants were placed into these two groups providing optimal conditions for comparisons with the cue-target association factor. We conducted a 2 (Low versus High Association) × 2 (Depletion versus Facilitation Group) ANOVA on prospective memory performance, task interference, and cue interference. Across all three ANOVAs there were no main effects of this grouping factor and no interactions with the association factor (all F's < 1.48, *n.s.*). Therefore, participants that showed the least amount of change in Stroop interference from the beginning to the end of the task over the course of 10 min nevertheless exhibited no prospective memory deficits.

4.5. Subjective measure of executive control depletion

Objectively measured Stroop performance was not related to prospective memory performance, task interference, or cue interference. However, participants were also asked to make three subjective ratings of their feelings of fatigue; one following the Stroop task, one retrospectively estimating fatigue while completing the prospective memory task, and one following the prospective memory task. Neither the manipulation of depletion nor cue-target association created significant differences in these three subjective fatigue ratings. Correlations between the objective Stroop performance, prospective memory performance, and subjective estimates of fatigue can be found in Table 3. Pooling across conditions, self-reported feelings of fatigue during and after the prospective memory task correlated negatively with prospective memory performance, $r(104) = -.20$, $p < .05$ and $r(104) = -.22$, $p < .05$ respectively. Also, participants retrospective subjective estimate of fatigue during the prospective memory task was correlated with task interference, $r(104) = -.20$, $p < .05$. Finally, subjective estimates of fatigue made directly after the Stroop task correlated with cue interference, $r(104) = .25$, $p < .05$. No other significant correlations between subjective ratings of fatigue and the other measures were uncovered in this analysis. Furthermore, the reported correlations did not differ between conditions. In sum, subjective estimates of fatigue were correlated with cue

Table 3
Correlations ($n = 106$) between Stroop, subjective fatigue, and prospective memory measure.

	1	2	3	4	5	6	7
l. Stroop Effect	1.00						
2. Stroop fatigue	0.01	1.00					
3. PM fatigue	−0.04	0.24*	1.00				
4. Post fatigue	−0.01	0.38*	0.76*	1.00			
5. PMP	0.01	0.03	−0.22*	−0.20*	1.00		
6. It	−0.03	−0.02	−0.20*	−0.09	0.40*	1.00	1.00
7. Ic	−0.16	0.25*	−0.08	−0.04	0.40*	0.31*	0.31*

Note: Prospective memory performance (PMP), task interference (It), and cue interference (Ic).
* $p < .05$.

detection, task interference, and cue interference but these correlations were sporadic and equivalent across conditions that theoretically differed in their demands on executive control.

5. Discussion

Consistent with the literature, prospective memory performance declined and cue interference increased when the prospective memory cues and target responses had low pre-experimental associations. However, contrary to our hypothesis, executive control depletion was not shown to impair prospective memory generally or in either the high or low association conditions. Additionally, depletion was not shown to have an impact on response times during the LDT. Individual differences analyses indicated that participants in depletion conditions were exerting more executive control, but that their Stroop Effect did not correlate with prospective memory performance, task interference, or cue interference. However, self-reported feelings of fatigue correlated negatively with prospective memory performance and sporadically with task and cue interference.

Before discussing the potential impact of our findings, it is important to note that our results illustrate that we successfully replicated both standard prospective memory effects and executive control effects. Our results show a significant difference in prospective memory performance between high and low cue-intention association conditions, consistent with McDaniel et al. (2004). Additionally, the results show the presence of a larger Stroop effect in the depletion conditions than in the control conditions, indicating that participants in the depletion conditions were indeed expending a greater amount of executive control in performing the Stroop task. These findings serve to validate our experimental approach and allow us to further discuss the implications of subjective depletion effects.

Rather than a correlation between objective measures of executive-control depletion and prospective memory, as we predicted, the results showed significant correlations between prospective memory performance and participants' subjective assessment of their own mental fatigue; the more fatigue that a participant reported *after* the prospective memory task, the poorer their cue detection and the slower their ongoing task. Furthermore, there was a significant correlation between the subjective fatigue measure taken *before* the prospective memory task and cue interference. These correlations were not affected by association type or depletion conditions, indicating that subjective feelings of fatigue tracked prospective memory abilities regardless of whether automatic or controlled executive processes were primarily engaged to complete the prospective memory task.

In light of these results, we turn our attention toward the potential importance of the role played by demand characteristics. Discussed at great length by Orne (1962), demand characteristics are defined as the expectations a participant perceives as placed on them for the purpose of the experiment. These perceived expectations can often lead a participant, whether knowingly or not, to adjust their behavior to better conform (or sometimes diverge) from said expectations. In our study, participants were asked after the Stroop task to provide a subjective account of their fatigue level. It is reasonable to assume that by drawing participants' awareness to the possibility that they should feel fatigued, some of them may have been susceptible to demand characteristics and reported feeling higher levels of fatigue than were indicated by the objective measures of their executive control usage; this would account for the lack of correlation between the subjective and objective depletion measures as well as the absence of significant differences between the high and low association conditions, as all groups received the same questions at the same point in the study.

It is important to recognize that demand characteristics are not limited to experimental settings. Perceived expectancies are present in many aspects of everyday life; it can be assumed that many people expect to feel cognitively fatigued after working all day or trying to solve a difficult problem, based on their prior knowledge and experiences. Given the principles of demand characteristics and the results of our study, it appears that the expectancy or reflection of fatigue can lead to a subjective feeling strong enough to affect behavior, regardless of an objective indication of fatigue. At the very least, it is clear that previous studies of executive control depletion that did not take this possibility into account and examine not only objective depletion measures, but subjective measures as well, suffer from an unclear interpretation of the locus of their effects by attributing any effects solely to objective depletion tasks. However, the ramifications of the current study appear to be more impactful.

Based on our replications of standard effects in the prospective memory literature and the theoretical models of depletion laid out by Baumeister et al. (1998) and Schmeichel (2007) our hypothesis regarding differential impacts of depletion on prospective memory should have been confirmed; requiring participants to exert executive control on the Stroop task should have subsequently impaired prospective memory performance when use of controlled retrieval processes were required. The absence of any depletion effects establish an important boundary condition on the existence of a limited cognitive resource pool and the theory of executive control depletion posited by Baumeister and Schmeichel. Future studies should continue to examine the validity of executive control depletion theory and incorporate socio-emotional moderators of the effect (e.g., motivation; Inzlicht & Schmeichel, 2012).

6. Conclusion

The current research adds to the growing body of literature reporting fairly limited evidence for negative transfer from executive-control depletion (Brewer, Spillers, McMillan, & Unsworth, 2011; Healey, Hasher, & Danilova, 2011; Persson

et al., 2013; Sanjram & Gupta, 2013; Shelton et al., 2010, 2013). Prospective memory serves as a critical process for everyday functioning, playing a role in tasks ranging from the mundane (remembering to go to the grocery store) to the imperative (remembering to make sure a child is safe). As such, it is important that we understand the factors that can hinder prospective memory abilities. It is clear that executive control plays a vital role in both supporting and limiting prospective memory performance, and the current study has shown that prospective memory can influence and be influenced from one's own subjective feelings of executive control limitations, even when externally imposed executive-control depletion does not appear to be a factor. Recognition of one's expectancies of executive control limitation could assist in improving prospective memory ability, the benefit of which would stretch across a variety of tasks, especially those in which remembering to remember carries far-reaching consequences.

Author note

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