Reconceptualizing Ego Depletion as Transient Cognitive Fatigue

Patrick J. Hurley
D'Amore-McKim School of Business, Northeastern University

Author Note

Patrick J. Hurley <https://orcid.org/0000-0003-4117-187X>

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Correspondence concerning this article should be addressed to Patrick J. Hurley, Northeastern University, 360 Huntington Avenue, Boston, MA 02115. Email: p.hurley@northeastern.edu

Abstract

Ego depletion is embroiled in a crisis that has cast doubts over the legitimacy of the phenomenon itself and its theoretical explanation. I first summarize and analyze the strength model of self-control as cohesive theoretical explanations of the phenomenon and highlight the difficulties it creates for depletion researchers. I conclude that the strength model is not the best theoretical explanation for the depletion phenomenon. Rather, I propose reconceptualizing the ego depletion effect as *transient cognitive fatigue* (TCF). To support this theoretical shift, I highlight how both the classic and disparate findings in the depletion literature cleanly map into the literature on cognitive fatigue, and how considering depletion to be TCF accommodates existing theoretical alternatives to the strength model.

Keywords: ego depletion, motivation, transient cognitive fatigue, mental fatigue

Reconceptualizing Ego Depletion as Transient Cognitive Fatigue

Ego depletion features prominently in psychology's replication crisis due to meta-analyses (e.g., Carter et al. 2015) and registered replication reports (e.g., Hagger et al. 2016; Vohs et al. in press) that have cast doubt that depletion is even a legitimate phenomenon, despite several hundreds of published studies supporting its existence (Cunningham & Baumeister, 2016; Baumeister, 2019). Some scholars have even cast doubt that depletion will be reliably detected as a significant effect after 2020 (e.g., Vadillo, 2019). The main threats to ego depletion entail two questions: first, does depletion exist as a valid psychological phenomenon; and second, do the existing theoretical accounts that purport to explain the phenomenon succeed in doing so?

In this paper, I primarily address the theory underlying ego depletion, which I argue does not accurately capture the phenomenon. I discuss some issues regarding the phenomenon itself, as do others (e.g., Friese et al. 2019 for an in-depth analysis) and conclude that the ego depletion phenomenon has not been invalidated, but is likely overstated in the prior literature. However, based upon shortcomings of existing theory at explaining the phenomenon, I suggest reconceptualizing ego depletion as transient cognitive fatigue. Contrary to popular belief and despite over 100 years of research, the literature on cognitive fatigue has not reached a comprehensive theory (Hockey, 2011). I highlight numerous empirical and theoretical similarities between the depletion and cognitive fatigue literatures and propose that it is more appropriate to consider the depletion phenomenon to be transient cognitive fatigue (TCF). This reconceptualization of the depletion phenomenon at a theoretical level is intended to guide continued study of this phenomenon and to contribute to a more holistic understanding of cognitive fatigue. It is also important to integrate the concepts of depletion and TCF, because if concepts are

fragmented in the literature it can slow the dissemination of research findings and lead to less-well-informed research (Pattyn et al., 2018).

Ego depletion research is grounded in the concept of self-control.¹ Self-control has been defined in prior research as numerous inhibitory and initiatory processes through which individuals alter their own thoughts, emotions, impulses, performances, and behaviors, based upon standards and/or to guide behavior toward desired end states or goals (Baumeister & Vohs, 2016a; Inzlicht et al. 2020). The depletion literature has largely relied upon the strength model of self-control (hereafter also “strength model”), which posits that self-control behavior relies upon a finite and expendable cognitive resource. Exercising self-control resource depletes this resource and causes a state of diminished self-control resources termed “ego depletion” (Baumeister and Vohs, 2016 p. 70). Ego depletion was originally posited as individuals’ inability to effectively exercise self-control when depleted (e.g., Baumeister et al., 1998; Muraven et al., 1998; Baumeister, 2002; Baumeister et al., 2007), although researchers have increasingly acknowledged that it is an unwillingness, rather than an inability to do so (Baumeister & Vohs, 2016a).

Crisis of Phenomenon: Is Ego Depletion *Real*?

Meta-Analyses and Conflicting Results

Despite hundreds of published studies both supporting and extending depletion in various ways (Cunningham & Baumeister, 2016), and supportive meta-analyses (e.g., Hagger et al. 2010), many researchers have begun to doubt the validity of depletion as a phenomenon. Given that a number of papers address the issue of whether depletion exists as a phenomenon, subsequent to the replicability crisis (e.g., see Friese et al., 2019; Inzlicht & Friese, 2019; Hurley 2021 for

¹ While the ego depletion literature uses self-control and self-regulation somewhat interchangeably, these terms likely refer to distinct processes (Milyavskaya et al. 2019a). Self-regulation is the broader term that subsumes self-control (Inzlicht et al., 2020); as a result, I conservatively use self-control in the current paper.

reviews), I only briefly discuss the challenges to depletion as a phenomenon, which primarily arise from two sources: meta-analyses and registered replication reports.

Carter & McCullough (2014) re-analyzed the data in the Hagger et al. (2010) meta-analysis and found evidence of significant publication bias; however, they report statistically significant and moderate-to-large effect sizes for depletion using the trim-and-fill method for correcting publication bias ($g = 0.48$ to 0.50), but do not find a significant effect using PET-PEESE bias-correction. Carter et al. (2015) conducted an updated meta-analysis to alleviate publication bias by including both published and unpublished studies.² In their broadest analysis, Carter et al. (2015 p. 806) report a medium effect size of depletion ($g = 0.43$), and significant depletion effects for six of their eight task-based subgroups using the trim-and-fill bias-correction method, with a significant but small combined effect size ($g = 0.24$). Using PET-PEESE correction in each of their eight subgroups, Carter et al. (2015) fail to find a true effect of depletion that is significantly different from zero. It is seemingly based upon this analysis that Carter et al. (2015 p. 796) conclude that they “find very little evidence that the ego depletion effect is real phenomenon.” However, the vast majority of these authors’ analyses seem to suggest that depletion *is* a real phenomenon.

Several additional meta-analyses supportive of the depletion effect have subsequently been published. Dang (2018) reports a small-to-medium effect size across all studies ($g = 0.38$) and a small effect size ($g = 0.24$) when using trim-and-fill bias correction. In an analysis of only low heterogeneity tasks, Dang (2018) finds a small-to-medium effect ($g = 0.42$) and a large effect size using PET-PEESE bias correction ($g = 0.56$). Blázquez et al. (2017) re-analyze the results from

² Of 620 experiments identified by Carter et al. (2015 p. 799), only 116 were included in their broadest meta-analyses and, of these 116 studies, only 28 of the 198 published experiments from the Hagger et al. (2010) sample were included.

Hagger et al. (2010) and Carter et al. (2015) using the p-uniform test and find medium-to-large effect sizes ($d = 0.64$ to 0.66) for both datasets.³ Table 1 summarizes the findings of the broadest samples within each meta-analysis and largely indicates that each meta-analysis finds a significant depletion effect with the notable exceptions of models employing PET-PEESE bias correction.

Table 1: Summary of Ego Depletion Meta-Analyses

Paper	k	Analysis	Bias Correction	Effect	CI	I^2
Hagger et al. (2010)	198	FE	None	$d = 0.62^{***}$	[0.57, 0.67]	34.72%
Carter & McCullough (2014)	198	FE	None	$d = 0.62^{***}$	[0.58, 0.66]	38.60%
	198	RE	None	$d = 0.68^{***}$	[0.63, 0.74]	
	198	FE	Trim and Fill	$d = 0.48^{***}$	[0.44, 0.51]	
	198	RE	Trim and Fill	$d = 0.50^{***}$	[0.44, 0.56]	
	198	WLS	PET	$b^0 = -0.10$	[-0.23, 0.02]	
	198	WLS	PEESE	$b^0 = 0.25^{***}$	[0.18, 0.32]	
Carter et al. (2015)	116	RE	None	$g = 0.43^{***}$	[0.34, 0.52]	71.55%
	116	ME	None	$b^0 = 0.33^{***}$	NR	
	116	RE	Trim and Fill	$g = 0.24^{***}$	[0.13, 0.34]	
	116	WLS	PET	$b^0 = -0.27^*$	[-0.52, -0.01]	
	116	WLS	PEESE	$b^0 = 0.003$	[-0.14, 0.15]	
Blázquez et al. (2017)	198	FE	p-uniform (MM)	$d = 0.64^{***}$	NR	34.72%
	198	FE	p-uniform (K-S)	$d = 0.65^{***}$	NR	
	116	FE	p-uniform (MM)	$d = 0.66^{***}$	NR	71.55%
	116	FE	p-uniform (K-S)	$d = 0.66^{***}$	NR	
Dang (2018)	142	RE	None	$g = 0.38^{***}$	[0.31, 0.45]	60.67%
	142	RE	Trim and Fill	$g = 0.24^{***}$	[0.16, 0.32]	
	142	RE	PET	$b^0 = -0.18$	NR	
	142	RE	PEESE	$b^0 = 0.05$	NR	
	39	RE	None	$g = 0.42^{***}$	[0.32, 0.51]	25.08%
	39	RE	Trim and Fill	$g = 0.42^{***}$	[0.32, 0.51]	
	39	RE	PET	$b^0 = 0.79^{***}$	NR	
	39	RE	PEESE	$b^0 = 0.56^{***}$	NR	

³ The p-uniform method corrects publication bias but performs poorly with high average p-values (i.e., $0.025 < p < 0.050$) or if heterogeneity is high (Blázquez et al., 2017). However, average p-values for the Hagger et al. (2010) and Carter et al. (2015) datasets were 0.011 and 0.012 (medians both = 0.007), respectively, and only Carter et al.'s (2015) data exhibiting heterogeneity above the reasonable threshold.

This table presents the results of several meta-analyses of the ego depletion effect. Column 'k' indicates the number of independent tests of depletion included in the meta-analysis. The 'Analysis' column classifies analyses as fixed effects (FE), random effects (RE), mixed effects (ME), or weighted least squares (WLS). In the 'Bias Correction' column, MM refers to the method-of-the-moments test and K-S refers to the minimal Kolmogorov-Smirnov test. Column 'I²' refers to heterogeneity in effect size. NR indicates that confidence intervals were not reported within a specific study. It is important to note that Dang's (2018) sample size of 39 reflects studies using three specific depleting tasks with low heterogeneity (attention essay, emotion video, and Stroop task); the low heterogeneity of this sub-sample allowed PET-PEESE bias correction to be used effectively. *, **, and *** correspond to significance at the 0.05, 0.01, and 0.001 levels, respectively.

Of significant concern for depletion meta-analyses is a body of literature that has identified significant concerns with meta-analytic methodologies for bias correction. Psychological data often violate the assumptions of the trim-and-fill method (Duval & Tweedie, 2000), and researchers argue the trim-and-fill method for bias correction over-corrects for non-existent bias and fails with high heterogeneity (Friesen et al., 2019; Carter et al., 2019 p. 121). With respect to PET-PEESE analyses, researchers recommend avoiding these analyses due to general unreliability, over- and under-corrections, and tendency to underestimate effect sizes, especially under conditions typical of psychological data (e.g., heterogeneity in effect sizes and publication bias) (Carter et al., 2019 pp. 123-124). The creators of this method (Stanley & Doucouliagos, 2014; Stanley, 2017) also highlight that PET-PEESE methods exhibit “unacceptable performance” in areas with few (e.g., < 20) studies, small sample effects, and high heterogeneity of results, which are all common to ego depletion research (Carter et al., 2019 p. 124). For example, there were less than 20 studies in seven of eight task-based groupings (the other had 21) in which Carter et al. (2015) applied PET-PEESE to arrive at their conclusion of little to no effect of depletion. Finally, the *p*-uniform method (Blázquez et al., 2017) assumes homogeneous effect sizes, that non-statistically significant studies are uninformative, and that significant studies have equal likelihood of publication regardless of the level of statistical significance (Friesen et al., 2019), and exhibits upward bias on effect sizes when its assumptions are violated (Carter et al., 2019).

In summary, it seems that the various meta-analyses that are both supportive (Hagger et al., 2010; Dang, 2018; Blázquez et al., 2017) and not supportive (Carter & McCullough, 2014; Carter et al., 2015) of depletion being a real phenomenon suffer from potential bias resulting from methodological issues (Cunningham & Baumeister, 2016). Despite these issues, nearly all of the broadest analyses in these meta-analyses indicate that depletion is a real phenomenon. As a result, these meta-analyses do not seem to provide sufficient evidence to conclude that ego depletion is not a real phenomenon.

Registered Replication Reports

Two large-scale registered replication reports (RRRs) have emerged in the past five years: Hagger et al. (2016) and Vohs et al. (in press). Hagger et al. (2016) found a tiny effect size of ego depletion (Cohen's $d = 0.04$) with a 95 percent CI that included zero. These findings led the authors to conclude “if there is any effect [of depletion], it is close to zero” (Hagger et al. 2016 p. 558). Despite the statistical power of the Hagger et al. (2016) study, researchers have questioned whether the authors successfully manipulated depletion (Drummond & Philipp, 2017; Baumeister & Vohs, 2016b; Dang, 2016), and whether motivational differences may have produced the results (Sripada et al. 2016).⁴

Vohs et al. (in press) conducted a large-scale “paradigmatic replication” of the depletion effect. Confirmatory tests yielded a non-significant result ($d = 0.06$) with Bayesian meta-analyses indicating the data were four times more likely to obtain under the null hypothesis than the alternative hypothesis. In exploratory analyses that relaxed strict exclusion criteria, the authors

⁴ Specifically, Sripada et al. (2016) expressed concern at the high exclusion rate of participants due to low accuracy (26 percent on average versus 13 percent in Sripada et al. 2014). Specifically, 958 of 3,099 (30.9 percent of) original participants were excluded, of which 808 (83.4 percent) were due to low accuracy. The accuracy-related exclusions fell disproportionately in the depletion condition (462 of 1,550, 29.8 percent) versus the control condition (346 of 1,549, 22.3 percent) ($t_{3,097} = 4.75$, $p < 0.001$). When including these participants, Hagger et al. (2016) find a small but statistically significant depletion effect ($g = 0.08$).

found a statistically significant, but small effect ($d = 0.08$), with Bayesian meta-analyses indicating that the data were equally likely under the null and alternative hypotheses. Further, of interest to my theoretical arguments, moderator tests indicated that the depletion effect was larger for participants reporting higher levels of fatigue.

While these RRRs findings of a null effect do represent a significant threat to the existence of depletion as a phenomenon, they should be viewed in context. As Friese et al. (2019 p. 112) note, a few particular IV-DV combinations are necessarily limited in their ability to validate or invalidate depletion as a phenomenon, and “[i]t appears premature and logically unjustified to dismiss the phenomenon and the complete existing ego depletion literature based on...one specific study, even a statistically powerful one”.

Conclusions about the Threats to Ego Depletion as a Phenomenon

In this section I have briefly discussed the main threats to the depletion phenomenon, which include contradictory meta-analyses and two high-powered RRRs that found a null effect for depletion. However, the large number of studies finding evidence of depletion provide support that depletion is a real phenomenon, although they do not necessarily indicate that the strength model is the correct theoretical account for depletion. Even considering the influence of publication biases, p-hacking, and other questionable research practices (see Friese et al. 2019 for a detailed discussion), to observe so many published studies on a topic for which no true effect exists seemingly implies either capitalizing on chance or academic fraud on a massive scale, neither of which seems plausible.⁵

⁵ For studies to have capitalized on chance for a non-existent phenomenon implies that results should systematically vary around a mean of zero, which would necessarily produce negative results (i.e., depletion improves performance, or a “reverse effect”) that are novel and counterintuitive relative to theory, and thus highly publishable (Friese et al., 2019; Baumeister, 2019; Hagger & Chatzisarantis, 2014). Yet, only a handful of studies report reverse effects (e.g., Converse & DeShon, 2009; Job et al., 2010; DeWall et al., 2011; Carter & McCullough, 2013; Tuk et al., 2015; Van Reet, 2015; Savani & Job, 2017), and many of these studies predict these results based upon other theories, meaning they are not theoretically unexpected effects, as would occur if depletion had a true null effect.

While the threats to ego depletion presented in this section are significant and challenging, none of them provides conclusive evidence that ego depletion does not exist as a phenomenon. As a result, it seems premature to dismiss the phenomenon altogether (Frieze et al., 2019). Indeed, one might view the current crisis in ego depletion as normal science operating as it is intended. In normal science, findings accumulate through tests of theory, and this process generates “anomalies” (i.e., deviations from theory-driven expectations) that accumulate until they reach a critical mass (Kuhn, 2012). At this point, theories are revised so as to accommodate the anomalies or are discarded and replaced if a competing theory emerges that can better account for the phenomenon. Ego depletion research has certainly uncovered anomalies in the form of the RRRs discussed above and mixed findings in recent studies. Efforts to provide theoretical updates to the strength model (Baumeister & Vohs, 2016a) and alternative theories to explain the depletion phenomenon indicate that this is, at a high level, precisely how scientific research is supposed to work. Nowhere in this view of scientific progress is it considered a best option to entirely dismiss hundreds of studies and abandon theoretical explanation for a phenomenon that much of prior research supports as valid.⁶ Yet, as Inzlicht and Frieze (2019) note, this is what many researchers seem ready to do with depletion.

In my view, the accumulating mixed results are not to be viewed so much as evidence that the phenomenon does not exist, but that it does not exist as specified by the theory, due to the overly broad and vague nature of the strength model.⁷ In the context of normal science, the accumulation of anomalies suggests that the theory may not be appropriately specified, which

⁶ Kuhn (2012 p. 77) notes “[t]hough they may...lose faith and...consider alternatives, they do not renounce the paradigm that has led them into crisis. They do not, that is, treat anomalies as counterinstances.”

⁷ Kuhn (2012 p. 65) specifically notes “Anomal[ies] appear only against the background provided by the paradigm. The more...far reaching that paradigm is, the more sensitive an indicator it provides of anomaly and hence of an occasion for paradigm change.”

serves as the impetus for my suggested theoretical re-specification of ego depletion as transient cognitive fatigue. This process seems to be what Kuhn envisioned when he detailed the accumulation of anomalies compared to theoretical predictions, and the process by which an alternative theory is formulated to replace the incumbent theory.

Crisis of Theory: What *is* Ego Depletion?

Issues with and Updates to the Strength Model

While it seems that ego depletion does exist as a real (albeit likely overstated) phenomenon, it also seems that the strength model is too vaguely specified to be certain as to the exact causal mechanisms underlying the phenomenon. The strength model defines depletion as a behavioral phenomenon (reduced self-control performance subsequent to self-control exertion), rather than by specifying precise causal mechanisms (Frieze et al., 2019). The strength model specifies that the causal mechanism in the depletion effect is self-control resources, which are not readily observable or measurable, leaving depletion to be inferred from impaired performance on the dependent variable task. The inability to observe or measure the underlying causal mechanism in energy or resource models has led researchers to criticize these models as being unfalsifiable (Hockey, 2013; Inzlicht & Berkman, 2015; Navon, 1984).

This resource-based theoretical specification has led to overly broad definitions of self-control and circular logic in justifying task choice (Lurquin & Miyake, 2017), while also making it difficult for researchers to know if they have successfully manipulated depletion. As a result, the depletion literature features loosely-related tasks (e.g., taking standardized tests, Schmeichel et al. 2003; balancing on one leg, Tyler & Burns 2008) that purport to capture self-control. Vague theoretical specification has also created considerable confusion regarding what tasks reliably produce depletion, which is evident when different studies use the same task (e.g., 3-digit by 3-

digit multiplication) as both a depleting manipulation (e.g., Stillman et al., 2009) and a control condition (e.g., Burkley, 2008).

To address criticisms and incorporate recent evidence, Baumeister & Vohs (2016) update the strength model and provide a detailed review of competing theories before settling on adding to the strength model a controversial concept from exercise psychology: a central governor (Noakes, 1997; Evans et al., 2015). In this view, a vague “central governor” monitors the body’s self-control exertion and seeks to conserve glucose if the body’s current rate of consumption would eventually create untenably low glucose levels. Notwithstanding the fact that prior research does not find that self-control exertion consumes inordinate amounts of energy (e.g., Inzlicht & Marcora, 2016), adding a central governor to the strength model exacerbates issues of falsifiability rather than resolves them (e.g., Inzlicht & Marcora, 2016; Lurquin & Miyake, 2017).

Conclusions about the Threats to Ego Depletion Theory

Based upon the preceding discussion I conclude that the strength model of self-control does not seem to be best equipped to explain the depletion phenomenon. In response to the issues surrounding the strength model as a theoretical explanation of the depletion phenomenon, researchers have set forth numerous competing theories to explain depletion. I review these alternative theories, all of which seemingly entail motivation as a key component, in a later section of the paper when comparing them to a view of depletion as transient cognitive fatigue.

Contrary arguments that depletion is not cognitive fatigue (e.g., Vohs et al., 2010), researchers have increasingly acknowledged that depletion is a form of cognitive fatigue (e.g., Baumeister et al., 2018; Baumeister, 2019; Hagger & Chatzisarantis, 2016), and Inzlicht et al. (2014) posit that ego depletion and mental fatigue may refer to identical psychological constructs. Thus, it seems that integrating depletion and cognitive fatigue can yield significant insights

through further study of this phenomenon. Indeed, alternatives to the strength model suggest commonalities between depletion and cognitive fatigue (e.g., Kurzban et al., 2013; Inzlicht et al., 2014; Inzlicht & Berkman, 2015). In the next section, I draw extensive parallels between the depletion and cognitive fatigue literatures and later discuss how a motivation-centric reconceptualization of depletion as transient cognitive fatigue can subsume competing theoretical accounts of the depletion phenomenon.

Ego Depletion and Transient Cognitive Fatigue

Below I argue that the depletion phenomenon is best theoretically conceptualized as transient cognitive fatigue (“TCF”). This reconceptualization clarifies that tasks expected to cause TCF do so through cognitive effort demands and motivation and resolves the theoretical ambiguity inherent in the strength model. I examine the cognitive fatigue literature and highlight similarities between this literature and prior findings on depletion. In doing so, I demonstrate that many findings in the depletion literature map cleanly into a motivation-centric theory of TCF.

Defining Cognitive Fatigue

Cognitive fatigue (hereafter also “fatigue”) is ubiquitous, has a pervasive impact on everyday life, and is nearly universally experienced at some point or another. Thus, the appeal of both fatigue and depletion seems largely driven by the commonality and relatability of the experience in everyday life. However, this ubiquity and widespread experience of fatigue has fostered an incorrect belief that fatigue itself and its consequences are well understood. The existing academic literature on fatigue does not support this belief, as fatigue remains poorly understood among both the scientific community as well as laypeople (Hockey, 2013; Ackerman, 2011). Fatigue is a complex state entailing changes in motivation, emotion, behavior, and information processing capabilities (van der Linden, 2011), and therefore requires further research

to understand this complexity. I propose that considering depletion as TCF can help to further our understanding of fatigue and how it might affect individuals in specific ways.

Cognitive or mental fatigue is “a psychobiological state caused by prolonged periods of demanding cognitive activity and characterized by subjective feelings of 'tiredness' and 'lack of energy’” (Marcora et al., 2009). Fatigue is a state of mental discomfort and an aversion to effortful mental activity that accumulates with continued effort on a task (Thorndike, 1900). It is therefore easiest to conceptualize fatigue by relying upon the universally recognized and understood subjective experience of feeling mentally tired (Hockey, 2013 p. 13). While it is typically assumed that cognitive fatigue results only from task performance exceeding 30 minutes (e.g., Van Cutsem et al., 2017), it is likely that cognitive fatigue is broader and occurs in situations other than prolonged exposure to high levels of cognitive activity (Hockey 2013).

It is also important to note that while many consider fatigue to represent simple interference with an individual’s ability to effectively perform tasks, fatigue is not necessarily associated with a decrement in task performance because individuals can employ compensatory effort to maintain performance and goals, especially when motivated to do so (Locke & Braver, 2008; Sarter et al., 2006; Hockey, 1997). This is an important contrast with ego depletion, as the dual-task paradigm is predicated upon observing a performance decrement as evidence of depletion. However, performance is just one aspect of goal regulation and need not occur concurrently with strong subjective feelings of fatigue (Hockey, 2013 p. 76).

OBSERVATION #1: Short-term effort exertion is not necessarily followed by a performance decrement, which potentially explains the mixed results in depletion studies.

Components of Cognitive Fatigue

Because fatigue is a multi-causal phenomenon, it is first useful to specify and elaborate upon the executive functions that are closely related to fatigue: goal maintenance and monitoring;

motivation; effort regulation; and attention regulation.⁸ First, goals represent the starting point for any meaningful behavior, and effort is (or is not) expended, monitored, and maintained in an attempt to achieve that outcome (Powers, 1973).

Second, a lack of motivation is a primary characteristic of fatigue (Hockey, 2013) and almost all definitions of cognitive fatigue include some motivational aspect (Kanfer, 2011). Unless cognitive fatigue is extreme, researchers have long considered it to represent a lack of desire, rather than an inability, to engage in a specific action or behavior (Bartley & Chute, 1947 p. 53). That is, cognitive fatigue is not solely a question of reduced capacity (Webster et al., 1996). The core effect of fatigue is therefore an aversion to (i.e., a lack of motivation for) performing additional activities that demand high levels of cognitive effort (Holding, 1983). This observation aligns with updates to the strength model, which indicate that depletion is an issue of unwillingness, rather than of inability (Baumeister & Vohs, 2016a p. 81). Indeed, it is the unwillingness to exert additional effort in service of task performance that underlies many of the arguments I make in this section, as motivation mediates the cognitive fatigue-performance relation (Boksem & Tops, 2008).

To view how motivation influences subsequent performance, it is useful to consider that individuals essentially have three options for goal pursuit. First, assuming individuals place a sufficiently high value on the goal, they can maintain performance levels for a time by increasing effort. Second, if changing the goal is not possible (e.g., in work environments or in experiments through social norms) individuals can continue to pursue the goal with a lower level of effort. Finally, individuals can abandon the current goal and replace it with competing activities that are preferred, though it is not typical for individuals to display a deliberate unwillingness to perform

⁸ By comparison, Baumeister & Vohs (2007 pp. 117-118) list four “ingredients” for self-regulation: standards, monitoring, self-regulatory strength (i.e., willpower), and motivation. These authors specifically note that high motivation can compensate for low willpower.

a task (Hockey, 1997). While some depletion researchers implicitly consider only the first and third options (e.g., Baumeister & Vohs, 2016a), the second option (i.e., continuing a task with lower effort) seems likely to account for the depletion effect. Further, as dependent variable tasks used in prior literature to measure depletion are typically repetitive and/or unpleasant, it is unlikely that individuals regularly have sufficient motivation to increase effort to maintain performance.⁹

OBSERVATION #2: Updates to the strength model parallel the fatigue literature and a motivation-centric account of depletion as TCF in reflecting that the depletion phenomenon is due to an unwillingness, rather than an inability, to engage in self-regulation.

OBSERVATION #3: Motivation is a central component of cognitive fatigue and several theories of depletion.

OBSERVATION #4: Depletion studies typically measure depletion through low-motivation dependent variable tasks; as a result, many observed depletion findings may be due to low motivation rather than an inability to exert effort.

Third, effort regulation is controlled by general and task-specific motivation. Effort can be viewed as "the subjective intensification of mental and/or physical activity in the service of meeting some goal" (Inzlicht et al., 2018 p. 338). While effort is related to motivation, the latter is a distinct concept that refers to a force driving behavior in a specific goal-related direction and the corresponding intensity with which that goal is pursued. Effort provision and regulation involve maintaining information in memory, selecting which information to attend to, avoiding distraction, and suppressing affective responses (e.g., frustration and/or boredom) and the urge to yield to fatigue. Maintaining task goals by engaging in effortful cognitive control is a primary source of fatigue (Hockey, 2013 p. 110; Ackerman, 2011), as fatigue studies find effort is a marker for

⁹ For example, Vohs et al. (2008), which has garnered nearly 1,300 citations according to Google Scholar, utilizes several examples of unpleasant depletion measures across seven experiments: consuming a beverage comprised of vinegar and water; holding one's arm in freezing cold water; studying instead of playing video games; performing unsolvable puzzles; solving tedious math problems; and spending time watching a broken video before telling the experimenter that it was not working properly. As is apparent, it is unlikely that these tasks engender intrinsic motivation on the part of the participants.

maintaining motivation and/or goal pursuit, and individuals generally avoid effort as a default strategy (Kool et al., 2010; Kurniawan et al., 2011). Further, fatigue leads to a preference for lower-effort strategies, or a reduced motivation for effort exertion following demanding tasks (e.g., Massar et al., 2018; van der Linden, 2011; Hockey & Earle, 2006).

OBSERVATION #5: TCF leads to a preference for lower-effort strategies, which can account for findings that depletion reduces task persistence and effortful processing and increases heuristic processing and status quo bias.

Finally, maintaining attention requires continued effort on the focal task and continued maintenance of task goals to avoid task interruption. For example, Kanfer & Ackerman's (1989) fatigue model indicates that individuals can allocate attention/effort to three areas: on-task, off-task thoughts and distractions (e.g., anxiety, apprehension, other tasks one could engage), and self-regulation. Maintaining task goals requires effortful resistance and cognitive control against competing motivations and attention requirements, and cognitive control mechanisms are especially impacted by fatigue (Bartlett, 1943, 1953; Myers, 1937). Fatigue is therefore associated with difficulty sustaining attention on a specific task for an extended amount of time because maintaining attention and vigilance is cognitively demanding (e.g., Grier et al., 2003; Warm et al., 2008; Smit et al., 2004). For example, cognitive fatigue impedes attention (van der Linden & Eling, 2006; Boksem et al., 2005), which leads to difficulty focusing on relevant information (Lorist & Faber, 2011) and engaging in cognition (Lorist, 2008). However, fatigue does not inhibit automatic processing (van der Linden et al., 2003a, 2003b, 2006; Boksem et al., 2005; Lorist & Faber, 2011) due to its minimal effort requirements (e.g., Dehaene et al., 1998), and can increase procedural (i.e., automatic processing) learning (Borragán et al., 2016).

OBSERVATION #6: Effortful cognitive control is central to both fatigue and depletion.

OBSERVATION #7: Neither fatigue nor depletion (e.g., Schmeichel et al., 2003) significantly influences individuals' automatic processing.

Phases of Cognitive Fatigue

While there generally exists a positive relationship between time on task and subjective cognitive fatigue (Boksem et al., 2006; Kaneko & Sakamoto, 2001; Lorist et al., 2000), fatigue is theorized to operate in three distinct phases: transient cognitive fatigue (“TCF”), resistance to fatigue (“RF”), and sustained-effort fatigue (“SEF”) (Hockey, 2013 p. 135). Figure 1 summarizes these three phases. TCF is characterized by low time on task, decreased performance following initial effort exertion, and no long-term after-effects (Hockey, 2013). Individuals may experience TCF only as a vague sense of cognitive discomfort, rather than subjective cognitive fatigue, and Bartlett (1953) argues that feeling tired may represent a late stage in the fatigue process, after fatigue exerts some negative influence on performance. Indeed, Baumeister and Vohs (2016) note that most studies do not reliably find differences in self-reported fatigue; however, this is likely because subjective fatigue is likely to arise after longer effort exertion on a task. Further, fatigue is often measured in post-experimental questionnaires, whereas it is of interest immediately following the manipulation. In this view, TCF can occur and impair performance in just a few minutes of task performance (e.g., Helton et al., 2007; Temple et al., 2000; Balkin & Wesensten, 2011; Loh et al., 2004) in a manner similar to depletion.

However, some participants may enter the RF phase, which is characterized by accumulating fatigue but a lack of a performance decrement due to increased effort. Therefore, the key difference between participants in the TCF and RF phases is motivation. Specifically, motivated participants will enter the RF phase and maintain performance levels through increased effort provision. By contrast, unmotivated individuals will not enter the RF phase, but will remain in the TCF phase and withhold additional effort, thus exhibiting decreased performance levels.

This is especially noteworthy when considering the dependent variable tasks employed in previous depletion research and the likelihood that they do not engender motivation among participants.

Figure 1: Summary of Patterns of Fatigue Responses to Tasks (Adapted from Hockey 2013)

<i>Fatigue Mode</i>	Subjective State	Performance Decrement?	After-Effects?
Transient Fatigue (TF)	Minor (transient) fatigue	Yes	No
Resistant to Fatigue (RF)	Increasing effort and fatigue	No	Yes
Sustained-Effort Fatigue (SEF)	Sustained high effort and fatigue	Yes	Yes

OBSERVATION #8: Depletion studies do not reliably find increased subjective fatigue because in short tasks fatigue may only manifest as a vague sense of cognitive discomfort.

OBSERVATION #9: TCF can hinder subsequent task performance after a few minutes of initial task performance. This captures the depletion effect, as short bursts of self-control lead to performance impairment. This is especially true if participants are not sufficiently motivated to enter the RF phase and increase effort provision.

By contrast, SEF represents what laypeople most commonly associate with cognitive fatigue. SEF entails feelings of effortful exertion, which lead to a growing feeling of mental tiredness that dampens motivation and/or increases the need to reduce effort or disengage from the task entirely.¹⁰ This effect is driven by continued effort provision to maintain task goals and performance, prevent task interruptions, and maintain attention on the focal task in the RF phase. Only under extreme conditions would both SEF and impaired performance manifest, when even high levels of effort cannot sustain task performance. Indeed, Ackerman & Kanfer (2009) provide evidence that subjective fatigue increases with the length of performance on the SAT (e.g., 3.5, 4.5, or 5.5 hours), yet performance significantly *increases* with test length. By contrast, field study evidence also indicates that SEF: decreases schoolchildren's exam scores when they start exams later in the day (Sievertsen et al., 2016); reduces hospital workers' compliance with mandatory handwashing later in a 12-hour shift (Dai et al., 2015); leads physicians to overprescribe

¹⁰ SEF can also potentially result from brief task workloads if demands are extreme or intense (Hockey, 2013).

medications more frequently later in the day (Linder et al., 2014); and is associated with abstention or use of shortcuts in voting (Augenblick & Nicholson, 2016). In an auditing setting, Hurley (2017) finds between-day carryover effects of depletion within (versus outside of) busy season, which is suggestive of SEF as the underlying mechanism.

By contrast, performance is generally expected to decrease with TCF *before* subjective feelings of fatigue emerge, consistent with the vast majority of depletion research. I contend that these effects are driven by motivational influences on effort provision rather than performance impairments due to the inability to effectively perform the task. It bears repeating that this observation stems from the conclusion that both depletion and TCF result from the *unwillingness*, rather than the *inability* to maintain effort and task performance. As a result, participants' performance may suffer on subsequent tasks because they are unwilling to continue to use aversive effortful strategies that require continued cognitive control, rather than the inevitable decline in performance specified by the strength model. Subjective cognitive fatigue leads higher levels of effort to have lower utility (Kanfer, 2011) and results in a shift toward lower-effort strategies (Shingledecker & Holding, 1974; Schellekens et al., 2000). Importantly, while a break from or significant change in the task can counteract this effect, this is not the case if the new task also demands significant cognitive effort and control (Hockey, 2013), as is typical in depletion studies.

OBSERVATION #10: SEF is typically not captured in most depletion studies because the tasks are too short. Longer manipulations of depletion do reliably decrease performance (Sjåstad & Baumeister, 2018; Guilfoyle et al., 2019; Brown & Bray, 2017; Lopez et al., 2019; Palma et al., 2018; Tsai & Li, 2019). It is likely that these studies capture TCF-related decreases in performance, coupled with decreased effort provision in lieu of entering the RF phase, which leads to decreased performance.

OBSERVATION #11: While taking a short break mitigates decreased performance in depletion studies (e.g., Tyler & Burns, 2008; Friese et al., 2012), switching tasks does not improve performance because the second task also requires significant cognitive effort and control.

Summary of a Proximate Account of Cognitive Fatigue

Summing up, I have outlined a proximate account of how fatigue occurs, the mechanisms through which it can influence performance, and how considering depletion to be TCF provides a more accurate depiction of the phenomenon.¹¹ As Hockey (2013 p. 142) notes, “fatigue may be thought of as a process that starts as soon as a task begins, taking the form of an increasing bias against current task goals...such effects occur in advance of perceptions of fatigue in terms of sensed effort, though they may be felt vaguely as a state of cognitive discomfort.” Thus, fatigue operates by decreasing effort through decreased motivation. If exercising cognitive effort in service of self-control is effortful and individuals’ default is to use lower-effort strategies when cognitively fatigued, it stands to reason that they do not fully engage in self-control when not sufficiently motivated to do so. This account is therefore consistent with what is observed in the depletion literature. Overall, it seems that the overlap in findings between the literature attributing effects to ego depletion and those associated with fatigue is more easily accounted for under a view of ego depletion as TCF, which places motivation as the central mechanism.

Reconciling Specific Depletion Findings with Fatigue

Above I have argued that the ego depletion phenomenon is better explained by considering depletion as TCF. I first present the major findings of the fatigue literature (Hockey, 2013 p. 82) in Figure 2, and note the compatibility of each with depletion. Based upon this analysis, it seems most appropriate to consider mild depletion as TCF and severe depletion as SEF. I next discuss specific findings in the depletion literature and how they map into the fatigue construct.

¹¹ It is also important to discuss fatigue in terms of an “ultimate” (i.e., evolutionary) explanation (Scott-Phillips et al., 2011): why does fatigue occur? Fatigue is adaptive in that it manages our motivational priorities to regulate effort allocation to various goals. The overall purpose of fatigue is to alert individuals to the costs of their current activities and focus them on re-evaluating and/or changing their motivational priorities (Hockey, 2013 p. 104), which contradicts criticism that the motivational account for self-control is not evolutionarily adaptive (Baumeister & Vohs, 2016a).

Figure 2: Comparison of Fatigue and Ego Depletion Findings

Fatigue (Hockey 2013, p. 82)	Relation to Depletion
(1) Decrements [in performance] are not always observed, even in quite long and demanding tasks. Where they were observed, they may be a result of a loss of interest in the work, rather than a genuine impairment of processing effectiveness.	Many recent studies both do and do not report a depletion effect (cf. Footnote 6). Further, Milyavskaya et al. (2019b) provide evidence that many of the control conditions in the depletion literature may induce boredom, which can lead to a similar loss of interest in the task as do effortful (i.e., depleting) activities. As a result, many of these null results may be attributable to a lack of a true comparison because boredom and effortful performance may both lead to similar levels of reduced interest on subsequent tasks.
(2) Decrements [in performance] occur more commonly in tasks that are highly repetitive, fast, and continuous.	This is a hallmark of many depletion studies, which often assess subsequent performance (i.e., depletion) via variants of the Stroop task (Hagger et al. 2010) or similar interference tasks (e.g., the multi-source interference task in Hagger et al.'s [2016] RRR). Indeed, Dang et al. (2017) find that the Stroop task is one of the most reliable methods of measuring depletion.
(3) Decrements [in performance] are generally greater when work is more intense, in terms of workload and effort requirements.	This seems true of depletion studies, as studies utilizing longer or more demanding depleting tasks typically report stronger results (e.g., Sjøstad and Baumeister 2018; Guilfoyle et al. 2019; Brown and Bray 2017; Lopez et al. 2019; Palma et al. 2018; Tsai and Li 2019).
(4) Both rest and a change of task help performance to recover from decrement, though not when the change task makes major demands on executive control.	This is supported by depletion studies find that rest (e.g., Tyler and Burns 2008; Friesse et al. 2012) leads to improved performance (i.e., reduced decrement). The second finding is especially relevant to depletion; depletion studies by definition entail a second task that makes major demands on executive control. This contradicts Baumeister and Vohs's (2016) argument that a motivation explanation of depletion should not lead to decreased performance on a second task.
(5) Following a period of executive control, there is a resistance to continue in a high effort mode.	This is the suggested relationship between initial self-regulation and subsequent impaired self-regulatory performance, which is the basis of the depletion finding.
(6) Under some conditions, decrements [in performance] can be observed very rapidly, within the first minute[s]	This is perhaps the hallmark of the depletion effect, as most depletion studies find inhibited subsequent self-regulatory performance after initial exertion lasting less than 10 minutes.
(7) Rapid continuous tasks show increasing interruptions in the form of lapses, preceded by increased slowing and errors, and followed by faster, more accurate responding.	This is difficult to assess in many depletion studies, given the lack of specific testing for this effect. This effect is also potentially confounded with learning effects, making its assessment difficult in the context of depletion.

Motivation

While few depletion studies explicitly measure motivation (Baumeister & Vohs, 2016a), it is clear that motivation plays a significant role in moderating and/or mediating depletion (Baumeister & Vohs, 2007; Robinson et al., 2010).¹² Self-control issues are essentially motivational conflicts where efforts to advance long-term/abstract goals directly compete with short-term/concrete goals, and sufficiently motivated individuals will employ all possible strategies to maintain performance in pursuing long-term goals (Fujita, 2011).

Prior depletion studies find that depletion is mitigated when participants are motivated via encouragement or economic incentives (Muraven & Slessareva, 2003), through self-determination and related motivation (e.g., Legault et al., 2009), when individuals do not expect high demands of future tasks (e.g., Muraven et al., 2006; Katzir et al., 2020), or when the depleting task activates intrinsic motivation through personal relevance of the goal (e.g., Moller et al., 2006; Muraven et al., 2007). Similarly, fatigue research finds that while performance tends to decrease on a continuous task over a long period of performance, rewards (Boksem et al., 2006) and task engagement (Hockey & Earle, 2006) restore performance levels.

Glucose

Initial evidence suggested that glucose could be the depleted resource specified by the strength model as responsible for self-regulatory failures (e.g., Gailliot & Baumeister, 2007; Gailliot et al., 2007). However, reanalysis of the original data (Kurzban, 2010) and accumulating evidence (e.g., Finley et al., 2019; Baumeister & Vohs, 2016a) strongly contradicts this idea.¹³

¹² With respect to a noted lack of findings regarding motivation being a mediator in depletion studies (e.g., Baumeister & Vohs, 2016a), there are a number of potential explanations. First, most depletion studies do not explicitly or directly measure motivation (Baumeister & Vohs, 2016a). Second, these motivational shifts are likely to occur subconsciously, as does fatigue, unless they are extreme. Finally, it is possible that there is a demand effect when researchers ask participants how motivated they were in task performance.

¹³ This conclusion is consistent with studies finding brain energy is consistent over a wide range of cognitive processes (Raichle & Mintun, 2006), and with nutrition research (Gibson, 2007; Gibson & Green, 2002; Rogers & Lloyd, 1994).

Interestingly, strong support still exists that ingesting (Masicampo & Baumeister, 2008; McMahon & Scheel, 2010; Wang & Dvorak, 2010) or swishing glucose in the mouth (Carter & McCullough, 2013; Hagger & Chatzisarantis, 2013; Molden et al., 2012; Sanders et al., 2012) mitigates the depletion effect. Based upon this literature, the Process Model, which I describe in the next section, specifies that glucose still has a role, albeit an unclear one, in observed performance decrements (Inzlicht et al., 2014 p. 128) while Baumeister and Vohs (2016) argue a motivation-centric theory cannot cope with the link between depletion and glucose.

By contrast, I propose that glucose is neurologically linked to motivation by being detected and encoded as rewarding through the anterior cingulate cortex (ACC) and dorso-lateral prefrontal cortex (DLPFC). Indeed, prior studies find that if rewards are not anticipated then ACC activity decreases (Raichle et al., 1994; Shidara & Richmond, 2002), consistent with the ACC's role in effort regulation. Hagger & Chatzisarantis (2013) cite evidence that the anterior cingulate cortex (ACC) increases activity in response to tasting glucose. The ACC and DLPFC are both associated with a number of topics in the depletion and fatigue literatures. The ACC is involved in attention allocation (Pardo et al., 1990), reward anticipation and decision-making (Bush et al., 2002), ethics and morality (Sevinc et al., 2017), impulse control (Aharoni et al., 2013), and emotion (Decety & Jackson, 2004; Jackson et al., 2006). Further, evidence shows that the DLPFC is related to rewards and motivation (Luethi et al. 2016), and decreased DLPFC activity is linked to decreased inhibition (i.e., self-control) (Loftus et al., 2015). The ACC and DLPFC also work in concert to regulate attention shifting and executive control in task goal pursuit (Kondo et al., 2004). The anterior cingulate cortex (ACC) is also ubiquitous in cognitive control, such as processing rewards, performance monitoring, execution of control and action selection (Shenhav et al., 2013). Effort

Thus, while specific local areas in the brain may differ in energy use based upon demands from mental activities, overall glucose levels are maintained within very narrow limits in the brain.

is tracked by activity in the ACC, which is associated with the subjective aversiveness of effort (Inzlicht et al., 2018 p. 339). As a result, glucose can potentially influence depletion/TCF through increased motivation by being encoded as rewarding by the ACC and DLPFC.

Affect

Fatigue also shares a substantial overlap with low levels of positive affect (Hockey, 2000), and some researchers refer to fatigue as the “stop emotion” due to its role in interrupting and resetting motivational direction (Meijman, 2000; van der Linden, 2011). This view is compatible with findings in the depletion literature that inducing positive affect or having implicit positive emotion can mitigate depletion (e.g., Mullis & Hatfield, 2018; Shmueli & Prochaska, 2012; Ren et al., 2010; Tice et al., 2007) and that enjoying experimental tasks decreases depletion (Polman & Vohs, 2016; Vohs et al., 2008). The link here is also motivational in nature, as prior literature finds that positive affect fosters intrinsic motivation (Isen & Reeve, 2005), increases task motivation (Erez & Isen, 2002), and improves cognitive control through motivation (Liu & Wang, 2014). Similarly, while Baumeister and Vohs (2016) argue that a motivational account of the depletion phenomenon cannot cope with the association between depletion and negative affect, Gillet et al. (2013) note that amotivation is associated with negative affect, and negative affect may decrease motivation because effort is required to restore one’s mood (e.g., Brose et al., 2012).

Self-Affirmation and Self-Efficacy

Prior studies also find that self-affirmation (Schmeichel & Vohs, 2009; Wan & Sternthal, 2008; Alberts et al., 2011) or encouraging individuals to feel autonomous (Graham et al., 2014; Muraven et al., 2007) can counteract depletion. Self-affirmation also increases motivation to achieve goals (e.g., Taylor & Sherman, 2008), which can account for the increased performance noted in these studies. Baumeister & Vohs (2016 p. 99) state that findings of self-regulatory

strength improvement as a result of long-term practice pose a significant threat to a motivation-centric account of depletion findings. However, it is difficult to believe that individuals who practice self-regulation over a long period of time do not experience a heightened sense of self-efficacy in that domain, which can increase goal persistence and goal-striving behavior (Bandura, 1997). As a result, long-term practice studies are consistent with an account of depletion as TCF.

Boredom

Hockey (2013 p. 16) draws out similarities between boredom and fatigue, noting that boredom can be conceptualized as fatigue absent the motivation and effort required to continue to actively engage with the task and/or its goals. This view of boredom as severely low motivation is compatible with neuroscience evidence from Milyavskaya et al. (2019b), who argue that many control conditions in prior depletion studies may actually induce boredom. Specifically, Milyavskaya et al. (2019b) find that participants in a boredom condition reported significantly greater fatigue *and* significantly less effort than participants in control or depletion conditions. While O'Hanlon (1981) suggests that boredom is a response to highly repetitious and/or monotonous tasks that are *not* typical of fatigue-inducing tasks, it is notable that repetitious and monotonous tasks *are* prototypical of *depleting* tasks. Thus, boredom provides one potential explanation for the mixed results that characterize the recent depletion literature. Viewing depletion as TCF makes sense of these differences, as participants who are bored and/or exerted significant initial effort will exhibit similar decreases in motivation, effort, and performance.

Construal

Low-level construal is consistent with focusing on specifics of completing a task, whereas high-level construal is focused on the overall purpose of the task (Trope & Liberman, 2003, 2010). Self-control is effortful because it pits distal and abstract motivations against proximal and

concrete motivations, and higher-level construal allows individuals to focus on the former (Fujita, 2011; Fujita et al., 2006). As a result, individuals with lower motivation will likely focus on simply completing the task with lower-level construal, and individuals who find the task meaningful will engage in higher-level construal. Depletion is associated with low-level construal (Bruyneel & Dewitte, 2012; Wan & Agrawal, 2011; Vohs & Schmeichel, 2003), and self-control failure can be viewed as “succumbing to the motivation implied by the low-level [construal]” (Trope & Liberman, 2010 p. 454). Therefore, it is possible that fatigue reduces motivation, which drives low-level construal and associated reductions in performance observed in depletion studies.

Summary of Specific Depletion Findings and TCF

In this section, I have summarized numerous specific depletion findings. It seems that an account of depletion as TCF can cleanly accommodate these disparate findings with motivation as the common thread that links these factors to performance outcomes. Motivation is a key component of both TCF and depletion theories. In the next section, I discuss the compatibility of viewing depletion as TCF with existing alternative theories to the strength model of depletion.

Reconciling Competing Depletion Models with TCF

The preceding discussion makes clear that the depletion literature overlaps considerably with the literature on cognitive fatigue and that reconceptualizing depletion as TCF at a theoretical level can account for the seminal depletion findings as well as the disparate findings and null results that characterize recent depletion research. While the strength model has dominated depletion research, it is important to note that researchers have set forth alternative theories for the depletion phenomenon in response to the overly broad and vague specification of the strength model. I discuss and compare each model below to viewing depletion as TCF.

The Resource-Allocation Model

The resource-allocation model (“RAM”, Beedie & Lane, 2012) posits that individuals do not have a limited supply of self-control resources (glucose, in their model), but rather choose whether or not to allocate these resources to specific tasks based upon their underlying motivations. This explanation fits some existing data well, including the conservation hypothesis of depletion (Maranges & Baumeister, 2017; Tyler & Burns, 2008; Muraven et al., 2006; Muraven & Slessareva, 2003). However, it is apparent that part of this model is likely incorrect due to accumulating evidence that contradicts the notion that glucose is the limited resource behind self-control. However, at its core the RAM relies upon the concept of motivation in selective allocation of resources. Thus, considering depletion as TCF cleanly subsumes the RAM with one slight change: individuals selectively allocate *effort*, based upon motivation, rather than a cognitive or physical *resource* such as glucose. Exerting self-control is effortful, and an abundance of evidence exists that individuals seek to take efficiency shortcuts in cognitive processing.

The Implicit Beliefs Models

A second alternative theory to the strength model is what I term the Implicit Beliefs Models (“IBMs”). IBM studies find that individuals do not exhibit depletion if they hold certain subjective beliefs, such as believing they have unlimited willpower (Job et al., 2010, 2013; cf. Vohs et al., 2012) or believing they are not depleted or possess optimal resources for task performance (e.g., Clarkson et al., 2010, 2011; Silvestrini et al., 2019). Thus, the IBMs consider depletion to be a self-fulfilling prophecy based upon erroneous beliefs. Importantly, evidence supporting the IBM is also consistent with cognitive dissonance theory (Festinger, 1957), which can be viewed as consistency motivation. Individuals are motivated to create consonance between their actions and beliefs, and this motivation can account for implicit beliefs mitigating the depletion phenomenon,

consistent with viewing depletion as TCF. Further, personal theories of the self significantly affect motivation (Dweck, 2000) so it stands to reason that personal theories regarding the nature of willpower would function similarly. This view can thus also incorporate the literature on perceived depletion (e.g., Clarkson et al., 2010, 2011; Silvestrini et al., 2019) through parallel logic; individuals who believe they are not depleted would seemingly be motivated to prove that they can maintain task performance to avoid dissonance between the results of their performance and their beliefs. Thus, it is plausible that individuals' beliefs about willpower or perceptions of their own depletion motivate effort provision to enhance performance to be consistent with these beliefs. Thus, considering depletion to be TCF accounts for the findings of the IBMs through motivation.

The Process Model

The Process Model ("PM", Inzlicht & Schmeichel, 2012; Inzlicht et al., 2014) posits that exerting self-control is effortful and therefore concurrently shifts both motivation and attention away from regulating one's behavior and toward more personally gratifying actions. In concert, these processes increase positive affect and emotion, and register as rewarding to the individual. Thus, the PM shares similarities with viewing depletion as TCF, although a fatigue-centric view focuses more broadly on executive functioning while the PM primarily focuses on self-control.

In the PM, effort provision leads to two concurrent consequences: decreased motivation to engage in cognitive control, and increased attention devoted elsewhere (Inzlicht & Schmeichel, 2012 p. 451). While both effects *can* and likely *do* occur, only one task is necessary to observe decreased performance. Based upon the fatigue literature, motivation would be the primary mechanism due to its role in effort provision, as both motivation and effort are superordinate to attention provision and control. The PM also seemingly requires a competing task for an individual to use in assessing comparative motivations, but does not provides an explanation for situations in

which there is no competing alternative (Hagger 2013). Further, the inclusion of a concurrent/competing task is unnecessary in explaining most depletion findings, and actually runs counter to most experimental designs in this literature. In conclusion, viewing depletion as TCF, while sharing similarities with the PM, has broader explanatory power.

The Opportunity-Cost Model

The Opportunity Cost Model (“OCM”, Kurzban et al., 2013) argues that exerting effort for self-control highlights the opportunity cost of doing so (i.e., other uses of this effort), which triggers a cost-benefit analysis that can lead to reduced effort and decreased performance observed in the depletion literature. With a focus on motivation for effort and performance and on attention paid to the posited cost-benefit consideration, the OCM has substantial overlap with the PM and viewing depletion as TCF. While Baumeister & Vohs (2016 p. 105) dismiss the OCM as only relevant for persistence tasks, this argument seems to consider effort as an all-or-nothing proposition, rather than existing on a continuum. Individuals do not typically choose between exerting full effort or quitting a task entirely; rather, they control how much effort to exert in self-regulation based upon their motivation, allowing them to reduce the “cost” of task completion. Similar to viewing depletion as TCF, the OCM identifies the importance of the ACC in continued effort provision, goal pursuit, and persistence (Kurzban et al., 2013). Prior studies have found that heightened ACC activity during decision tasks significantly increases when tasks are that the task is deemed worthy of pursuing (i.e., sufficient motivation exists), but that ACC activity must be sufficiently strong to continue goal pursuit and persistence (Amiez et al., 2005; Hillman & Bilkey, 2010, 2013; Quilodran et al., 2008; Sallet et al., 2007; Shidara & Richmond, 2002). However, ACC activity does not always correspond to the costliest action, contrary to the OCM (Hillman & Bilkey, 2010; Kennerley et al., 2006; Rudebeck et al., 2008).

Like the PM, the OCM requires a second, competing task as necessary for generating model predictions. In the OCM, this competing task is used to produce an opportunity cost calculation. Like the PM, the OCM does not provide an explanation for situations in which there is no competing alternative task that would trigger an opportunity-cost calculation (Hagger, 2013). It bears repeating that the inclusion of a concurrent/competing task is unnecessary in explaining most depletion findings, and does not mirror most experimental designs in this literature.

Considering depletion as TCF, by contrast, is more parsimonious than the OCM. It is notable that the OCM assumes that individuals objectively conduct cost-benefit calculations, which is at odds with accepted views of human rationality (Inzlicht & Schmeichel, 2013). Further, the requirement of an alternative task makes little sense when considering that individuals often have no realistic choice between tasks (e.g., feeling obligated to continue an experiment; being unable to realistically quit a task at work).¹⁴ This choice can be viewed as completing a task with varying degrees of effort on a continuum, with the endpoints being exerting maximal effort or quitting a task altogether. It is far more likely that individuals continue the task out of necessity but reduce their effort due to effort aversion and decreased motivation from cognitive fatigue. This strategy would result in task completion, but at a lower level of performance, consistent with a view of TCF and findings in the depletion literature.¹⁵

Given that individuals tend to default to lower-effort strategies, it is sufficient for participants to experience reduced motivation in the dependent variable task, lower their effort, and exhibit a decrease in performance as predicted by considering depletion as TCF. For example,

¹⁴ While the OCM notes that someone can “daydream” instead of performing their current task, this is essentially using cognitive effort to avoid distraction/task interruption (e.g., Kanfer & Ackerman, 1989).

¹⁵ Reinforcing this notion, fatigue studies find that individuals typically keep some aspect of performance at acceptable levels while other aspects suffer, rather than being deliberately unwilling to perform a task (e.g., Hockey, 1997). This observation is consistent with reduced task engagement resulting from decreased motivation (van der Linden, 2011), and depletion studies that decreased performance in Stroop accuracy or reaction-time, but not both (Dang et al., 2017 p. 287).

Giacomantonio et al. (2019) provide evidence that depletion leads to two contradictory motivations: 1) to conserve energy; and 2) to seek rewards. Importantly, these motivations can exist concurrently without the need of an alternative competing task. While competing motivations can account for some instances of self-regulatory failure, they are not necessary components of such a model, and fail to account for most of the basic findings in the depletion literature where competing tasks are not prominent.

In summary, considering depletion as TCF can account for the vast majority of the findings of the depletion phenomenon and provides a better fit with and more parsimonious explanation of the findings in the depletion literature than do other alternative depletion theories. This is especially true when considering situations in which individuals do not have strong competing alternative tasks that can draw their motivation from the focal task (e.g., in depletion experiments).

Moving the Literature Forward with Transient Cognitive Fatigue

Theory Testing

It seems time to rigorously test an alternative theoretical account of the ego depletion phenomenon (Lurquin & Miyake, 2017; Friese et al., 2019). By reconceptualizing depletion as TCF, we can derive a number of falsifiable hypotheses. For example, short, effortful tasks will lead to TCF and an associated increase in cognitive discomfort, but not necessarily full self-reports of cognitive fatigue. Absent an increase in motivation from switching to a subsequent task, TCF should also lead to decreased performance on the dependent variable task. Further, if an initial task's effort demands are extreme, participants may report subjective fatigue.

It is also useful to consider predictions in terms of the overall causal process. Tasks resulting in TCF are expected to decrease motivation for continued task performance. This decreased motivation is expected to reduce effort *provision* while potentially increasing *self-*

perceptions of exerted effort. Decreased motivation is also expected to reduce attention to task performance on a subsequent task and increase interference from distractions. That is, an initial task that causes TCF should decrease performance through decreased motivation, but this relationship may potentially be mediated by actual effort provision, reduced attention, and boredom. However, levels of subjective fatigue and how TCF influences performance are unlikely to be fixed between participants; rather, fatigue is a dynamic process that can differ between individuals and tasks and can fluctuate over time (van der Linden, 2011 p. 157). These observations are consistent with those of Baumeister (2019), who posits that depletion may only occur sometimes, but not necessarily all the time. As a result, it is important to consider task duration and obtaining valid measures of potential mediators when examining TCF.

Task Duration

One open question is: how long or demanding must a task be to shift from TF to RF to SEF? It is difficult to answer such a question, given differences across individuals, tasks' effort demands, and task-individual interaction. However, based upon the fatigue literature, it stands to reason that researchers should observe an initial decrement in task performance through TF with short or moderate-length tasks (e.g., ranging from ten minutes to perhaps an hour), potentially followed by a quasi-rebound effect in the RF phase whereby individuals resist fatigue through effort provision, if they are sufficiently motivated. Following the RF phase is an SEF-driven decline when individuals are unable to sustain performance, again assuming sufficient motivation to continue providing effort. Given prior fatigue literature and laboratory constraints on participants' time, it is perhaps unlikely that SEF will be observed in shorter experiments of less than 30 minutes or one hour. However, researchers can investigate this issue by carefully manipulating time on the initial task to map out performance decrements due to either TCF or SEF.

For example, some studies examine what could be considered SEF (Linder et al., 2014; Dai et al., 2015; Augenblick & Nicholson, 2016; Sievertsen et al., 2016; Hurley, 2017) outside of a laboratory. Although this involves some loss of experimental control and introduces potential alternative explanations, such sacrifices are likely necessary to address the different phases of fatigue by leaving the lab (Frieze et al., 2019). This seems a fruitful avenue for future research given the broad applicability of both TCF and SEF in work environments.

Researchers must also employ more strongly designed manipulations of TCF compared to many of the depletion manipulations used in prior literature. For example, some recent studies in the depletion literature use manipulations ranging from 24 minutes to two hours (e.g., Sjøstad & Baumeister, 2018; Guilfoyle et al., 2019; Brown & Bray, 2017; Lopez et al., 2019; Palma et al., 2018; Tsai & Li, 2019) and find significant effects on subsequent performance. While some of these studies closer to the two-hour range may arguably be capturing SEF rather than TCF, the important aspect is that these manipulations are generally far stronger than those that are less than ten minutes in duration, typical of the depletion literature (e.g., the Hagger et al., 2016 RRR used a manipulation of ~7.5 minutes). Using longer and/or more effortfully demanding manipulations will provide some assurance that researchers are effectively manipulating fatigue. Further, researchers should go beyond initial tasks that are centered on self-control to focus on the use of executive functioning to elicit TCF. Finally, another possibility is formally manipulating task motivation. Depletion studies assume that participants are sufficiently engaged in the initial task so as to incur depletion (Lee et al., 2016); however, given the nature of the depleting tasks used in prior studies, this assumption is dubious at best.

Measures

While re-specifying ego depletion as TCF provides a more precise theoretical account for the findings in the ego depletion literature, the reader will also note that the process is more complex. This is necessarily the case when moving from a vague resource-based account where effects are simply inferred from performance levels to one that identifies specific causal mechanisms behind a phenomenon. The upshot for continued research in this area is that researchers must obtain a variety of measures to faithfully attempt to conduct falsification tests of the central tenets of depletion as TCF. To date, depletion researchers have given little attention to determining participants' level of exertion during the T1 task beyond self-reported effort and fatigue (Chatzisarantis & Hagger, 2015; Lee et al., 2016).

First, given the centrality of motivation, effort, and fatigue to TCF, researchers should attempt to measure each of these constructs in a variety of ways.¹⁶ For example, effort can be measured via self-report in a post-manipulation question, but can also be inferred from time spent on a task, or through other relevant measures determined by experimental design (e.g., number of clicks within an experiment, depth of responses to free-response measures) or physiological markers. Similarly, researchers can assess motivation via direct self-report measures, through indirect self-report measures that focus on interest or types of arousal, through questions that measure goal commitment, or via neuropsychological measures. While fatigue and motivation may often only be measurable by self-report, researchers can also attempt to measure changes in these variables from pre- to post-task, and should encourage subjects to be as honest as possible to avoid experimenter demand effects (e.g., believing it is desirable to report high motivation for the task).

¹⁶ Hagger et al. (2010) find support in their meta-analysis for increased subjective perceptions of effort ($d = 0.64$), difficulty ($d = 0.94$), and fatigue ($d = 0.44$) in depletion studies. These findings are consistent with TCF and reinforces the importance of measuring these variables in future studies.

It is also important to obtain measures of participants' mental discomfort, given the observation that TCF may not result in self-report measures of subjective cognitive fatigue. Further, given the link between boredom and motivation, and initial neuroscience evidence that control tasks used in the ego depletion literature may induce boredom among participants (Milyavskaya et al., 2019b), it is important that researchers obtain accurate measures of participants boredom or, conversely, engagement with experimental tasks. It is also important that future research uses various measures to validate tasks used to induce fatigue (cf. Lurquin & Miyake, 2017). To this end, researchers should validate tasks through the use of multiple measures of the same construct to provide some assurance that the manipulations used are indeed effective. This is of utmost importance, because if participants in manipulated conditions are not sufficiently engaged with or motivated to perform T1 tasks, this may have contributed heavily to the mixed findings and poor understanding of the depletion phenomenon. Further, this will allow researchers to distinguish between individuals who are fatigued, indifferent, or activated by an initial task (Dang & Hagger, 2019; cf. Converse & DeShon, 2009; Xiao et al., 2014).

Finally, researchers may need to abandon the dual-task paradigm of ego depletion research (Inzlicht and Schmeichel 2012) and the SEF-driven designs of prior fatigue research to fully explore TCF. The dual-task paradigm is designed with the sole focus of detecting decrements in performance on the T2 task. The preceding discussion of TCF makes it clear that performance should not necessarily be the focal, or certainly not the only, measurement of interest. As a result, it seems that a more fruitful approach may be to isolate various T1 tasks and conduct a battery of post-task questions and tests in order to determine the effects of the T1 task on the individual (e.g., motivation, effort, fatigue, boredom). Such an approach can help to resolve questions of task validity that have plagued depletion studies (Lurquin & Miyake, 2017) and provide strong

evidence of the underlying processes that may lead to performance decrements from TCF. This approach can also address the potential usefulness of control tasks, especially considering the possibility that control tasks induce boredom (Milyavskaya et al., 2019b). Given the mediation processes specified in the TFM, this work would provide a crucial building block upon which to test the efficacy of this theoretical re-specification.

Conclusion

In this paper, I propose that the ego depletion phenomenon is more appropriately viewed as transient cognitive fatigue (TCF). Further, I propose that this reconceptualization of depletion as TCF provides a more appropriate theoretical account of the depletion phenomenon than do the strength model or competing alternative theories of depletion. Rather than abandoning work on this phenomenon, as many researchers have done (e.g., Inzlicht and Friesen, 2019 p. 370), it seems more fruitful to re-evaluate the theoretical explanation of the phenomenon and to conduct testing using the theory underlying TCF. This paper thus provides an opportunity for researchers to continue to contribute valuable knowledge about this phenomenon, its generality, and its ability to provide a greater understanding of cognitive fatigue.

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