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Some observations on the puzzling world of self-regulation and depletion

John. L. Dennis^{1,2*} and Edwin A. Locke³

Abstract: This paper identifies problems with ego depletion theory including failures to replicate, non-support for glucose as a mediator, the stress on single replication studies rather than replication with variation, the failure to document generalizability, the stress on physical as opposed to psychological moderators and mediators, and the overemphasis on deduction as the core scientific method.

Subjects: Behavioral Sciences; Psychological Science; General Psychology

Keywords: self-regulation; ego-depletion; glucose; replication; moderator; mediator; theory building; induction

1. Introduction

The capacity for humans to direct thoughts, feelings, and actions toward the attainment of one's goals is one of the most impressive abilities possessed (Locke & Latham, 2002). This capacity is often described as self-regulation, and it is impressive both for its failures and successes.

Self-regulation is the capacity to direct oneself toward the achievement of goals. To achieve a goal, especially difficult ones, people need to face and overcome obstacles, think more goal-related thoughts, perform goal-related behaviors, and resist (sometimes powerful) temptations that lead them away from their intended direction.

ABOUT THE AUTHORS

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PUBLIC INTEREST STATEMENT

The capacity for humans to direct thoughts, feelings, and actions toward the attainment of one's goals is one of the most impressive abilities possessed. This capacity is often described as self-regulation, and it is impressive both for its failures and successes.

Self-regulation is the capacity to direct oneself toward goal achievement. To achieve a goal, especially difficult ones, people need to face and overcome obstacles, think more goal-related thoughts, perform goal-related behaviors, and resist (sometimes powerful) temptations that lead them away from their intended direction. This paper identifies problems with ego depletion theory including failures to replicate, non-support for glucose as a mediator, the stress on single replication studies rather than replication with variation, the failure to document generalizability, the stress on physical as opposed to psychological moderators and mediators, and the overemphasis on deduction as the core scientific method.

Recent controversies have led some to question the validity of the phenomenon of self-regulation and depletion. These controversies bring up issues related to replication, glucose, logical problems, and theory building. The paper identifies two primary fields of concern in ego depletion theory. The first revolves around methodological faults that lead to failure to replicate, replication without variation, failure to document generalizability, and a heavy-footed usage of deduction as the core scientific method. The second deals more technically with nonsupport for glucose as a mediator, and equal consideration of physical and psychological moderators and mediators.

2. Depletion theory

In brief, depletion theory (Baumeister, 2014) argues that acts of self-regulation deplete a limited resource of self-regulation (e.g. glucose), making people less able to exert self-regulation on a subsequent task. Depletion theory focuses on situations where a person is in conflict, such as performing a complex task or at variance with past habits (e.g. a Stroop task; Webb & Sheeran, 2003), which allegedly depletes energy thus leading to poorer performance and/or loss of focus on a subsequent task. It is claimed that this depletion can be achieved after only a few (5–10) minutes work, but recently depletion theory research has come into question (e.g. Carter, Kofler, Forster, & McCullough, 2015; Carter & McCullough, 2013, 2014; Hagger, Wood, Stiff, & Chatzisarantis, 2010; Lurquin et al., 2016).

3. Registered replication study

In an attempt to deal with various disputes, Hagger and Chatzisarantis (2016) organized a registered replication study using one task (e-crossing) in 23 different labs from 10 countries using 2,141 subjects. The overall effects size was negligible ($d = 0.04$ which included 0 though there were minor variations across labs).

Baumeister and Vohs (2016) immediately took issue with the study because of the choice of task. Although Baumeister had previously endorsed the use of the e-crossing task, which had been used in many previous studies, in retrospect he took with the claimed lack of fatiguing. Reported fatigue, he argues, moderates the effect based on Dang's (2016) reanalysis. Of course, fatigue is not necessarily the same thing as glucose depletion even if such a thing occurs. He plans to do another registered study. But Baumeister brings up what we believe is an important issue: that of the generalizability of results (see below).

4. Glucose as a mediator

We know that the brain uses 120 g of glucose (which represents ATP concentration) a day (Berg, Tymoczko, & Stryer, 2002), which represents half of the requirements of the human body. The brain does not have the ability to store glucose, but the brain has sensors, which continuously sense glucose (ATP) levels and can draw a supply instantaneously from the body whenever needed; this is called energy on demand. The brain takes priority, making glucose level very stable under normal circumstances. "The ATP content in the brain is held constant within tight limits, irrespective of the state of the body" (Wikipedia, "Selfish Brain theory", p. 5).

Three questions follow from this: (1) How much glucose does a 5–10-min cognitive task require? (2) How much glucose depletion does it take to make a difference in cognitive capacity? and (3) How fast does the brain replenish? We are not sure if these questions have been answered. Further, glucose blood level is not the same as brain glucose level; if not, only brain glucose level should be measured.

Vadillo, Gold, and Osman (2016) recently published a *p*-curve analysis of the glucose-as-mediator theory. If this method is valid, then the results indicate that the glucose theory results are not reliable. Combined with replication failures noted by the authors, it seems accurate to say that this aspect of the theory has not been proven. (Glucose in these studies was measured by blood level).

Other physiological mediators of depletion have been suggested, e.g. heart rate variability (Segerstrom & Nes, 2007) and blood pressure (Wright, Stewart, & Barnett, 2008) as well as electroencephalographic activity in brain areas associated with effort (Inzlicht & Gutsell, 2007). Validation of physiological mediator effects requires applying the standard mediation model such that with the mediator controlled an initially significant effect would be vitiated. It is not clear whether this has been done.

The relationship between glucose depletion and fatigue also needs clarification. We have known for many decades that fatigue undermines life in many different ways, but typically, fatigue comes from long hours of work, lack of sleep, illness, medications, various psychological problems, and more. But these tend to be long-term or continuous problems, not five to 10-minute tasks. Hockey's (2013) review of the fatigue literature views it as mediated by motivational prioritization rather than strictly physical changes (see Inzlicht, Schmeichel, & Macrae, 2014, Box 2).

5. Replication and theory building

Last year in PPS, the first author discussed (Locke, 2015) the issue of theory building at some length and in that article, questioned the usefulness of exact replication. "What has been achieved? You have now done virtually the same study twice ... But in reality you have not created a theory at all even if you replicate the same 'exact' study 100 times" (p. 410). (A recently reported multi-lab registered study was designed to replicate only a single published study in order to establish a causal relationship; it failed; APS Observer, 2016). Baumeister is right that you need generalizability. However, you cannot establish that by doing one study repeatedly. To get generalizability, you need what the second author calls "replication with variation" (p. 410).

One type of generalizability, which Baumeister recognizes, is generalizability across tasks. This seems to have been done in depletion research to some extent. Sripada, Kessler, and Jonides (2016) note that task differences may be important. There is also the need for generalizability across time spans (a critical issue in depletion research), settings (lab, field), and dependent variables (Locke & Latham, 1990, 2013).

If the goal of research is theory building, single study replication can hold science back due to it being too narrow. Replication with variation should help reveal the robustness of a main effect and relevant contingencies.

6. Theory building and moderators/mediators

It is also critically important in theory building to find moderators (boundary conditions; Locke, 2015; Locke & Latham, 1990). It is not necessarily the best strategy to look for physiological moderators or mediators of depletion. The relation between mind and brain is very complex; you need a brain to think but ideas do not have the same attributes as neurons. A more productive strategy might be to look for psychological moderators first.

In a series of three studies, Job, Dweck, and Walton (2010) demonstrated that people who think or who were primed to think of self-regulation as a limited resource showed depletion, whereas people who thought or were primed to think of self-regulation as a non-limited resource did not. Interestingly, they found that beliefs about self-regulation as a limited resource predicted better self-regulation (e.g. subjects were less likely to watch TV than study) during heightened periods of stress (i.e. student's final exam period). These results dovetail nicely with other research that demonstrates that beliefs about depletion effects are more likely to be caused by people's beliefs about depletion than by the actual depletion experimental task (Clarkson, Hirt, Jia, & Alexander, 2010). These results about the relationship between beliefs and depletion raise an interesting question about the relationship between one's beliefs about one's ability to overcome depletion or fatigue, e.g. self-efficacy (Bandura, 1997).

Depletion beliefs are not the only psychological moderator to have been found. Brockner (2016) has summarized other moderators including: positive mood, self-affirmation, beliefs about the importance of the second task, and money incentives. Indeed, in one study simply being told that performing an effortful task can improve your performance on an unrelated task (Martijn, Tenbült, Merckelbach, Dreezens, & de Vries, 2002) neutralized depletion.

In research projects of the present authors (Dennis and Locke, 2017), we've found that performance goals moderated the self-regulation depletion effect. In these experiments, participants first performed a standard brainstorming task (e.g. list uses for a pencil), and then immediately following this task, participants in the experimental condition engaged in standard self-regulation depletion task, e.g. the White Bear task where participants in the depletion condition are instructed to write down their thoughts while not thinking of a white bear (Muraven, Tice, & Baumeister, 1998). Participants in the control condition are simply instructed to write down their thoughts. Following the depletion task, participants are asked to complete another brainstorming task (e.g. list uses for a brick). Participants at this point were either assigned an easy or hard goal or chose their own goal for the number of uses they should or would try to list for the brick. We found a self-regulation depletion effect only when goals were easy. When assigned or self-set goals were hard, there was no self-depletion.

Why are such moderators important to study, especially in depletion research? They bring up an important phenomenon that seems to have been neglected in the depletion literature and is very relevant to daily life. It is *the ability of people to mobilize physical or psychological energy when they believe something personally important or significant is at stake*. (This may be related to ego involvement or achievement motivation; see Vroom, 1964). Such mobilization cannot be just a matter of the task or the situation; it would have to include how the individual appraises the task or situation. This idea is consistent with the fact that the brain can get glucose on demand. Glucose depletion, even if it occurs and is relevant, may be readily offset (on demand) by accretion based on value judgments or value appraisals or may not need to be replenished at all. Arousal can drop simply through boredom or disinterest, including doing something tedious or difficult which one has no real interest in. People can work very hard, even to exhaustion, if what they are doing something that has personal urgency to them.

7. Theory building and induction/deduction

As an antidote to the widespread practice of making up hypotheses after the fact and cherry-picking data, it is now widely recommended (e.g. Lindsay, 2016) that people register their hypotheses and methods before doing their studies, as was done by Hagger and Chatzisarantis (2016) above.

The first author does not see this as a panacea and in some respects believes that it can be harmful. The most serious problem is that it would further institutionalize a primarily deductive approach to science. I have argued at length against this because science is first and foremost an inductive process (e.g. Locke, 2007). Theory building means trying stuff, accumulating evidence, integrating it into a non-contradictory whole. Once a theory is well developed, deductions can be made. Nevertheless, it is impossible to predict what new things might be discovered in the future. APS President Goldin-Meadow (2016b, p. 5; see also 2016a) writes "How can we make new discoveries if our studies need to be catalogued before they are run?" Many scientific findings are unexpected and valid theories evolve gradually as the data accumulate (Bandura, 1997; Locke & Latham, 1990).

The deductive method encourages premature (and often phony) theorizing and closure. This is reinforced by journal policies that constantly demand new theory-based papers rather than gradual theory development using replication with variation. This discourages programmatic research.

There is also a probable psychological problem inherent in the deductive approach. People desperately want to be right about their theory because they may feel like they have one shot and it's over. This can certainly motivate the pernicious procedures we know about. The deductive mindset encourages a closed system. The inductive approach has a very different mindset. An inductively built theory is properly open ended so new discoveries which are not part of or modify the original theory

are welcomed as opposed to being seen as a threat. For example, the discovery of a new moderator does not move the theory backward or disprove it, but rather it moves the theory forward through refinement and enlargement (see Locke & Latham, 1990, 2013). New discoveries and revisions make the theory stronger. The inductive mindset encourages an open system. Premature, registered, single replications encourage the opposite.

In the end, a number of journal policies could encourage inductive research. An article could report an initial study that was exploratory accompanied by a replication. A study could simply start with questions. A hypothesis could be based just on a previous result but not an actual theory (replication with variation) and new, unpredicted findings could be shown to possibly move the field forward. Better yet, moderators could be actively sought.

Although introspection is, in effect, a forbidden method in psychology it is actually very important (Locke, 2009). The idea that one can mobilize energy based on the appraisal that some task is important is an everyday experience and is easy to further validate through experiment.

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Competing Interests

The authors declare no competing interests.

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