An expanded perspective on the role of effort phenomenology in motivation and performance

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An organism that utilizes an opportunity cost model of effort expenditure requires the ability to rapidly adjust task engagement in response to information from the environment and internal homeostasis monitors. The locus coeruleus (LC) receives input from the anterior cingulate cortex and orbital frontal cortex, structures implicated in the evaluation of cost/benefit trade-offs and valuation, as well as arousal-related inputs from the autonomic nervous system (Aston-Jones & Cohen 2005). Additionally, human and animal studies demonstrate that prefrontal networks are sensitive to norepinephrine concentration (Robbins & Arnsten 2009), with optimal levels necessary for successful task performance. This literature advocates for continuous feedback between the LC and cortical structures estimating the utility of maintaining the current effort-allocation policy. Critically, top-down cortical signals and peripheral autonomic input may shift the activity of the LC-NE system in a temporally relevant manner (Aston-Jones & Cohen 2005). For example, projections from the anterior cingulate cortex may shift the firing rate of the noradrenergic neuron population, in turn altering the level of norepinephrine in the cortex, which decreases stability of the current effort policy and promotes disengagement and selection of a new action plan (Aston-Jones & Cohen 2005; Sara & Bouret 2012).

A system that adaptively shifts among action contingencies, as proposed in prominent theories of LC-NE system function, is central to an opportunity cost model of effort. Theories of LC-NE function broadly conceptualize its activity as shifting the balance of exploratory versus exploitative behavior or mediating a global signal to reset brain networks involved in action selection (Aston-Jones & Cohen; Sara & Bouret 2012). Examining LC-NE system activity in humans is difficult, due to the small size of the nucleus, its brainstem location and the feasibility of assessing cortical levels of norepinephrine in vivo. However, several functional neuroimaging studies have described patterns of activity in LC. An early study described patterns of activation in a putative LC region and right lateralized prefrontal regions that appear to respond parametrically to task difficulty (Raizada & Poldrack, 2007). Although consistent with a connection between LC and lateral prefrontal self-control networks, the study lacked the spatial specificity necessary to attribute a specific role to the LC. A subsequent study claimed to pharmacologically modulate LC activity (Minzenberg et al. 2008) but faced similar scrutiny about the precision of LC localization (Astafiev et al. 2010). Recently, a group applied improved brainstem spatial alignment to conclude that activity in LC correlates with unexpected uncertainty in a decision-making task (Payzan-LeNestour et al. 2013), consistent with a theoretical model (Yu & Dayan 2005).

Assessing the LC-NE system in humans remains a challenge, but recent studies point to a possible alternative solution. Several groups have demonstrated the utility of peripheral neurophysiological measurements, notably changes in pupil diameter, as an index of LC-NE system activity. As classically described by Kahneman (1973) and revived by Jepma and Nieuwenhuis (2011), Nassar et al. (2012), Eldar et al. (2013) and others, changes in pupil size appear linked to the noradrenergic arousal system and related to decision variables such as novelty and uncertainty that are useful for a system estimating opportunity costs to control effort-allocation policy. As Kurzban and colleagues note, a normative account of effort will benefit from unification of executive and self-control literature. We propose that validation of peripheral measurements of LC-NE activity and their integration with effortful tasks constitutes a worthwhile approach to test Kurzban et al.'s opportunity cost model. Evaluation of LC-NE activity in effort contingency, trade-off, and performance tasks will provide key evidence to support or refute particular mechanisms by which valuation and control systems interact to shift behavior in accordance with an opportunity cost model. Together with parallel investigations of other neuromodulatory systems, this work will provide the quantitative framework that a normative model of effort requires.

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Abstract: Kurzban and colleagues propose that experiences of effort alter motivations to persist during goal pursuit by highlighting costs of persistence. I expand this proposal by discussing how effort experiences (a) not only influence, but can be influenced by motivations to persist on a goal; and (b) not only highlight costs that undermine persistence, but can also signal progress and increase persistence.

Declines in effort and performance following sustained goal pursuit are frequently explained in terms of people's limited resources for engaging in self-regulation (Muraven & Baumeister 2000). Although many findings support such limited-resource explanations (see Hagger et al. 2010a), emerging evidence has produced a growing consensus that changes in people's motivation, rather than their capacity for self-regulation, may be responsible for decreases in performance over time (Beedie & Lane 2012; Inzlicht & Schmeichel 2012; Molden et al. 2012). The target article by Kurzban and colleagues not only adds to this consensus, but also provides a more detailed account of how such changes in motivation and performance arise.

Perhaps the most novel and intriguing aspects of Kurzban et al.'s account of self-regulation is the proposed role of people's experiences of effort and fatigue on their motivations to persist with a current task or goal. In this account, such experiences alter the perceived opportunity costs involved in maintaining this goal versus pursuing an alternative goal, and thus shift motivations away from the present task and toward different endeavors. This opportunity cost mechanism helps to explain and integrate many findings from a variety of literatures. However, the phenomenology of effort is also connected to additional motivational processes that influence self-regulation and performance. Below, I review research that illustrates these additional processes and extends Kurzban et al.'s motivational analysis.

Determining the perceived costs and benefits of particular outcomes is certainly one of the primary routes through which motivations affect goal pursuit and performance (see Molden & Higgins 2012). However, another influence of motivation on goal pursuit is how it alters the experiences people have during this pursuit (Higgins 2006). That is, many motivational interventions that boost performance do not merely influence evaluations of the costs and benefits of different goals or outcomes, but instead change people's experiences of effort and engagement while pursuing these outcomes.

For example, much research has shown that goals involving feelings of autonomy and self-direction, rather than feelings of control and coercion, create greater engagement and enjoyment (Deci & Ryan 2000). Consistent with these general findings, people who perceive that they have autonomously chosen to perform vigilance-related self-control tasks (e.g., monitoring for the appearance of a particular stimulus) experience less fatigue and more energy, which then increases how long they can successfully perform these tasks (Muraven et al. 2008; see also Moller et al. 2006; Muraven 2008). Moreover, additional research has shown that when the strategies people employ during goal pursuit are motivationally compatible with their broader self-regulatory preferences, this creates experiences of *regulatory fit* (Higgins 2008). Such fit also increases engagement in and enjoyment of goal pursuit, which subsequently improves performance on self-control tasks involving vigilance (e.g., avoiding distraction) and resistance to tempting alternatives (e.g., choosing fruit over chocolate as a snack; Freitas et al. 2002; Hong & Lee 2008).

The effects on self-regulation of experiences of engagement arising from autonomy or regulatory fit are broadly consistent with the central role that Kurzban and colleagues give to feelings of effort and fatigue in goal pursuit. However, these findings also demonstrate that, just as experiences of effort can affect motivations to sustain performance on current goals, so, too, can the broader motivational context in which a goal is pursued affect performance by influencing experiences of effort.

Beyond directly altering experiences of effort during goal pursuit, various motivational processes can also affect self-regulation and performance by influencing how people interpret these experiences (see Molden & Dweck 2006). That is, although people may often attribute feelings of effort and fatigue to diminishing returns for the continued pursuit of a current goal, and thus shift attention to other alternatives, research has also shown that other attributions for these feelings with different implications for self-regulation and performance are possible. Indeed, some studies have even shown that, in particular contexts, experiences of effort are interpreted as signs of progress and sustain goal pursuit.

One clear demonstration of how varying interpretations of effort experiences can dramatically influence the effect these experiences have on subsequent self-regulation and performance was provided by Clarkson et al. (2010). When people were led to attribute feelings of effort to a superficial source unrelated to the pursuit of their primary goal (e.g., the color of the paper on which their task instructions were printed), they no longer showed subsequent declines in persistence or performance. Furthermore, when they view effort as an instrumental part of achieving their desired goals, people then interpret experiences of effort as signaling progress toward goal completion, and these experiences help sustain rather than undermine self-regulation and performance (Labroo & Kim 2009; Miele et al. 2011; Miele & Molden 2010). Thus, instead of highlighting growing opportunity costs, effort experiences can also at times indicate that continued goal pursuit is likely to yield benefits.

The effects on self-regulation of attributions for effort experiences are also broadly consistent with the important role that Kurzban and colleagues give to effort phenomenology in explaining the maintenance of or disengagement from goal pursuit. However, these findings also demonstrate that effects of such phenomenology are not limited to static considerations of opportunity costs but are instead altered by people's dynamic interpretations of their experiences of effort, engagement, or fatigue during self-regulation.

To summarize, Kurzban et al. have made a substantial contribution to the literature on self-regulation and performance with their analysis of how people's experiences of effort during goal pursuit affect their likelihood of sustaining this pursuit. Here, I expand this contribution by noting that: (1) Experiences of effort are not simply determined by bottom-up evaluations of goal progress, but can also be influenced by top-down orientations that determine the broader motivational context within which the goal is pursued. (2) Effort experiences can afford many other attributions beyond the rising opportunity costs associated with continued pursuit of the same goal, and, within mindsets where effort is directly linked to progress, such experiences can even increase goal commitment. These expansions broaden the scope of the model proposed by Kurzban et al. and make it applicable to an even wider range of phenomena.

Willpower is not synonymous with "executive function"

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Abstract: Kurzban et al. make a convincing case against the idea that willpower is a depleting resource. However, they do not advance a positive account of willpower. Rather than treating "willpower" as a synonym of "executive function," we argue that the term *willpower* should be designated for mechanisms individuals deploy to reduce dynamic inconsistency in their behavior.

The typical effect-size of depletion experiments (~d = .6; Hagger et al. 2010a) is not the right order of magnitude to go with the idea that there is a literal store of willpower that is being "used up." Nor is the fact that post-depletion, self-control can be restored by receipt of a gift, or by a self-affirmation (Schmeichel & Vohs 2009). Compare self-control depletion effects with the actual muscle fatigue from repeatedly lifting a heavy weight – here total muscle failure can easily and reliably be produced, and any effect of self-affirmation is likely to be modest. Although it remains to be seen whether Kurzban et al.'s model has it just right, it is on its face a more plausible account.

However, we think neither Baumeister et al. (2008) nor Kurzban and colleagues characterize *willpower* usefully (although in fairness, only Baumeister and colleagues seem to want to use this term). The phenomenon that both deal with is variously referred to as "executive function," "conscious processing," and as the output of "System 2" (Baumeister et al. 2008). The incongruent condition of the Stroop fits well, and is a standard depletion paradigm. The task requires color naming, which competes with the automatic tendency to read lexical items. There is no question that the Stroop Task is an interesting example of an important category of mental functioning. But the term "willpower" has a more specific meaning – it is *not* a synonym for "executive function". In particular, we believe that the mechanisms of willpower are directed at reducing the otherwise marked tendency most people have to systematically change their preferences over time.

The case of addiction is illustrative. The criteria used in the United States for "substance dependence" and for "substance use disorder" include (paraphrasing from the *Diagnostic and Statistical Manual of Mental Disorders IV-R*) "failed attempts to quit or moderate use" and "repeated episodes in which the individual uses more than she originally planned." In everyday use of the terms, these central features of addiction are considered struggles of "willpower" and of "self-control."

What does the self-control struggle of the addict have in common with an executive function task such as the Stroop? This is a point of some disagreement, but we suspect that the answer is *not very much*. First, peak performance on executive control tasks is observed in early adulthood; performance declines dramatically with aging. If this type of functioning were synonymous with "willpower," one would have reason to expect addiction to be a rare problem among young adults, but to increase in prevalence as people age. But the opposite is observed, with prevalence highest in early adulthood, and with a large percentage of addicts "aging out" in mid to late life (Anglin et al. 1986). Second, there is a mismatch between the timescale of failures on the incongruent Stroop and the self-control failures of an addict. When a person makes a mistake on the Stroop, she is succumbing to a reflexive tendency to read lexical items. If she is given an opportunity to slow down, she will fix her error. By contrast, when the cocaine addict who has been clean for a month "falls off the wagon," she may have to go to some lengths to get cocaine. It is not a momentary "oops" that is reliably corrected if she is given a moment to collect her thoughts. Unlike the participant performing the Stroop, the individual looking for cocaine is engaged in sustained goal-directed action, and even complex problem solving.

Of course, the situation of the addict falling off the wagon is so interesting because it is goal-directed action she previously dismissed as undesirable, and which she likely will later regret. Indeed, she may even believe she will regret it, even as she currently devotes herself to obtaining the drug. And these are the critical features that define the domain of willpower/self-control