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Current Opinion in Psychology

The sense of effort

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Exerting 'effort' or 'self-control' is experienced as aversive. From an evolutionary point of view, this is something of a mystery insofar as aversive phenomenology is usually associated with fitness costs or threats, whereas exerting self-control seems to be associated with positive outcomes. Recent theorizing surrounding the sense of effort suggests that there are costs to exerting effort, and these costs explain the accompanying unpleasant sensations. Debate remains, however, about the nature of and the mechanisms underlying these costs.

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Current Opinion in Psychology 2016, **7**:67–70

This review comes from a themed issue on **Evolutionary psychology**

Edited by **Steven W Gangestad** and **Joshua M Tybur**

For a complete overview see the Issue and the Editorial

Available online 17th August 2015

http://dx.doi.org/10.1016/j.copsyc.2015.08.003

Introduction: phenomenology measures and motivates

From an evolutionary point of view, it is relatively obvious why sex is fun [1]. An organism that experiences sex as rewarding — and is, therefore, motivated to engage in it — will, everything else equal, out-reproduce an organism that experiences sex as aversive, motivated to avoid it. The wiring of the reward system leads to reproductive success, conferring advantages on the genes involved in the production of the system.

Phenomenological experiences, in general, follow this logic [2,3]. Selection crafted motivational systems to guide organisms toward adaptive behavior [4]: the kinds of behaviors that would have led, on average, to increased reproductive success over evolutionary time (even if they currently do not necessarily do so; [5]). 'Fitness-good,' behaviors (following [6]) are, generally, experienced as rewarding. Hunger motivates calorie-acquisition; eating is rewarding. Thirst motivates drinking water; slaking one's thirst is rewarding. In these cases, and doubtlessly many similar others, the motivation — and the reward — is state-dependent. Organisms low on calories experience greater hunger, a greater motivation to seek and consume food, and experience greater reward when they eat.

This framework suggests that phenomenological experiences ought to be able to be understood, ultimately, in the language of *costs and benefits*. Selection would not have sculpted a motivational system, with attendant phenomenology, if there were no (distal) fitness stakes. Phenomenology, then, might be thought of as *measuring* the current marginal fitness benefit of the current need or opportunity and *motivating* the organism appropriately, given the measurement. Sex, an activity with profound potential fitness gains, is especially rewarding. Generally, the magnitude of reward experienced is linked to the expected value of the benefits, denominated in fitness.

Symmetrically, unpleasant phenomenology is linked to potential fitness costs. Pain is, broadly, measuring damage, often tissue damage. The pain experienced when one has one's hand in a fire can be thought of as measuring the cost of the damage that is being done and motivating removing the hand to reduce further damage. Related, hunger gets increasingly unpleasant as the costs of continuing to go without food — the risk of starvation — increase. Unpleasant phenomenology is an index of experienced or expected costs, again denominated in fitness; the source of the costs are multiple and varied.

Set against this backdrop, the sensation of *effort* is mysterious. People report that engaging in behaviors that are, in the long run, adaptive — working on career-advancing manuscripts, practicing status-building skills, exercising at the gym, eating healthful foods, and so on — to be *un*pleasant (e.g. [7••]). Why does exerting effort, or self-control, feel bad rather than good?

The unpleasant sensation of effort drives what appear to be puzzlingly shortsighted decisions. Decisions to avoid tasks that are long-run-good — and effortful — are often made in favor of indulging in behaviors that are rewarding in the short term, including playing games, socializing (virtually or otherwise), and so on. Generally, many tasks that have been grouped in the self-control literature (e.g. [8]) have this property, being good in the long run (for health, professional achievement, etc.) yet evoking unpleasant sensations. To be sure, many tasks in this literature are not so naturally construed; the Stroop task (e.g. [9]), in which the subject's task is to say the color of the word they are presented with rather than the word itself, is an example. People find such tasks aversive, sometimes exceedingly so [10]; other than pleasing an experimenter, the benefits of performing these tasks accurately are unclear. In short, why are some behaviors that undermine long term success pleasant while those that facilitate it unpleasant?

Costs and Benefits of Effort

The idea that there is some cost to exerting effort [11] resonates with the proposal by Kool and Botvinick [7••], who suggest that the 'exertion of cognitive control' — roughly parallel to expending 'effort' — 'is intrinsically costly or aversive' (p. 131). On this view, cognitive effort is akin to working: people make the decision to exert effort depending on the incentives, in the same way a worker chooses to work depending on the incentives, typically wages. The alternative is not to exert effort, akin to consuming leisure, which is intrinsically rewarding. This view holds that the way to understand effort is that it reflects a choice that takes into account the intrinsic reward of leisure on the one hand and the combination, on the other hand, of the extrinsic reward and intrinsic costs of working. According to this motivational model [12•], people will stop exerting effort when they have reached the amount of effort they wish to exert, given these costs and benefits of doing so, explaining why people do not persist arbitrarily long on self-control tasks.

Inzlicht *et al.* [13•] draw on this model, but construe the phenomenology as a signal to stop doing what one is doing (see also [14]). They suggest that 'feelings of fatigue, boredom, and negative emotion... may serve the adaptive function of preventing fixation on current activities and redirecting behavior toward other activities with higher inherent utility' (p. 130; see also [15]). This proposal also suggests that people's decisions to engage in these aversive activities depends on external rewards, and that people balance the benefits of the rewards for persisting in effortful tasks against the costs of continuing. In terms of explaining why self-control diminishes over time, Inzlicht *et al.* [16] suggest that it is due to changes in motivation and attention; they propose that after exerting control, people 'notice and attend to cues associated with reward and gratification,' (p. 451) and so become 'less motivated to engage in further deliberative control and more motivated to engage in things that are more personally rewarding, interesting, and enjoyable' (p. 451).

A related view is that the relevant currency for the cost of exerting effort is *energy*. Boksem and Tops [17], setting their proposal in the context of understanding mental fatigue, suggest that 'fatigue can best be considered as an adaptive signal that the present behavioral strategy may no longer be the most appropriate' (p. 133) Whether or not the action is appropriate, in turn, depends on the energy required; they suggest that a decision about whether or not to take an action is 'based on the evaluation of both rewards and potential energetical costs of courses of action' (p. 129). A related view is that the availability of energy in the form of glucose acts as a constraint on exerting self-control ([18]; cites), though this view has come under robust criticism [19–23].

Kurzban *et al.* [24••] have advanced a similar proposal, but, according to this view, the costs of exerting self-control are neither intrinsic [25] nor energetic [17]. Instead, their focus is on opportunity costs. To see the structure of the argument, consider the habituation paradigm, used to measure what pre-verbal infants find novel. Day and McKenzie [26], for instance, presented infants with images of cubes from different angles, finding that their young subjects decreased their looking time at these cubes, as much as they did to a cube being presented from the same orientation repeatedly. The idea behind the use of looking time is that a tableau the baby finds familiar will be boring, and thus will not be worthy of much continued attention; a surprising scene, in contrast, merits more attention, in the same way that an adult might let her gaze linger on something they were not expecting to see. More attention translates to greater looking time indicates greater surprise; less attention connotes boredom.

A key function of the systems that direct attention likely has to do with the value of gathering information: information carries value, so organisms' brains have design features that motivate them to attend to more informative stimuli over less informative stimuli [27]. Boredom, on this construal, is the feeling the baby gets when little additional information is to be gained from continued attention [28,29]. The marginal benefit of attending elsewhere is greater than the marginal benefit of continuing to inspect the experimenter's scene. Foraging organisms move to a new patch when the opportunity cost of staying is overtaken by the expected benefit of moving on [30]. Similarly, *information foraging* organisms such as humans move on in an adaptive way. The (opportunity) cost of gathering no new information explains why boredom is unpleasant; looking away reduces this unpleasant sensation.

The habituation paradigm illustrates the problem of *simultaneity*. Because one cannot look in more than one place at once, looking at one thing carries the cost of looking at everything else. Related, some computational systems in the brain can, in principle, be used for many different tasks — for example, executive systems — necessitating decisions regarding which task to prioritize. Similarly, memory systems, which can maintain only a finite number data structures [31]. This limit requires decisions about which structures to keep in working memory.

According to the opportunity cost view, when systems that can be used for multiple purposes are engaged in a task, the potential benefit of ending the present task in order to perform some other task is computed. This