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What is the feeling of effort about?

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For agents like us, the feeling of effort is a very useful thing. It helps us sense how hard an action is, control its level of intensity, and decide whether to continue or stop performing it. While there has been progress in understanding the feeling of *mental* effort and the feeling of *bodily* effort, this has not translated into a unified account of the general feeling of effort. To advance in this direction, I defend the *single-feeling view*, which states that the feeling of effort is one and the same for both mental and bodily actions. This feeling represents the subjective costs, both mental and physical, of performing a given action. Cost-based approaches have recently become influential for the feeling of mental effort. Here I focus on arguing that our sense of bodily effort does not simply represent physiological processes, but rather represents the subjective costs of a bodily action. Through this paper I discuss the role of the feeling of effort (and affective states more broadly) in action guidance and the sense of agency. I also define efforts themselves in terms of the feeling of effort.

Keywords: metacognitive feelings, opportunity cost, value-based decision-making, subjective effort, objective effort.

1. Introduction

Philosophers have invoked the feeling of effort as central to understanding the experience of intentional action and the sense of agency (the experience of ourselves as agents in control of our actions (Bayne and Levy 2006; Pacherie 2008; Lukitsch 2020)). It is held to be a characteristic feature of the exertion of self-control and willpower (Holton 2009; Sripada 2021). And yet, despite its role in these philosophical issues, we lack a general theory of the feeling of effort. While there have been considerable advances in understanding the feeling of *mental* effort (Kool and Botvinick 2018; Carruthers 2020) and the feeling of *bodily* effort (Pageaux 2016), this has not moved us closer to a *general* theory of the feeling of effort.

Bridging these two literatures would benefit both, however. On the one hand, work on the feeling of bodily effort [FBE] has contributed to clarifying the nature of agentive phenomenology: FBE is held to be constitutive of the sense of motor agency, and particularly the sense of control over motor actions (Pacherie 2008); but so far it remains unclear how and to what extent the feeling of mental effort [FME] could contribute similarly to the sense of control over mental actions. On the other hand, FME has been used to explain the nature of value-based decision making, playing a crucial role in guiding the selection of action by helping the agent assess the subjective costs of an action, and thus deciding when to continue performing it, and when to stop (Kurzban, Duckworth, et al. 2013; Székely and Michael 2021); but so far it is unclear whether FBE makes the same contributions to action guidance and selection. Could the same feeling play both roles (contributing to the sense of control and to decision making)? Alternatively, should we accept that the expression 'feeling of effort' picks out multiple diverse feelings? While a plurality of feelings is certainly possible, a unified account of the feeling of effort is desirable not only for the sake of parsimony, but also because it would help provide unified accounts of phenomena like the sense of agency, willpower, and self-control, given the feeling of effort's explanatory roles in influential theories of such phenomena.

Clarifying the relationship between FBE and FME also promises to help understand the nature of efforts themselves. We constantly make efforts in everyday life (to lift heavy weights, to concentrate, to stop smoking, to stay calm, to understand others, to win games, etc.), and effort is used as an explanans for a wide range of phenomena, from the nature of action and free will to the origin of ownership and economic value, merit and distributive justice, and the nature of achievement. Despite this vast explanatory potential, definitions of effort are surprisingly scarce (Massin 2017; von Kriegstein 2017). In helping clarify the nature of effort, a unified theory of the feeling of effort would contribute to explanations of these phenomena.

A satisfactory unified account would require identifying the common properties that make apparently different forms of the feeling of effort (particularly FME and FBE) a unified kind. I propose below a description of such common properties. It is the task of a general theory of the feeling of effort to specify the relationship between FBE and FME; to assess their respective roles in the phenomenology and the guidance of action; and to clarify the relationship between efforts and feelings of effort. To advance toward these goals, I defend here the *single feeling view*, according to which the feeling of effort (1) is one and the same feeling, regardless of whether the action it represents is bodily or mental, and (2) represents the subjective costs of performing a given action.

The single-feeling view provides a path toward a definition of efforts, through the

> *feeling-first approach*: An action is an effort if, and only if, its execution is accompanied by a feeling of effort.

I will argue that this approach to the definition of efforts bypasses some of the thorniest problems one encounters when trying to define efforts: those involved in trying to unify mental and bodily efforts, as well as the mental and bodily components of an effort.

Before diving in, here are a few starting points. First, I adopt a widely shared view according to which *feelings are action-guiding*. A feeling is produced by an action-monitoring system whose function

is to generate dispositions to act in adaptive ways whenever it notices that survival- or wellbeing-relevant parameters deviate from an expected value (Tooby and Cosmides 2008; Proust 2015). This, I take it, is something that feelings of effort share with pain, thirst, hunger, and the like, but also with cognition-related feelings like boredom (Elpidorou, 2018) and curiosity (Carruthers 2018). Second, this presupposes that *feelings represent*; they are not mere qualia, but rather represent aspects of the situation in ways appropriate for action guidance.

Third, *feelings of effort are by default aversive*. They are negatively-valenced affective experiences. Evidence for this comes from the literatures on the law of least effort (Ferrero, 1894; Hull, 1943; Zipf, 1949), and the more recent evidence in favour of a law of least mental effort (Kool et al., 2010): in both the bodily and mental realm agents seem to select the effort-minimizing alternative, all else (particularly reward and reinforcement history) being equal.

Finally, it follows from the previous points that *by default feelings of effort guide agents toward minimizing effort*: they tend to motivate agents to stop the effortful action they are performing, or to reduce its intensity.[1]

2. The heterogeneity question

Discussions about the unity of mental kinds often must face worries about heterogeneity. A popular case is that of pleasure. In Plato's *Philebus*, Socrates famously remarks that pleasures are so diverse that it makes no sense to consider them a unified kind (12C-ff.). The pleasures we take in

[1] I say 'by default' and 'tend to' because we also sometimes display 'effort-seeking behaviour': we curiously explore our environments instead of sticking to the known path; devote leisure time to playing difficult games and pursuing demanding hobbies; and seek and maintain states of flow even if this requires exerting effort. Inzlicht and colleagues (2018) propose this tension between effort aversion and effort seeking generates a paradox: if feelings of effort are by default aversive, how is it that we also value and pursue some efforts? They also point to several ways in which the paradox can be dispelled.

eating something sweet, reading a poem, scratching an itch, and witnessing an act of kindness seem so different that they give rise to the heterogeneity question: "Is there some feature common to all sensory pleasures, in virtue of which they are pleasures? If so, what is it?" (Feldman 1988: 61).

A similar worry can be raised with respect to feelings of effort. They can accompany actions as diverse as solving a math puzzle, pushing a heavy object, stopping yourself from blinking, trying to convince someone, and coming up with a pun. Is there some feature common to all feelings of effort, in virtue of which they are feelings of effort? If so, what is it?

Part of what makes the heterogeneity problem salient for the feeling of effort is the distinction between bodily and mental efforts. The effort involved in running as fast as you can and the one involved in memorizing a 10-digit number seem to have not much in common. Thus one may be tempted to answer in the negative: mental and bodily actions are two different kinds of efforts, and to each of them corresponds a different kind of phenomenology. The former has a bodily location, is associated with the tensing of certain muscles, and is inseparable from the tactile sensation of some external object (the weight one tries to lift, the ground one pushes against to jump). Following work on the sense of agency, its function is to signal to the agent that control over the current action is precarious. The latter is cognitive, has no bodily location, is not linked to muscular feelings, and need not be linked to the sensation of an external object—it is a 'cognitive phenomenology' involving the direction of attention and the juggling of mental representations. Following work on value-based decision making, its function can be identified as helping the agent decide whether to exert mental control, and how intensely.

Defending the single-feeling view requires providing a positive answer to the heterogeneity question by showing that, despite appearances of a diverging phenomenology, there are features common to all feelings of effort in virtue of which they are that kind of feeling. In what follows I attempt to do just that. I begin (§3) by briefly talking about the representational content of FME.

Most of the paper (§4–6) will be devoted to assessing different accounts of what FBE represents. This will lead to (§7–8) a formulation of the single-feeling view, and (§9–10) a discussion of some of its philosophical implications.

3. What is FME about?

One may try to answer the heterogeneity question positively by identifying a shared resource whose allocation underlies both mental and physical efforts. It is clear that physical efforts require the expenditure of metabolic resources, so if a metabolic resource can be found to also underlie mental efforts, we would be well on the way towards a unified account of the sense of effort.

A recently popular metabolic view held that *glucose consumption* was the metabolic basis for mental efforts (Gailliot and Baumeister 2007). Corresponding with this account of efforts, a metabolic view of FME might state that the experience of effort arises when actions deplete glucose resources, leading to an experience of said actions as effortful. But the glucose hypothesis of effort has not held up to further examination (Dang 2016; Finley, Tang, and Schmeichel 2019). A general problem for all metabolic accounts is that the brain spends roughly the same amount of metabolic resources while at rest and while engaged in mentally effortful tasks (Kurzban 2010; Raichle 2015; Lieberman 2020). This presents a serious obstacle to any attempt to unify feelings of effort on the basis of a common metabolic resource.

Recently, accounts of FME have adopted an alternative perspective, linking the experience of mental effort to the subjective costs of performing a mental action (Kurzban, Duckworth, *et al.* 2013; Shenhav, Botvinick, and Cohen 2013; Kool and Botvinick 2018). The starting point for this approach is that higher-order cognitive capacities (attention, working memory, inhibition, etc.) are

limited.[2] Allocating these capacities to a given activity therefore has opportunity costs, that is, the costs of not benefitting from performing another task, or from resting and recovering. FME motivates us to disengage from a task when its subjective costs (including its opportunity costs) become too high, thereby contributing to optimizing the allocation of scarce cognitive resources.

This approach implies the existence of an 'expected-value calculator': a neural mechanism in charge of estimating and comparing a given action's expected costs (including opportunity costs) and expected benefits. Such estimations would be based on predictions of the costs and benefits of effortful control, derived through reinforcement learning of the rewards encountered in past type-similar situations. While these calculations would take place subpersonally, they would output the feeling of mental effort, which the agent could access at the personal level. The view that emerges from this approach can be captured as:

> *FME-Cost*. FME represents a mental action as unattractive, and its unattractiveness level corresponds to the subpersonal estimation of its subjective cost.

A detailed cost-based phenomenology of mental effort is yet to be developed, but we may speculate that the particular unattractiveness at stake here has to do with a sense that the task at hand is difficult and laborious, and therefore that succeeding in its completion would require an overly intense level of focus. When feeling an action as mentally effortful, one feels that one is approaching the limit of one's mental abilities (for concentration, information processing, or

[2] While there is agreement that these limitations exist, and they are clear in everyday experience, there is no agreement as to the causes and origins of these limitations. For discussion of possible sources of these limitations see Musslick & Cohen (2021).

sustained attention). This may be also accompanied by an increased salience of alternative actions open to the agent, which by comparison with the current task would look appealing.

4. FBE: The problem with metabolic accounts

Metabolic accounts may be expected to be more successful for FBE than for FME, since effortful bodily actions involve consuming metabolic resources. Here is a version of such an account:

> *FBE-Metabolic*. FBE represents an action as strenuous and demanding, where the level of strenuousness and demand corresponds to the muscular exertions of some metabolic resource located in a certain region of the body.

This view can explain why FBE is frequently localized in certain body regions, and is also supported by studies suggesting that effort intensity correlates with the concentration of lactate and other metabolites in the muscle milieu (Noble and Robertson 1996). FBE-Metabolic amounts to a form of *peripheralsm* according to which FBE tracks afferent signals (that is, signals coming from the muscles to the brain).[3]

FBE-Metabolic and similar views are susceptible to a serious objection: afferent signals are neither sufficient nor necessary for FBE. They are not sufficient, since the addition of lactate and metabolites in the blood (characteristic byproducts of the metabolic processes involved in muscular exertion) generates feelings of muscle fatigue and pain, but not feelings of effort (Pollak, Swenson, *et al.* 2014; Pageaux and Gaveau 2016; Bergevin, Steele, *et al.* 2021). Distinguishing effort from fatigue is important: feelings of fatigue involve a sense of tiredness or heaviness, and are associated

[3] There is a long-standing debate between peripheralists and centralists (according to which the feeling of effort arises from commands originating in the central nervous system, identifiable with commands of the will). For discussion see Jeannerod (1983), Massin (2017), and Marcora (2010).

with pain; in contrast, feelings of effort (or "perceived exertion", as the sports scientists refer to it) are sensations that a certain activity is strenuous or hard, but are independent of experiences of pain and tiredness. Additionally, researchers have shown that disrupting the activity of the supplementary motor area (a brain region whose activity is associated with the experience of effort) through transcranial magnetic stimulation significantly reduces FBE while keeping afferent signals unmodified. This further corroborates the view that FBE relies on signals originating from the brain, and not only on afferent signals (Zenon, Sidibe, and Olivier 2015).

Afferent signals are not necessary either. In a demonstration of this, Kjaer and colleagues (1999) significantly blocked transmission of afferent signals to the brain's motor cortex by administering participants epidural anaesthesia, and then asked them to maintain an intense level of exercise (indoor cycling) for a few minutes. Participants reported FBE increases during their exercise, despite the significant blockage of afferent signals.[4]

So afferent signals are neither sufficient nor necessary for FBE to emerge. In fact, the evidence collectively seems to suggest that changes in muscles, heart, and lungs fail to correlate with FBE and its intensity (de Morree and Marcora 2015). Against the metabolic account, we can thus conclude that whatever FBE is ultimately tracking, it does not seem to be muscle exertion.

Consider now two objections. First, even if muscle exertion is neither sufficient nor necessary for FBE, the former can still be said to constitute the representational content of the former. The case of perception is analogous: sometimes people see objects when there is no object there (as in the

[4] The aforementioned studies used anaesthesia to block particular groups of muscle afferents (groups III and IV), leaving open the possibility that FBE relies on a signal coming from some other afferent pathway. (I thank an anonymous reviewer for raising this possibility.) I lack the space to discuss this literature in detail here, so I refer the interested reader to reviews by Marcora (2009) and Pageaux (2016) which report multiple studies using a diversity of methods that support the conclusion that no afferent signal is necessary for the production of FBE.

case of hallucinations), and sometimes people fail to see objects even when they are there (as in the case of inattentional blindness); but it would be a mistake to conclude from this that the function of perception is not tracking objects in our environment.

Notice, however, that when perceptual experience fails to track objects it is appropriate to consider the perceptual system as misfiring or malfunctioning. This does not apply to the cases of FBE and afferent signals just discussed: the system in charge of producing FBE works just fine by not producing experiences of bodily effort when metabolites are injected in the muscles, since there was no exertion; it also works appropriately by producing experiences of bodily effort after a few minutes of intense exercise despite not registering afferent signals. The system's proper functioning is independent of such signals: it can reliably track the presence or absence of effortful activities regardless of whether it receives afferent signals or not. The evidence goes beyond showing that such signals are neither sufficient nor necessary for FBE (as would be the case for perceptual inputs in perception): it shows that afferent signals are not constitutive of properly functioning experiences of effort. Whatever the effort system tracks to reliably produce feelings of effort, it is not afferent signals.

Another objection is that FBE seems to essentially involve bodily location: we feel we are exerting effort with the right arm while lifting a dumbbell, with both legs while jumping, and so on. But bodily localization may not be as essential as it seems. In a stunning experiment, Lansing and Banzett (1993) generated full-body paralysis (using vecuronium) in four volunteers (including themselves) who were then asked to make a series of maximal bodily efforts. After recovering from paralysis, participants gave a structured interview of their experience. They reported that, despite trying to generate maximal muscular force, they could not locate their tryings in the target muscles (p. 310). Patient RB explained that "there was no arm sense of effort or diaphragm sense of effort […] all I felt was a generalized, 'I'm trying to move,' but nothing specific" (312), and several of

them described the experience as of making "a mental effort" (310).[5] These reports suggest, first, that body localization is not an essential feature of FBE: in some (admittedly special) circumstances, even when there is no experience of bodily localization, the phenomenology of effort still functions as it should: it conveys a sense of striving to do something difficult. Second, feelings of bodily effort have a mental, or cognitive, component (Preston and Wegner 2009), related to the experience of resisting an impulse to abandon one's action, even in the absence of precise bodily location. We will come back to this point.

At this point I should add I do not mean to suggest afferent signals play no role in standard FBEs. While not essential to the experience, there can still be significant associations between afferent signals and FBE, and such signals can still provide useful information for action guidance, particularly about the magnitude and the localization of the effort (Lafargue and Sirigu 2006).

5. FBE: Motor-control accounts

If FBE does not represent afferent signals, then it would be natural to suggest that it represents efferent signals produced in the central nervous system. But which efferent signal, precisely, would correspond to the feeling of effort?

Sophisticated accounts of FBE along these lines have been built using the comparator model of motor action (Frith, Blakemore, and Wolpert 2000). When an agent is to produce a goal-directed movement, it produces a motor instruction for the action's execution, and on the basis of this instruction the system creates a predicted state representation (a representation of the expected sensory feedback which the system should receive if the movement is successful). The system then

[5] See Shepherd (2016) for a discussion of this study in connection to the role of experiences of trying in intentional action production.

compares its prediction with the actual sensory feedback it receives, and if they do not match it generates a prediction error signal. Prediction error signals are used to revise and update both the motor instructions and predicted state representations.

FBE has been linked to motor prediction error signals (Bayne 2011; Lukitsch 2020). According to these views, FBE emerges from the agent's attempts to reduce prediction error as the action unfolds. More specifically, the sense of effort signals that the agent needs to exert control to maintain the action on course despite obstacles (Pacherie 2008). FBE is the sense that the action being performed is difficult, that its performance is precarious or unpredictable, and thus requires the agent to exert constant monitoring to keep the process on track towards the goal (Lukitsch 2020).

The motor-control model solves the issues plaguing metabolic models: afferent signals can play a role in determining the magnitude of the prediction error signal, but an absence of afferent signals still allows for the presence of FBE (since having no afferent feedback to compare to the forward model still generates a mismatch). Additionally, the account usefully locates FBE within a mechanism of action monitoring, which allows it to provide an explanation for FBE's action-guiding properties: the experience of effort signals that exerting or intensifying control is necessary to keep the action on track.

Recall, however, that the feeling of effort is by default aversive. It is widely agreed upon that it leads agents to disengage from a task, rather than to intensify control over it. So FBE should signal agents to stop performing the action, or at least to switch to another strategy for competing the task, or to reduce the intensity of control. The motor-control account seems to depict us as effort-seeking, instead of effort-averse. Thus, although it portrays FBE as action-guiding, it does not accommodate its affective dimension and seems to invert its action guiding role.

In response it may be said that the motor-control account need not claim that the sense of effort motivates us to increase control over action; FBE merely signals to the agent that an increase in control is needed *if* obstacles are to be avoided and the action is to be successful. Whether this leads the agent to persevering in the deployment of the current strategy by increasing the intensity of control, to switch to a different strategy, or to disengage altogether from the task would depend on other systems, particularly motivational and valuational ones.

It seems correct that a certain phenomenology associated with the sense of control plays this role of alerting the agent that the current action requires control intensification. But that is not the phenomenology of effort, which involves an evaluation of the action being performed as negative. As I argue in this section and the next, the action-guidance mechanism to which the feeling of effort belongs seems to operate at a different level than that of motor control. Some mechanisms operate at the *action implementation* level: they allow the agent to control the parameters of their movements in order to reduce, and ultimately eliminate, prediction error signals. These mechanisms enter into play once the agent has fixed a goal to pursue right now. Fixing, maintaining, and revising a goal are processes performed by mechanisms operating at the *action selection* level. This is the level where alternative actions (or alternative strategies to perform a given task) are valued and one action (or one strategy) is picked as the one to be performed right now. Action-selection mechanisms are not only in charge of selecting an action to initiate; they also specify whether an agent should continue performing a certain action, and when the agent should stop and do something else instead.

FBE's aversiveness makes sense if it is seen as playing a role at the action selection level: it motivates the agent to disengage from the action being performed, or from the strategy being pursued. Its action-guiding contribution is not in helping agents specify the correct level of control intensity,

but in helping agents select which action or strategy should be performed, and when a given action or strategy should be given up.[6]

So far, the models discussed locate FBE at the action implementation level, linking it to the motor commands controlling action execution, or to the physiological processes involved in action execution. In doing so, such models have trouble explaining how FBE's aversiveness contributes to action guidance. In the next section I propose that, to properly account for its action-guiding role, we must locate FBE at the level of action selection instead.

6. FBE: A cost-based model

The proposal is that FBE is a feeling related to *action valuation*: the process of attributing a value to actions and action possibilities. To see how FBE could be the product of a valuational mechanism that would in turn play a role in action selection, let us take a step back and think about FBE's aversiveness. Why do we (and pretty much all animals) tend to dislike effort? After all, much value can come to individuals willing to exert more effort than their peers.

From an evolutionary perspective, however, FBE's default aversiveness makes sense (Kurzban, Duckworth, *et al.* 2013; Lieberman 2020). Effortful physical activity consumes calories, but throughout evolutionary history, and only until very recently, calories were a scarce, limited

[6] It is worth clarifying that in order for FBE to play its role in the action selection process, the agent need not explicitly consider alternative actions to perform. This assessment of alternative actions can take place through sub-personal calculations of the expected costs and benefits of current and possible actions. These calculations would then output an affective signal (the feeling of effort) representing the action negatively. This would be enough to prompt the agent to assess whether the action should be continued or not, even if no alternative action is considered: simply stopping the action is a sufficient alternative. Of course, FBE could lead to agents explicitly considering alternative actions, but it need not do so. (I thank an anonymous reviewer for raising this point. For more on expected value calculators, see §6–ff.)

resource.[7] This entails that each effortful action had high opportunity costs: calories spent running, hunting, dancing, or hiking were calories not spent on maintenance, growth, reproduction or storage. Thus, effort aversion is adaptive since it motivates agents to avoid spending precious calories except when it really seems to be the best use of the scarce resource. In other words, the adaptive strategy is to avoid effortful action unless it is valued as having greater expected value than resting, energy storage, growth, etc.

It thus makes sense to posit the evolution of an *expected-value calculator*: a mechanism that uses multiple cues to compare the expected benefits and expected costs of each activity. These calculations are sub-personal, but output the feeling of effort, whose function is guiding conscious decision-making about action selection.

FBE would be able to do this by representing the subjective costs of action execution in an affective, valenced format. To put it succinctly,

> *FBE-Cost.* FBE represents a bodily action as arduous and unattractive, and its unattractiveness level corresponds to the subpersonal estimation of its subjective cost.

The expected value calculator can use a variety of signals as inputs for estimating an action's subjective costs. These inputs can include an estimation of the calories required by the action, but they include many more. In the case of motor actions, prediction error signals would help estimate

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[7] According to Lieberman (2020), a calorie can be allocated only to one of five functions: growing one's body, maintaining one's body, storing energy (as fat), reproducing, or executing physically effortful tasks. For humans in evolutionary times, on average nearly two thirds of calorie consumption would go towards maintaining their bodies (through pumping blood, breathing, digesting, fighting infection, growing nails and hair, nourishing and replacing cells, etc.). This leaves only one third of all calories for the other four calorie-intensive functions.

the costs of reducing prediction error. Afferent signals conveying information about lactate accumulation, muscle tension, and cardiovascular processes, would also be helpful inputs for subjective cost estimation. Thus the cost-based model can maintain the appeal of the prior models by preserving the links of afferent and prediction-error signals with feelings of effort. But it can also avoid their downsides: on the one hand, even when afferent signals are unavailable the mechanism still works properly, because what FBE ultimately represents is the action's subjective costs and their magnitude, not the action's afferent signals and their intensity. On the other hand, since the expected value calculator is at the level of action selection, the model can account for FBE's function as promoting action disengagement.

Additionally, the cost-based account explains the aforementioned point that, in the absence of afferent feedback, FBE is a sensation of mental effort. Physical efforts feel like striving against a resistance (Massin, 2017). Although we often identify this resistance with features of the external world (the heavy object's weight, the force of gravity, etc.), there also is an internal source: the tendency to avoid effortful action due to its subjective costs. Exerting physical effort requires overcoming this internal resistance, even if no *external* resistance is being registered. There is thus is a mental element built into all bodily efforts.

7. A unified cost-based view

Once one accepts a cost-based account of FBE, the distance between FBE and FME seems to fade. It increases the plausibility of a unified cost-based view, according to which

> *Unified-Cost*. There is only one feeling of effort for both mental and bodily actions. This feeling represents an action as unattractive, and its unattractiveness level corresponds to the subpersonal estimation of its subjective cost.

One may suspect, however, that the costs represented by FBE are different from those represented by FME. After all, the discussion above seems to imply that the former are related to the consumption of calories and the latter are not.[8] However, what Unified-Cost states is not that the feeling of effort represents a specific kind of cost, but rather that the feeling of effort represents an overall estimation of the action's costs. The costs estimated may relate to the allocation of calories or not, and they may relate to the allocation of limited cognitive resource allocation or not. The crucial point is that they represent the global estimation of the action's subjective costs, as reckoned by a general-purpose expected value calculator, which integrates multiple sources of information to estimate the subjective costs and benefits of agentive exertion in both the bodily and mental domains.

There is evidence supporting the existence of this unified expected-value calculator. At the neurophysiological level, a meta-analysis of 25 studies reveals a network of brain regions systematically implicated in the estimation of effort costs. In one particularly relevant study, Chong et al. (2017) had participants perform an effortful cognitive task and an effortful physical task. Then in an fMRI scanner they had to make choices between performing low-effort + low-reward versions of the tasks or higher-effort + higher-reward versions of the tasks. During decision times, for both mental-effort and physical-effort choices there was an overlapping activation pattern in critical regions associated with valuation: dorsal anterior cingulate cortex, dorsomedial and dorsolateral prefrontal cortex. This suggests that there is a domain-general expected-value calculator in charge of estimating the subjective costs of both bodily and mental actions. (A caveat is that the amygdala was significantly activated exclusively for mental-effort choice.) The view that cost evaluations rely on a unified neural population is also supported by both human (Schmidt,

[8] I thank an anonymous reviewer for raising this point.

Lebreton, *et al.* 2012; Westbrook, Lamichhane, and Braver 2019) and animal (Borderies, Bornert, *et al.* 2020; Bornert and Bouret 2021) research.

Behavioural evidence also supports the existence of a unified expected-value calculator: Lopez-Gamundi and Wardle (2018) provided participants with an effort selection task (allowing them to choose between low- and high-effort versions of a task) and found a significant correlation between the percentage of times people picked a hard vs. easy cognitive task (for example, task switching) and a hard vs. easy physical task (for example, rapid key-pressing). Thus, they found correlations in the way individuals value the costs of physical and mental effort: those who seek more mental effort also tend to seek more physical effort, and those who tend to avoid the one also tend to avoid the other (Tran, Hagen, *et al.* 2021; see also Bustamante, Oshinowo, *et al.* 2022). This correlation in individual differences suggests a unified process underlying the evaluation of both kinds of efforts.

Moreover, prior experiences of mental effort affect an agent's ability to perform subsequent physically effortful tasks, and vice-versa. After experiencing FME in a task, participants' abilities to perform a physical task are compromised (Brown, Graham, *et al.* 2020). And after experiencing FBE in a task, participants' economic decision-making is altered (Blain, Schmit, *et al.* 2019).[9]

[9] These interferences, however, need not amount to a global 'ego depletion' phenomenon (Baumeister, Bratslavsky, *et al.* 1998). From a cost-based perspective, this phenomenon is not explained by the depletion of a resource, but by valuation mechanisms seeking to optimize limited resource management. Additionally, the 'depletion' effects are not as general as proposed by the original ego-depletion theory. Prior mental effort reduces people's ability to *sustain* physical effort — although maximal effort remains unaffected (Brown, Graham, *et al.* 2020). Additionally, what seems to drive depletion is not the exertion of action, but the *subjective feeling of effort*: at the same level of difficulty and task performance, it is reports of feelings of effort that predict depletion effects. But these effects are local: for instance, it is not that after feeling effort participants fail to inhibit more frequently in an inhibition task, but rather that they lower their decision boundaries (Lin, Saunders, *et al.* 2020).

Finally, there is some evidence of FBE-FME convergence coming from facial expressions: both physical and mental effort present a similar pattern of frowning (Van Boxtel and Jessurun 1993; de Morree and Marcora 2010). This all suggests that the processes underlying FBE and FME are largely overlapping.

8. Existential commitment: Toward the single-feeling view

A number of recent accounts portray the feeling of effort in terms of the costs of action.[10] However, all other accounts focus only on FME, while *Unified-Cost* applies to feelings of effort *in general*. In this respect, it goes beyond the existing literature. But it shares with other accounts a problematic trait.

A problem for cost-based approaches is that they misrepresent a basic feature of the feeling of effort, namely that it is *existentially committing*: the sense of effort accompanies actions that are actually and currently occurring, not possible actions that may occur. But any account that identifies the feeling of effort with the output of a cost-benefit calculation must extend the application of said feeling to any representation of an action as costly, regardless of whether the action is actual or hypothetical. And yet, according to cost-based accounts, the function of the feeling of effort is helping the agent select among multiple possible actions by affectively representing their subjective costs. This no longer portrays the feeling of effort as existentially committing.[11]

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[10] For example, Székely and Michael (2021) claim that "the sense of effort is the output of a cost-benefit analysis [which] employs heuristics to weigh the current and anticipated costs of mental effort for a particular activity against the anticipated benefits", and Kurzban et al. (2013) state that "the phenomenology of effort can be understood as the felt output of […] cost/benefit computations" (p. 661).

[11] I thank Fabrice Teroni for raising this crucial point.

A cost-based theorist might reply that feelings of effort can be existentially committing in their account. To begin, recall that action selection mechanisms are in charge not only of action initiation, but also of action continuation, termination, and modification. Feelings of effort would thus be involved in guiding the agent in deciding whether to continue or stop the current effortful action being performed. In these cases, cost-based views respect the existentially committing character of the feeling of effort.

But this does not solve the entire problem. Both while cycling up the mountain and while imagining myself cycling up the mountain I can affectively represent the arduousness of the task. And while deliberating whether to perform actions A, B, or C right now, I might have an affective experience of the costs that would be involved in performing each of the candidates. A cost-based view seems committed to calling all these experiences instances of the feeling of effort, thereby failing to portray it as existentially committing.

To solve this issue while retaining the advantages of a unified cost-based account, it is necessary to introduce a modification to *Unified-Cost*:

> *Single-feeling view*. There is only one feeling of effort for both mental and bodily actions. This feeling represents an action as involving the resistance of an impulse to stop the action, and the impulse's strength corresponds to the action's estimated subjective cost.

According to the single-feeling view, cost-benefit calculations output, not the feeling of effort, but an *impulse* against performing the action in question at the specified level of intensity—in short, an impulse to stop the action. The larger the action's subjective cost, the stronger the impulse. If the agent chooses to execute an action despite its high subjective costs, the action will be felt as effortful, that is, its execution will be experienced as involving a *resistance* against an impulse to stop.

Thus, the feeling of effort occurs only while performing an action with high subjective cost, and resisting the impulse to stop is experienced by the agent as constitutive of this action.

To put it in more mechanistic terms, when the expected value calculator assesses the performance of an action φ as having a high expected cost, the agent will experience an automatic, impulsive tendency with a specific strength guiding them towards not φ-ing. If, despite this felt impulse, the agent forms the intention to φ right away, and begins φ-ing, then their φ-ing will be accompanied by a feeling of effort, that is, a feeling that in φ-ing she is resisting an impulse to stop φ-ing. This sense of resistance corresponds to the experience of inhibiting the automatic impulse against φ-ing.

Thus, according to the single-feeling view, the feeling of effort is not the experience of a subjective cost (as cost-based theorists may have it), but rather the experience of resisting a felt impulse to stop performing a given occurring action. The single-feeling view portrays the feeling of effort as existentially committing, since the feeling of resistance occurs only while the agent is resisting. At the same time, it also retains the strengths of cost-based accounts by characterizing the impulse to stop in terms of subjective cost estimations, and relying on a general-purpose expected value calculator for the production of these estimations.

Additionally, the single-feeling view can explain why all FBEs include an element of mental effort, since the sense of struggle captures the cognitive process of inhibiting an automatic tendency to stop the action. The stronger the resistance, the more intense the effort must be in order to be successful.[12] Carruthers (2020) has argued that feelings of mental effort are explicit metacognitive

[12] It is understandable why cost-based accounts focus on cost signals despite being existentially non-committing. These signals play a key role in action selection cases in which the agent is not yet acting but deliberating about which action to perform, e.g. whether to select a high-effort, high-pay or a low-effort, low-pay action. This is exactly the setup of many laboratory tasks designed to test mental effort decision-making (Kool & Botvinick, 2018). Such situations are

states, since they are affective evaluations of a cognitive process and all evaluations must explicitly represent the evaluated object. The single-feeling view identifies the feeling of effort not with the evaluation itself (since that would break ontological commitment), but with the experience of resisting an impulse, which in turn represents an action as costly and to-be-stopped. This entails that all feelings of effort are *meta-representational*, because the impulse to stop the action includes a negative evaluation of the action. Whenever the represented action involves a cognitive process, the feeling of effort is metacognitive. As Carruthers points out, this is the case in all instances of FME, but it will also hold for many FBEs, since bodily efforts often require significant cognitive processes (like directing attention or precisely coordinating multiple movements).

The single-feeling view has several important upshots. For one, it clarifies the phenomenology of mental and physical efforts. FBE and FME turn out to be essentially the same feeling, even if they may differ in some nonessential features. The core dimensions of the feeling of effort include: (1) A *valence* dimension, along which the effortful action is always represented as more or less arduous or unattractive, (2) an *impulse-intensity* dimension, which represents the action's current degree of unattractiveness, and (3) a *resistance-intensity* dimension, which represents the strength of the control signal currently deployed to overcome the impulse. Other common, but not essential, dimensions of the feeling are bodily location (proprioceptive sensations signalling that the action is involving tension, movement, and exertion of certain muscle groups), signals related to the need for control (a feeling that the action's successful completion requires intensifying control), and the cognitive

helpful to establish how participants assess the costs of mental effort, but during the deliberation phase there is no feeling of effort, but rather feelings of resistance corresponding to the costs of the considered actions. Thus it turns out that many empirical studies purportedly on the sense of effort may be measuring the sense of resistance instead.

phenomenology of focus and representation manipulation associated with effortful mental operations.

Insofar as the single feeling view is compelling, it supports the claim that the term 'feeling of effort' picks out a unified kind, namely a kind of feeling characterized by the three core dimensions just mentioned. Despite appearances that FME and FBE constitute two distinct kinds of feelings, the fact that they share these core properties strongly suggests they both belong to the same kind. This unified view of the feeling of effort is attractive not only on grounds of parsimony, but also because it contributes to making progress on thorny philosophical issues involving the sense of control and the nature of efforts themselves. The next sections discuss these two upshots of the single-feeling view.

9. Philosophical upshot: FE and the sense of control

According to the motor-control account, the feeling of effort [FE] is constitutive of the sense of control. Emerging from motor prediction error signals, it conveys to the agent the need to exert or increase control. The single-feeling view inverts this relationship, turning the sense of (needing to exert) control into a proxy that can be used to estimate the action's subjective cost and thus the intensity of FE.

This coheres with the point that, while the sense of control works at the level of action implementation, the sense of effort works at the level of action selection. Once an action is being executed, FE guides agents toward deciding whether it makes sense to continue or stop its performance, to decrease or increase its intensity, and whether the strategy one is implementing should be revised. Thus, FE is not in the business of action implementation, but in the business of action valuation: guiding decision-making toward the most valuable use of our limited capacities and resources, both physiological and cognitive.

That said, the insight that FE is linked to prediction error signals is accurate, even at the action-selection level. While the agent performs an action, negative error signals about its subjective costs would increase the intensity of the action-related feeling of effort. Thus, the expected-value calculator is a comparator mechanism that works on the basis of the outputs of other comparators. Specifically, it is a general-purpose comparator that receives inputs from other motor and metacognitive comparator systems (like those in charge of assessing fluency, error, etc.).

10. Philosophical upshot: Defining efforts

In the burgeoning debate about how to define efforts (Massin 2017; Bermúdez and Massin 2023), the most promising positions are *resource-based approaches*, according to which an effort is the consumption or allocation of a limited resource in order to execute an action; and *force-based approaches*, according to which an effort is an agent's goal-directed exertion of a force against some resistive force.

There is one complex problem plaguing both approaches: providing a unified account of mental and bodily efforts. For resource-based approaches, this would entail identifying a common limited resource underlying both mental and bodily effort exertion—a tall order given the problems for these kinds of accounts mentioned above (§3–4).[13] Force-based approaches, in turn, would have

[13] To see the philosophical relevance of this issue, the central role that effort plays in theories about the value of achievements. Some theories either assume that effort is a primitive, and therefore undefinable, notion that is intuitively clear (Bradford 2015), but the notion is too ambiguous and theoretically complex to leave without a precise definition (von Kriegstein 2017). However, the most developed definition of the notion in the achievement literature, proposed by von Kriegstein (2017), is based on the assumption that either there is a resource common to mental and physical

to provide an account of mental forces that identifies them non-metaphorically with some entity in the cognitive and neural ontology, and then explain how physical and mental forces interact.

The single-feeling account bypasses the unification problem. Following a *feeling-first approach*, according to which one first defines the feeling of effort and then defines efforts by reference to the former, if the *feeling of effort* represents the currently executed action as involving a resistance of an impulse to stop, then *efforts* can be defined as actions that are accompanied by the feeling of effort. One may add that the intensity of the effort exerted is then determined by the intensity of the feeling of effort.

This solves the unification problem, at the cost of admitting that there is no lower-level unification of efforts in terms of mechanisms, resources, or forces. The nature of efforts is defined at the phenomenological level of FE and the subpersonal mechanisms that produce it by estimating the action's subjective costs; no further underlying commonalities unify all efforts. Every effort requires using some resource, and at least some efforts can be explained by reference to forces, but there is no unifying account that links all and only efforts by reference to a common resource, or a force model that can be used to explain all and only efforts.

Despite appearances, this account is not excessively subjective. Just like noetic feelings reliably co-vary with mental conditions (the feeling of knowing, for example, tracks the presence of first-order states of knowledge; see Dokic 2012), similarly agentive feelings like the feeling of effort reliably co-vary with agentive conditions. Feelings of effort track the costs of the action according to the

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efforts, or the multiple resources underlying them are commensurable. For the reasons discussed above, this assumption does not seem tenable. Thus, to the extent that achievement discussions are based on a notion of efforts, they are all built on unsteady grounds until a unification of mental and bodily efforts is found that is not based on positing a common resource.

best estimates available given the agent's current state and prior experience. So they can be considered to track the actual allocation of physiological and cognitive resources and other sorts of costs in a more or less reliable way. That said, the account also allows us to make sense of different effort profiles between people and within a single person at different times. Performing the same, difficult task requires more effort after a long, exhausting day than after a good night's sleep, even if the agent allocates the same resources, deploys the same forces, and meets the same external resistance. To explain such variabilities in effort, other accounts would have to introduce novel elements like second-order efforts, but a feeling-first account can accommodate these variations by appealing to the same mechanism: the expected-value calculator takes into account signals about the agent's current state and past experiences, so FE represents these features too.

In bypassing the unification problem, the single-feeling view can account for two powerful features of efforts and their feelings. First, agents can compare the magnitude of efforts across the boundaries of body and mind: a single agent can compare how much effort lifting a heavy weight, singing an intricate melody, or performing a complex calculation requires from her, by comparing the feelings of effort that each action elicits. Second, agents can use those effort comparisons to assess which among bodily and mental actions maximize expected value. Thus the single-feeling view is free from the unification problem, and that allows it to explain how the experience of effort can play its role in guiding action selection.

11. Conclusion

Theories of the feeling of effort are divided between the physical and mental realms. This awkward dualism is unnecessary, however. Once explanations of the feeling's origins and functions are examined, it becomes clear that there is only one feeling of effort common to our mental and bodily strivings. This single-feeling view can be defended without denying the phenomenological differences between diverse efforts: while different efforts may feel different, they are unified by

the fact that they all feel like resisting an impulse to stop the action. Additionally, they are unified by the function this feeling plays in our agential economy: providing us with crucial information about our action's cost, which allows us to make informed decisions regarding how we choose to allocate our limited agentive capacities.

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