What is (perception of) effort?

Objective and subjective effort during attempted task performance

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Abstract

Despite its apparent intuitiveness and widespread interest across various fields, ‘effort’ is a concept that seems difficult to define. The purpose of this article is to consider and define ‘effort’ during attempted task performance. In doing so I argue for distinction between the *actual* effort (objective effort) required, and the *perception* of that effort (subjective effort), during intentionally attempted task performance. I adopt a set theoretical approach to defining the intensional concepts, and extensional phenomenal constructs, and employ the tradition of Theory-Theory to illustrate tentative causal theories for and relating the concepts. The definitions I propose are deliberately agnostic of the specific task demands being attempted (e.g. physical, cognitive, self-control, or a combination) and thus reflect ‘general’ definitions of effort and its perception. Throughout, I draw upon and synthesise literature from across a multitude of disciplines, combining empirical evidence with armchair philosophising, and offer what insights I have from my own experience both as someone experiencing ‘effort’, and as a third-person observer investigating it. This work is intended to, at the very least, make my own current pretheoretical conceptualisation and understanding of ‘effort’ transparent to other researchers, and aid interpretation of subsequent empirical work, theory building, and theory testing on the topic. Further, I hope it might be useful to researchers across various fields, unify paradigms and help with integration of learnings across disciplines, and further understanding of the role of ‘effort’ and its perception from a broad scientific perspective.

Introduction

“There is no greater impediment to the advancement of knowledge than the ambiguity of words”
(Thomas Reid, 1852. *Essays on the Intellectual Powers of Man*)

Effort, that eponymous term of task attempts (physical, cognitive¹, self-control etc.; Preston and Wegner, 2009; Massin, 2017), is a concept that seems difficult to define despite being seemingly intuitive to many. Its distinct phenomenology appears easily recognisable; the fact that we seem capable of perceiving when we ourselves are employing it, and identifying it when others do the same. Given everyone’s somewhat tacit understanding, in addition to its history (briefly reviewed below), you might be forgiven for thinking that there is consensus at least on the character of the concept (Richter and Wright, 2014; Massin, 2017). The origin of the term apparently comes from the old French portmanteau of the Latin ‘ex-’ meaning ‘out’, and ‘fortis’ meaning ‘strong’; *esforcier* (or *esfort*,

esforz). However, the Oxford² (“A vigorous or determined attempt”) and Cambridge³ (“physical or mental activity needed to achieve something”) English dictionaries definitions of effort are somewhat vague, at least from a scientific perspective. Indeed, most scientific disciplines with interest in understanding it seem at a loss for an adequate definition.

Effort has been a source of interest to scientists and philosophers for some time. Indeed, wu wei (Chinese: 無爲; pinyin: *wú wéi*), literally meaning “in the absence of/without doing exertion” or “effortless action”, was a concept that emerged from Confucianism and became an important aspect of Daoism (Slingerland, 2003): “Act without action; work without effort” (Laozi, Dao De Jing, Chapter 63, cited in Lee et al., 2009). In Ancient Greece the spirit Horne (Ancient Greek: Ὀρμή, pronounced Ormí) personified energetic activity, impulse, or effort (to do a thing), and an altar was held to her in Athens (Pausanias, 1918). The concept of willed effort was central to much of the work of early French philosopher Maine de Biran (1805). An-

¹ Note, I use the term ‘cognitive’ in lieu of the term ‘mental’. As noted by Bruya & Tang (2018), most researchers agree upon the general reductionist desideratum that cognition has its origin in physiological processes in the nervous system and that the term ‘mental’ may be misconstrued as supporting a dualist conception of the body and mind.

² <https://www.lexico.com/definition/effort> [accessed 2nd June 2020]

³ <https://dictionary.cambridge.org/dictionary/english/effort> [accessed 2nd June 2020]

Figure 1. Usage of the words ‘effort’ and ‘exertion’ as a percentage of all books in the Google NGram corpus (<https://books.google.com/ngrams>)

other, Henri Bergson, revived many concepts of Biranian philosophy and psychology, in combination with aspects of Hellenistic thought; Hercules, the hero-god of the ancient Cynics and Stoics (Kotva, 2016). Indeed, there was a religiosity and mysticism in this such that Bergson thought “...*effort is of God, if not God [H]imself*” [my insertion⁴] (Kotva, 2016). Around the end of the 19th century a considerable body of work was conducted regarding the notion of effort in both physical and cognitive tasks. Bastian (1887) coined the term ‘kinaesthesia’ which encompassed not only the sense of movement, position, and muscle force or tension, but also the ‘sense of effort’. Although, there was considerable debate (which continues to this day) regarding where the sensory signals came from for the feeling or perception of effort (i.e., its phenomenology); some argued for its central origin (e.g., Bain, 1855; Helmholtz, 1866; Müller, 1842, Wundt, 1902), while others supported a peripheral source (Bastian, 1896; James, 1880, 1890). Around a similar time, the French philosopher Guillaume Ferrero discussed the role of effort in regulating human behaviour (Ferrero, 1894) and John Dewey (1897) wrote on the psychology of effort. Both Ach (1910; 1935) and Hillgruber (1912) in the early 20th century considered the role of the ‘will’ to overcome performance barriers. Effort as a concept involved in work was discussed in the 1940s by Hull (1943) and reviewed two decades later by Lewis (1965). Further, in the 1950s, von Holst and Mittelstaedt (1950), and Sperry (1950), both independently proposed (in agreement with earlier thought), that signals relating to motor commands (efference copies)

helped clarify whether sensory signals received from motor action where a result of volition or from external environmental forces (i.e., did I move my arm, or did someone else?). In 1973 Daniel Kahneman published his influential book *Attention and Effort* claiming that the two were in essence synonymous. Later, Brehm and Self (1989) formally described what is known as Motivational Intensity Theory; in brief, this suggested that how much effort someone is willing to put into achieving a given task is dependent upon what is termed their ‘potential motivation’. Regarding measurement, development of the first psychophysical scales for the perception of effort⁵, relating to the perception of ‘heaviness’ of activity, occurred in the 1950s (Stevens, 1957). However, at least in relation to physical tasks, nowadays people are mostly familiar with the scales developed by Gunnar Borg from the 1960s onwards (Borg, 1998). In the 1980s a multi-item scale for measurement of workloads, including effort, was developed for the National Aeronautics and Space Administration (NASA; Hart and Staveland, 1988). Lastly, it has been thought for some time that effort is inherently aversive; the “Principle of Least Effort” (Zipf, 1949). Yet more recently, others have discussed effort as being something of inherent value (Massin, 2017; Maharaj, 2017). A more balanced perspective argues that effort can be costly *or* valued dependent upon individual and contextual factors (Inzlicht et al., 2018).

General interest in effort, based upon usage of the term in books analysed using Google Ngram over the past ~200 years has increased (figure 1). Scientific interest in effort of all kinds (effort and the related

⁴ The misuse of lower case ‘h’ in referring to God in the original quote was pointed out to me by one of my PhD students, Emily Budzynski-Seymour, for which I am thankful.

⁵ They actually referred to perceived ‘exertion’ similarly to Borg – see later for a discussion of perceptions of ‘effort’ vs ‘exertion’, in addition to their distinction from ‘heaviness’

Figure 2. Number of articles using the words (top) 'effort' and 'exertion', (middle) 'physical AND effort' and '(cognitive OR mental) AND effort', and (bottom) '(objective OR actual) AND effort' and '(subjective OR perceived OR perception of) AND effort' as a proportion of all articles in Europe PMC (using the "europepmc" package - <https://cran.r-project.org/web/packages/europepmc/europepmc.pdf>)

term ‘exertion’, both physical and cognitive task efforts, and both objective/actual and subjective/perceived efforts) appeared to be most intense across the 19th century (figure 2).

After the Second World War there was a decline in productivity, as with many other fields. However, in the past two decades there has been a resurgence and growth of interest. In recent years, effort has been studied across many fields including: philosophy, cognitive and social psychology, neuroscience, clinical symptom testing, economics, ergonomics, project management, translation and editing, speech, language and hearing, robotics and artificial intelligence, and kinesiology to name but a few (e.g. Rosenbaum & Gregory, 2002; Parfitt and Hughes, 2009; Smirnaul et al., 2013; Pageaux, 2014; Fisher and Steele, 2014; Bigler et al., 2014; de Morree and Marcora, 2015; Abbiss et al., 2015; Shepherd, 2016; Cha et al., 2015; Shadmehr et al., 2016; Pageaux, 2016; Steele et al., 2017; Cos et al., 2017; Morel et al., 2017; Shenav et al., 2017; Massin, 2017; Picou et al., 2017; St Clair Gibson et al., 2018; Inzlicht et al., 2018; Charness et al., 2018; Scarton et al., 2019; Andre et al., 2019; Steele et al., 2019; Halperin et al., 2020; Cheval and Boisgontier, 2021). Across these disciplines there has been exploration and description of the phenomena of effort, in addition to its inclusion in numerous theories or models. Interests in the role that effort plays are often similar, despite the varied fields to which the concept is applied, for example: what sensory signals give rise to the phenomenological experience of effort? Which factors determine selection and initiation of behaviour? What determines behavioural persistence in task performance attempts? What are the underlying mechanisms involved in carrying out task performances? How do people adapt to the continued attempted performance of task behaviours? etc. Further, much of the work in these areas necessarily intertwines with other cognate concepts including ‘trying’, ‘forces’, ‘resistance’, ‘demands’, ‘work’, ‘difficulty’ etc.

My focus in this work is conceptual definition, and the value that presents in helping diverse fields further knowledge on ‘effort’. Without clear definition of concepts, theory formation is without its basic building

blocks (Dubin, 1969) hampering development in these varied fields. Further, without clear conceptual definition it is folly to think that operational definition of valid empirical indicators can follow to enable the propositions of developed or existing theories including effort to lead to testable hypotheses (Dubin, 1969; Gerring, 1999; Chang, 2004; Wacker, 2004; Wakefield, 2004)⁶.

Considering the diverse interest in the concept of ‘effort’ it has been noted that, though many specific ‘species’ of efforts have sometimes been operationally defined (that is to say, within specific fields and in certain applications or tasks), there are few if any *explicit* ‘general’ conceptual definitions⁷ of the term that could be applied across fields (Massin, 2017). I am in agreement with others (Massin, 2017; Bruya and Tang, 2018), who have argued that the lack of such a definition impedes interdisciplinary collaboration and the integration of findings from across fields; and further, has the potential to promote misunderstanding. Indeed, considering the Kuhnian doctrine of incommensurability (Kuhn, 1962) we might reasonably say that these fields, despite using the same words, are not expressing commensurable propositions in their varied theories further rendering incommensurability in tests of their hypotheses.

Massin (2017) recently took up the effort⁸ of producing a general definition for ‘effort’. The specifics of his definition and arguments will be touched upon throughout this article where I find myself both in agreement and disagreement in places; I note though that his work is admirable and certainly the first to my knowledge that has attempted such a challenging task. Initially, he notes that some may object to the determination of a definition prior to empirical investigation, though he makes a case for the role of armchair philosophising⁹ in determining a definition for effort. Some truths about it are clear. For example, he notes several things which to him seem plainly self-evident regarding effort:

⁶ Notably here I do not subscribe to what might be called the ‘strong’ version of operationalism from Bridgman’s (1927) but the softer views of later work (see Chang, 2004).

⁷ I confess an early and specifically frustrating example of lack of explicit conceptual definition comes in the early work of William James (1880) in *The Feeling of Effort*. In it he continually refers to “*effort properly so called*” without any such conceptual, or even operational, definition of the term.

⁸ Yes, that is intended to be a pun... Conceptual analysis of this sort can be heavy going. So, to make this more enjoyable to read be prepared for injections of light heartedness in this article including robots, zombies, comic books, wizards, videogame cheats etc. Note though, that these are all included with seriousness to help more clearly express the arguments contained herein.

⁹ Of the sort I engage in throughout this article, albeit interleaved with reference to empirical work including my own.

- “Effort is not a planet”¹⁰
- “Efforts are not feelings”¹¹
- “Efforts are actions”¹²
- “Efforts can fail or succeed”
- “Efforts are always exerted against some resistance”
- “Efforts are always made to reach some goal”¹³
- “The intensity of efforts is not a function of their failure/success”¹⁴

He makes a case for the provision of a definition prior to empirical investigation noting there are concerns with attempting to do the converse (that is empirically investigate before defining *what* it is we want to investigate):

- *The practical impossibility of investigation:* How are we to look for something we have no idea about?¹⁵
- *The theoretical impossibility of mistake:* Whatever is found can be claimed to be exactly what we were looking for.
- *The epistemic impossibility of disagreement:* If it cannot be characterised independently of varied empirical investigations, no two explanations could ever conflict as no two would be about the same explanandum.

However, we should be cautious of putting the cart before the horse, or indeed trying to define the cart or horse before looking to adequately describe them as phenomena. As Dubin (1969) notes, description is essential in developing the units (concepts) to be used for building theory, yet he differentiates description from definition:

“Without adequate description, we would not have models that connect with the world that man perceives and about which he theorizes. This statement, of course, suggests that description is to be distinguished from definition. An adequate definition is fully descriptive of that which it denotes. What is indicated by the

definition, however, may have no counterpart in the experiential world of man. Such a defined unit may very well be included in a theory. It is a scientific theory, however, only if some of the units employed in its construction have empirical counterparts on which values may be measured. If all the units of a theory are defined but not linked to the real world, then we are dealing with a belief system, not a scientific theory.”

Given the premium placed on theory development and testing in science, and that as noted effort is employed as a unit in many theories across diverse disciplines, ensuring its definition is extensional of some described phenomena based in reality is key. Though we could engage in purely philosophical analysis from the arm-chair to determine a conceptual definition for ‘effort’, this would be nothing more than a floating abstraction. However, a combination of both approaches ensures that conceptual definition is formally defensible yet tethered down to reality.

What’s in a Word

“It is words that are to blame. They are the wildest, freest, most irresponsible, most unteachable of all things. Of course, you can catch them and sort them and place them in alphabetical order in dictionaries. But words do not live in dictionaries; they live in the mind”

(Virginia Woolf, 1937. *Craftsmanship* [BBC Broadcast])

As already noted, the lack of clear definitions for the words used as labels for the concepts we build our theories upon precipitates an incommensurability across scientific fields (Kuhn, 1962). Without an agreed upon definition of ‘effort’ it will remain a possibility that researchers from different fields, and even within the same field, use the term to refer to distinctly different phenomena (Gerring, 1999; Wacker, 2004; Wakefield, 2004; Haslam, 2016; Massin, 2017; Knudson, 2019; Fiske, 2020). Using the Tower of Babel and considering Forscher’s (1963) parable “Chaos in the Brickyard”, Knudson (2019) notes that in kinesiology

¹⁰ Though, see later a ‘tongue in cheek’ example wherein we might imagine a planet that could ‘experience’ effort, and may even have a perception of its efforts.

¹¹ As will become clear, I agree with this in the notion that effort is an objectively definable phenomenon which we can, but may not always, have a feeling or perception of.

¹² On this I also agree, but caveat that this does not imply they need a conscious actor.

¹³ Similarly, to footnote ¹⁰ this ‘goal’ does not have to be a goal in the sense of that sought by a conscious actor. Just that they are directed at, or toward something.

¹⁴ Though it also seems reasonable to me that in ‘most’ tasks the intensity of effort likely modulates the probability of failure/success

¹⁵ He notes “Meno’s paradox” in this regard (Plato, *Meno*, 80d, in Cooper, 1997: 880)

the lack of consistent nomenclature likely results in researchers erecting their own sub-disciplinary ‘walls’ or piles of unconnected ‘bricks’. These have little connection to other walls in the ‘tower’ of the field’s knowledge. One might extend the metaphor further to say that they also lack ‘bridges’ between the towers of each field’s knowledge to enable them to cooperate with one another in an interdisciplinary fashion; there is a paradigmatic ‘castle’ missing.

Particularly for scientific fields that seek to create abstractions to explain reality, common language is a prerequisite for clear communication (Starosta and Petrynski, 2007). Indeed, this is a problem for fields like psychology and other social sciences that deal with malleable concepts; what Hacking (1995) calls ‘human kinds’ as opposed to the ‘natural kinds’ of the ‘harder’ sciences. Such concepts can ‘stretch’ (Osigweh, 1989) and ‘creep’ (Haslam, 2016) in their definitions.

In an attempt to leverage an agreed upon definition it might make sense to begin with the dictionary definitions of the term. Though, as noted, at least those in English appear to be vague in their description. Further, as Fiske (2020) notes in his discussion of the ‘lexical fallacy’ in emotion research:

“... it is not uncommon for psychologists to begin an article by quoting a dictionary definition, as if an entry in a dictionary or vernacular language consisted of a psychologically, socially, or culturally valid construct that extends beyond linguistic usage... lexicographers merely record how people use words; they make no claims about what’s in the real world beyond language.”

I contend most of the fields interested in effort are not interested in the word usage¹⁶, but instead in a scientific understanding of ‘effort’ itself. In fact, this desire not merely to identify facts pertaining to ordinary language has arguably been the *modus operandi* of the social sciences for some time. As Durkeim (1964 [originally 1895]) suggested:

“It is not our aim simply to discover a method for identifying with sufficient accuracy the facts to which the words of ordinary language refer and the ideas they

convey. We need, rather, to formulate entirely new concepts, appropriate to the requirements of science and expressed in an appropriate terminology.”

Though I am reluctant to *a priori* presume I will be successful in doing so, I am interested, as I believe many others are, in understanding whether or not a concept of ‘effort’ can be produced that describes some a ‘natural kind’¹⁷. Conceptual analysis, though it can be complimented with empirical research of professional and lay language use, is often couched within a given theory and some even suggest concepts are defined by the theories within which they exist (Meehl, 1978). Others have contested this and argued conceptual analysis is a valuable pursuit that can occur independent of theory (Wakefield, 2004; Wakefield, 2007), and in fact concepts are the units of good theory building (Dubin, 1969). Indeed, I will to some extent attempt to outline a clear ‘theory’ of effort as a concept itself in the tradition of Theory-Theory (Murphy and Medin, 1985). As Keil (1989) proposes:

“[m]ost concepts are partial theories themselves in that they embody explanations of the relations between their constituents, of their origins, and of their relations to other clusters of features.”

Though I will refer to others terminology and definitions throughout this article, I aim to try and avoid the ‘lexical hang-ups’ that come with reifying existing word usage, both in lay and scientific language, merely because it is common. Indeed, Fiske (2020) further points out the ‘linguistic chauvinism’ of assuming that *“English, alone among languages, fortuitously captures a scientifically valid taxonomy... Does the English lexicon get [effort] right, cutting nature at its joints, whereas 7000 other languages fail to do so?”* [my insertion]. Many languages have words that might be translated to ‘effort’ which may or may not have polysemy, and may or may not have colloquial synonyms: for example, ‘exertion’¹⁸.

Science is a cross-language and cross-cultural endeavour and the language it uses to communicate must not fall prey to lexical fallacies irrespective of their linguistic origins. In this sense, one could be so bold as to begin by suggesting that we drop the term

¹⁶ Though appreciably this may in fact be an interest of some specific fields such as linguistics.

¹⁷ As Fiske (2020) notes in reference to their work on *kama muta* *“Of course, our stipulation may turn out not to delineate a natural*

kind, but we hope that explicating the construct as clearly as possible will enable us to find out – and thereby incrementally delineate more valid approximations...”

¹⁸ An example of the issues caused specifically in kinesiology regarding recent debates upon perceptions of ‘effort’ or perceptions of ‘exertion’ is noted as a later section.

‘effort’ entirely choosing a new term that is not marred with historical lexical baggage. Fiske (2020) termed the emotion of his groups research focus *kama muta* using the dead Sanskrit language to avoid the issues of using an existing vernacular lexeme. For my endeavour, it could be as simple as using a typographical symbol instead to denote the concept (e.g. E, Ε, ϕ, or μ etc.) which maybe more felicitous. Or similarly to Fiske (2020) we could also use a dead language translation of ‘effort’ (Latin – Conatum; Old English – Anginn; Sanskrit - Thital), or adopt the term *Horme*¹⁹ in recognition of the Ancient Greek spirit. Though I am inclined towards this idea due my belief that clear definition of the ‘concept’ and extensional ‘construct’ is of greater importance than the label we give to it (Markus, 2008; Slingerland, 2003; Fiske, 2020)²⁰, there are some practical concerns in following it through (Gerring, 1999; Fiske, 2020). Adopting a novel term potentially limits communication with those who already use the existing terminology, and it is a tall demand to expect researchers across fields to begin to utilise this new term. Indeed, Gerring (1999) considers two of his eight criteria for what constitutes a ‘good’ concept to relate to the term used itself. This includes its ‘resonance’ (“Does the chosen term ring?”) and ‘parsimony’ (“How short is... the term...?”). His criteria of ‘familiarity’, though primarily in reference to the definition itself, also applies to the term. Thus, though I am partial to adopting the term *Horme*, I will for the sake of ease of communication continue to use the term ‘effort’ in this article; but I stress that the definition, and not the label, is in my opinion the more important component.

Unsurprisingly, despite varied folk notions and both colloquial and scientific uses of the term, few have explicitly clarified whether they considered effort as being a fundamentally objective or subjective phenomena: that is, distinguished between *actual* effort and *perception* of that effort. Implicitly at least, in many cases effort is typically (though not always) considered as one or the other. Certainly, within many fields, effort is often operationalised as an ordinal variable whereby experimental conditions manipulate the degree of effort required to *actually* achieve a task without specifically quantifying the intensity of that effort (i.e., high effort, or low effort) nor the *perception* of it. Yet, it is my ex-

perience²¹ that many people upon hearing the term ‘effort’²² immediately assume that a feeling or perception is being referred to. Either way, there seems to still be some ‘lexical hang-ups’ with merely use of the term effort in isolation and probably dependent on field. As such, I will argue here that an additional adjective and verb are required to aid in differentiation of the *actual* effort required (objective effort), and the *perception* of that effort (subjective effort). The two are almost self-evidently related yet distinct concepts both of which have been rarely conceptually defined, inconsistently operationally defined, and thus vary in their experimental manipulation and measurement across the fields which study them. This is an issue as without appropriate conceptual definitions for these terms which are agreed upon and accepted by these fields, a scientific understanding of either, or indeed their relation, will remain out of reach.

Aim of The Present Work

The overarching aim of this piece is to consider and define ‘effort’ during attempted task performance in an attempt to bring clarity to the topic and permit unification of the concept across different fields of inquiry. I will draw distinction between the *actual* effort required (objective effort), and the *perception* of that effort (subjective effort), and propose appropriate means of defining, and therefore considerations for operationalisation for manipulating and measuring, both. I will focus my definitions following a set theoretical approach for both *actual* and *perception* of effort as both *concepts* and *constructs* (Markus, 2008); wherein the former refers to an intensional population-independent definition of the variable and the latter an extensional population-dependent definition of the variable. Further, I will couch these definitions within the aforementioned tradition of Theory-Theory (Morton and Medin, 1985) and offer their synonymous tentative causal models (Glymour, 2001), in addition to considering criteria for ‘good’ concept formation in the social sciences (Dubin, 1969; Gerring, 1999; Wacker, 2004). Lastly, given the proposed necessity of the separation of *actual* effort and the *perception* of that effort, I will consider their proposed reunification after formal con-

¹⁹ Though the pronunciation is ‘Ormi’ and in modern Greek the word means ‘momentum’. Thus, to avoid confusion we might instead adopt the word as written in English, *Horme*, and pronounced with a hard /h/ - as in /ˈhɔːmi/

²⁰ Partly due to the influence of Slingerland’s (2003) discussion of wu wei as a conceptual metaphor. We could call what I intend to

define ‘blue elephants’ for all I really care. The definition itself is the more important factor, though I acceded that resonance and parsimony are of value.

²¹ Largely within field of kinesiology and closely related fields.

²² In addition to other cognate terms, in particular ‘fatigue’

ceptual definition, and its value to aid in theory building and operationalisation of hypotheses for theory testing.

It should be noted in advance that it is not the intention of this article to provide an exhaustive interdisciplinary review of effort. Though I have attempted to draw from as wide a range of fields as possible, it may appear that work from kinesiology is overrepresented; yet, this is to be expected given my background in the field. However, it is from a position of dissatisfaction with how my *alma mater* has handled the concept, finding existing definitions to be lacking, that I came to expand the breadth of my enquiry. In doing so I like to think that I have identified where there may be opportunities for integration of learnings across disciplines. As such, I explicitly aim to present discussion and definitions that are agnostic of the specific task demands being attempted (e.g., physical, cognitive, self-control, or a combination of task demands [*dual* tasks or *net* task demands²³]); that is to say I will offer ‘general’ definitions of the concepts.

This work I hope will allow for further understanding of the role of effort and its perception from a broad scientific perspective. At the very least, doing so will provide others with a transparent overview of my own assumptions and aid in the interpretation of my own subsequent empirical work, theory building, and testing. Indeed, as Massin (2017) stated:

“...looking for a definition of effort consists in trying to make explicit our *pretheoretical* understanding of effort; we make a lot of assumptions about efforts in ordinary life and in sciences. By unearthing them, one may hope to arrive at a clear understanding of the nature of efforts.” [my emphasis]

Why separate actual effort (objective) and the perception of that effort (subjective)?

“Centuries and centuries of idealism have not failed to influence reality”
(Jorge Luis Borges, 1940. *Tlön, Uqbar, Orbis Tertius*)

In the short story, *Tlön, Uqbar, Orbis Tertius*, Borges describes an imaginary world named Tlön wherein the people hold an extreme form of George Berkeley’s subjective idealism or ‘immaterialism’. This philosophy in essence denies the existence of matter, with everything existing only as ideas in the minds of perceivers. As such, things cannot exist unless they are perceived. Within the history of research regarding effort there have been many who hold a view, at least of effort, that is in keeping with idealism. In Borges story, the idealism of the inhabitants of Tlön begins to affect reality itself with ideas begetting the production of duplication of objects called *hrönir*. I interpreted this story as somewhat allegorical regarding the state of thought, at least from some thinkers, regarding ‘effort’. Many early thinkers on the topic explicitly endorsed the view that effort was no more than a *feeling*. Massin (2017) notes that Maine de Biran explicitly endorsed this view, and that many of those involved in the early debates regarding centralism versus peripheralism spoke regarding effort and the feeling of effort as freely interchangeable; at the least giving the impression that effort *is* just a feeling²⁴. More recent thinkers have noted regarding effort: “If a person feels loaded and effortful, he is loaded and effortful...” (Johanssen, 1979, pp 105); “... there is no objective counterpart to this perceptual phenomenon...” (Gamberale, 1990); “Effort by definition is an inference or perception” (Kuppuswamy, 2017); and some seem unclear as to whether they consider it²⁵ as an objective or subjective phenomenon (Hockey et al., 2011).

However, though such thinking has been influential, and indeed I have experienced much of it, not all historical, nor contemporary thinkers hold the view that effort is *just* a feeling or perception. John Dewey (1897) was at least one early thinker to explicitly differentiate between what he referred to as the ‘fact’ of effort, and the ‘sense’ of effort. Indeed, he noted that “Practically stated, this means that effort is nothing more, and also nothing less than the tension between means and ends in action, and that the sense of effort is the awareness of this conflict.” Some have focused primarily on ‘effort’ as an objective phenomenon. For example, Kahneman’s (1973) conceptualisation of effort was objective, though he and others acknowledged the accompanying subjective experience (Mulder, 1986;

²³ It could be argued that dichotomising physical/cognitive tasks, even if merely for simplicity of communication, is inaccurate as any volitional physical task for example will have some cognitive component. For example, Herold et al. (2020) explored the cognitive demands required during the physical task of squatting with a barbell. It may merely be better to just consider *net* task demands.

²⁴ Massin (2017) himself seems to favour a realist view of ‘effort’ being that he opts for a ‘force-based’ account of it, whilst noting his arguments for force realism (Massin, 2009) in opposition to Cartesian and Humean traditions

²⁵ And indeed, other cognate concepts such as ‘fatigue’.

Bruya and Tang, 2018). Others clearly differentiate the actual effort and the perception of it (Preston and Wegner, 2009). In philosophy of action, Shepherd (2016) differentiates between the ‘experience of trying’ and ‘actual trying’, and Lafargue and Franck (2009) note that “... *one has to consider that an action is always carried out with a certain amount of effort...*”. Massin (2017) notes “*Pace the primitive-feeling view of effort, the “of” in the “feeling of effort” must be the representational “of” after all: Feelings of effort are feeling-acts directed at efforts as their objects.*” In discussing methods for the study of effort in economics experiments, Charness et al. (2018) note the need to differ between “*stated effort and real effort*”. In project management, though more often applying to anticipated effort, there is acknowledgement of the need to differentiate between that and the actual effort required (Höst and Wohlin, 1997; Jørgensen, 2004). Most recently André et al., (2019), in their integrative model of effortful control, clearly differentiate between effort actually required to attempt and perform tasks, and the accompanying feeling of effort.

Intuitively, at least to me²⁶, the separation of the objective and subjective dimensions of ‘effort’ *conceptually* seems simple. Effort in an objective sense might best be thought of as that which is *actually* done in attempting to perform a task (i.e. to try to do a thing). Massin (2017) argues that efforts are not veridical, but here the *feeling* or *perception* of that effort can be considered as the phenomenology accompanying the ‘attempting’ or ‘trying’ and thus as a likely related, but distinct, veridical phenomena²⁷. The *actual* effort (objective effort) done in attempt to meet a set of task demands might track closely with our *perception* of that effort (subjective effort). However, though under most normal circumstances this may be the case, and indeed in populations where this is so we would be justified in treating them as being the same *construct* (Markus, 2008)²⁸, their *conceptual* distinction seems intuitive. In fact, differentiation is considered a virtue of a ‘good’

concept (Gerring, 1999; Wacker, 2004) and indeed there may be instances where the two are clearly incongruent suggesting two separate constructs and thus representing an *actual* effort – *perception* of effort illusion of sorts.

Perceptual illusions have been defined as “...*a discrepancy between one’s perceptions of an object or event observed under different conditions...*” (Reynolds, 1988). Even when you explain illusions, you often still fall prey to them. Considering the strong effects of such visual illusions as the Ebbinghaus’ Titchener circles, Müller-Lyer lines, and the Necker cube, in addition to exteroceptive illusions regarding our own bodies such as the rubber hand illusion, it should perhaps be uncontroversial to propose that our *perceptions* of the effort done in attempt to perform a task (the ‘event’²⁹) may not match the *actual* effort done in that attempt and may be influenced by other factors (‘*conditions*’). Given that functionally speaking a ‘sense organ’ is intended to provide some representation of how the world *is*, it seems reasonable to suggest that interoception such as the perception of effort also operates in such a way (Serban, nd.). It could be considered that interoception, as compared to exteroception is unique in that it is not clear *what* the reality is we are saying it is intending to represent and thus how can it be said to misrepresent it.³⁰ Can something ‘feel’ effortful but not ‘be’ effortful, or vice versa? If we accept the assumption here that *actual* effort *is* involved in trying to perform tasks, then I think it is plainly obvious that we can experience interoceptive illusions regarding effort. In fact, the world is rife with examples that illustrate this.

Examples of the incongruence between representation, the *perception of effort*³¹, and of what can be said to be objectively happening given that the task is being attempted, the *actual effort*, are wide. As noted earlier, the Daoist concept of wu wei clearly differentiates the phenomenology from what is actually happening³². Indeed, within the system of conceptual meta-

²⁶ Though notably I do not expect anyone to also hold these intuitions necessarily.

²⁷ Shepherd (2016) goes so far so to say that from a neural basis the ‘experience of trying’ and ‘actual trying’ is more than veridical in that they are one and the same i.e. experience is causal. Though he notes that it is clearly possible to have actual trying without the experience of it and thus it is sufficient, but not necessary. As noted, later I will try to delineate a reunification of my conceptual definitions of effort and its perception into a tentative veridical causal model of effort psychophysics.

²⁸ And in this case, perhaps even extending measurement of *perception* to be a valid operationalisation of *actual*. I discuss this later.

²⁹ Or event(s) given continued or repeated attempted performance of a task and considering each instantaneous moment in time as an ‘event’.

³⁰ For example, it seems easy to catch the intuition that something can ‘look’ red, but may not actually ‘be’ red. However, it is difficult to catch the same intuition about interoceptive senses... can something that ‘feels’ itchy not ‘be’ itchy?

³¹ Or at the very least, the ‘self-report’ behaviour indicating it – see brief discussion of methods of third person phenomenological inquiry in a later section.

³² Though of interest, in modern practice (at least in Chinese bank managers) the application of this concept has been found to be more

phors presented by Slingerland (2003), an actor (person) is commonly considered in two ways; as *subject* and as *self*, where ‘subject’ is the locus of consciousness and subjective experience, and the ‘self’ is considered as an object (the body, a location, faculty etc.). Under this the use of *objective* to refer to the actual effort the ‘self’ does in any task attempt, and the *subjective* to refer to the experience of that effort by the ‘subject’ become clear. Slingerland (2003) clarifies:

“It is important to realize, however, that wu-wei properly refers not to what is actually happening (or not happening) in the realm of observable action but rather to the state of mind of the actor. That is, it refers not to what is or is not being done but to the phenomenological state of the doer.”

Emblematic of this are so called *flow* states; clear cases of objective effort being required and indeed being put forth (as evidenced by attempted performance of the task at a high level of performance), and yet is accompanied by a negligible perception of effort (e.g. Csikszentmihalyi, 1990; Csikszentmihalyi et al., 2005). Hypnotic states are another example where people are induced to perform tasks, which arguably require effort to perform, and yet they experience them as ‘effortless’ (Ruehle and Zamansky, 1997). Indeed, hypnosis can be used to induce a decrease or increase in reported perception of effort during exercise tasks, despite the actual task demands remaining the same (Williamson et al., 2001). Reviews of the literature report on studies that have shown attentional focus, the use of music, imagery, the presence of different olfactory and visual stimuli, conditions of virtual reality, and the presence of an audience, can all alter the reported perception of effort even when actual task demands for physical tasks are the same and presumably no change in the actual capacity to meet them has occurred (Razon et al., 2012; Hutchinson and Tenenbaum, 2019). Manipulation of auditory feedback regarding heart rate has similarly been shown to affect perception of effort despite similar actual task demands and no impact on heart rate itself, referred to as an ‘interoceptive illusion’ (Iodice et al., 2019).

There are also many examples, where relative to maximum capacity, there are discrepancies between the actual effort required based upon the task demands and the perceptions of effort experienced. For example,

in studies of force matching tasks people tend to underestimate their effort at low forces, and overestimate it at high forces (Taylor, 2009). Even with application of calibration methods, though accuracy is improved, people still find they are inaccurate in their perception of effort in application of force (Spielholz, 2006). With continued attempted performance of physical tasks, though the perception of effort is often *directionally* associated with the actual effort required, there is not necessarily a one-to-one agreement between the two (Steele et al., 2019; Emanuel et al., 2020). In ergonomics and work, directional associations between actual task demands have also been shown for a range of tasks, despite agreement again not necessarily being present (Fleishman et al., 1984). Indeed, in physical tasks people are able to apply greater efforts with the ordinal increase in actual demands but are still poor at estimating the amount of effort actually required (Richter, 2015; Armes et al., 2020). Though, this lack of congruence is not always present; across different muscle actions and tasks people are sometimes able to match relative force based upon perception of effort (Taylor, 2016). Similar results have been reported for different physical task modalities matched to oxygen costs relative to peak (Shepard et al., 1992). The perception of effort in physical tasks thus seems at least to be directionally accurate, albeit a very coarse representation of the actual effort required most of the time.

An extreme case of the incongruence between *actual* effort and *perception of* effort is in the case of schizophrenia. For both physical (Lafargue and Franck, 2009) and cognitive tasks (Gerrans, 2015), schizophrenia is associated with a lack of the sense of agency or ownership of their performance, which is thought to be due to a malfunctioning of the sensory apparatus and processing of sensory stimuli to generate the perception of effort. Yet, even in normal healthy persons, task performances that are both unconscious and unintentional still require actual effort as evidenced by capacity limitations (Weingarten et al., 2016; Melnikoff and Bargh, 2018).

Review of studies in project management for software development highlight that findings regarding the congruency of expert estimations of effort are mixed; some showing good agreement, and others poor (Jørgensen, 2004). For consumer responses to loyalty programmes, perception of effort can be manipulated

akin to finding the path of least resistance and thus perhaps seeking out ways to attempt to perform tasks such that they require objectively less effort (Xing and Sims, 2012).

by use of different reference efforts (e.g. what is required of other individuals) such that, despite the same actual demands, people's perception of effort to meet programme requirements can be higher or lower (Kivetz and Simonson, 2003). Similarly, to the noted coarse-grained representation of effort in physical tasks, the same seems to be the case in economics; the directional relationships of actual effort and perception of effort is often similar, though the degree of congruency between the two is less clear (Charness et al., 2018). This has also been found for post-editing (Moorkens et al., 2015; Scarton et al., 2019) and listening tasks (Moore and Picou, 2018; Picou et al., 2017). In performance of math tasks, despite similar actual demands the degree of interest can also impact the perception of effort (Song et al., 2019). Indeed, Dunn et al. (2016) argue that the perception of effort is a meta-cognitive process involved in the evaluation of task demands (actual effort) and that it is possible to manipulate this perceptual and inferential process, even when objective demands remain similar.

The intention of this section was simple; merely to provide examples to convince readers of the need to differentiate the “*actual* -” and the “*perception of* -” with respect to “*effort*”. Given the myriad examples of a lack of congruence (at least a lack of fine-grained accuracy³³), and that we know people's introspections regarding cognitive processes are sometimes imperfect and often entirely mistaken (Nisbett and Wilson, 1977) it seems difficult to argue otherwise. Indeed, Dewey (1897) went so far as to note “*In some cases it seems almost as if the relation between effort as objective fact, and effort a psychical fact, were an inverse one.*” In this regard we might consider extensions of Wittgensteinian thought on perception to include effort (Davies, 2011; Campbell and O'Sullivan, 2015; Block, 2007). Could we imagine a person who, much like a blind person has no visual perception, has no conscious perception of the effort required to perform attempted tasks? Most people don't think that because the blind person cannot see this means light and spatial qualities of objects do not exist; so why would we treat the example of a person who cannot perceive effort any differently? Surely, they still require *actual* effort to attempt performance of tasks.³⁴ Is there the possibility of aspect perception, like the famous duck-rabbit illusion, whereby objectively equal task performance attempts

are perceived in different ways? Or the potential for something similar to the idea of spectrum inversion (i.e., red things look green) such that objectively difficult tasks are perceived as ‘easy’ and vice versa?

Though clearly, the perception of effort is unlikely to be merely *just* for the representation of some objective thing called effort (Preston and Wegner, 2009), this seems likely to be a major function. As noted, debate regarding the neural underpinnings of sensory stimuli for the perception of effort date back some time; though today there is wider agreement on key elements of some sort of efferent-afferent comparator model (Lafargue and Franck, 2009; Gerrans, 2015; Seghezzi et al., 2019). Nevertheless, it is not my intention to review this here. The intention is to merely highlight that, in order to understand such cases when objective and subjective do and do not relate to one another, and the implications of this in development of theories regarding effort, it is necessary to define separately both the objective, and subjective, concepts of effort.

Actual (objective) effort

To begin with I offer an analogy which I feel provides an intuitively simple solution to the definition of objective effort. In keeping with the consideration of the Theory-Theory of concept formation, analogical abduction has been argued to be useful in what has been referred to as the ‘prototheory’ part of Theory Construction Methodology (Borsboom et al., 2021). Within materials mechanics, effort is a concept often referred to denoting the stress that a material experiences as a result of the application of force. Indeed, some dictionaries offer such a technical definition for the term ‘effort’ (“*A force exerted by a machine or in a process*”)³⁵; though of course we should be cautious in laying too much credence on this as noted (Gerring, 1999; Fiske, 2020). Similarly, it is often considered relatively with respect to the strength, or maximal capacity, of the material to withstand the imposed force and thus stress. In this field, effort can be objectively defined in terms of the absolute demands imposed upon the material (i.e. Pascals) and often a factor of safety is considered and determined by the maximal strength relative to the absolute demands. The latter could, however, also be expressed such that the absolute demands

³³ Of course, such incongruence may merely result from lack of reliability in either operationalisation of the objective or subjective components, similar to the typical lack of correlation between self-report and behavioural measures (Dang et al., 2020).

³⁴ This strays into the realm of philosophical zombies... and as zombies can be scary (and the cause for much consternation amongst philosophers) we will leave it here for now.

³⁵ <https://www.lexico.com/en/definition/effort> [accessed 2nd June 2020].

are relative to the maximal strength and thus reflect the relative demands imposed. Such a seemingly simple approach whereby the effort experienced can be objectively defined as the demands relative to capacity presents useful applications for fields interested in intentional attempts of task performance.

Massin (2017) also mentions this example: that effort and force are often used equivalently in mechanics. He differentiates between what he refers to as ‘resource/capacity’³⁶ based accounts and ‘force’ based accounts of effort. Though he notes that these accounts of effort could be considered extensionally equivalent, he dislikes the option of a ‘mixed’ approach that permits the encompassing of both³⁷. Instead, he appears to opt for a purely *absolute* force-based account³⁸. However, I believe it is possible to combine the two in a simple account of effort as being the demands of a task relative to the capacity to meet those demands. In doing so it is possible to retain Massin’s (2017) suggestion that effort is conceptualised as a vector quality with magnitude and direction. Indeed, we can allow for that magnitude to vary not only as a function of changing task demands and that they provide resistance to trying to perform a task, but also if we consider that the capacity need not necessarily be fixed and can differ at any given instant.

³⁶ Though, as Massin (2017) notes, these differ with respect to whether they consider ‘capacity’ as being some non-depletable (e.g. Kahneman, 1973; Kurzban et al., 2013) or depletable (Gendolla and Wright, 2009) resource, as well as whether they specify *what* the resource is: Physiological e.g. glucose (Gailiot and Baumeister, 2007) or ‘toxic neural waste accumulation’ (Holroyd, 2016); functional e.g. computational capacity (Kahneman, 1973; Kurzban et al., 2013); ‘ego’ (Baumeister et al., 2000); or some ‘non-committal conceptual resource’ (“*Although agents engaging in effortful behaviour can fruitfully be described as if they were allocating some limited resource, this does not entail that there is any finite resource really allocated by the agent.*”)

³⁷ It is worth noting though that he has more recently noted to me in correspondence, based upon feedback from reading an early draft of this manuscript, that the two accounts should be combined, yet professes to be unsure exactly how best to do so.

³⁸ Though he discusses the relativity of subjective efforts.

³⁹ Though in his conception ‘moral’ capacity was not sufficient *per se* and required effort to be *added*:

“*The facts may be most briefly symbolized thus, S standing for the sensual motive, M for the moral and E for the effort:*

$$\begin{aligned} M \text{ per se} &< S \\ M + E &> S \end{aligned}$$

In other words, if E adds itself to M, S immediately offers the least resistance, and motion occurs in spite of it.”

⁴⁰ Despite Gamberale (1990) noting just prior that “...there is no objective counterpart to this perceptual phenomenon...” he subsequently states “... it also reflects real conditions such as the interplay between the requirements of the physical task and the capacity of the individual.”

Actual effort has sometimes been conceptualised in a manner similar to this, albeit not always explicitly. William James (1880) considered ‘moral’ effort in action wherein the ‘moral motives’ might be likened to a capacity of sorts and effort utilised to overcome ‘sensual motives’³⁹. For effort in physical tasks many have considered this idea of task demands relative to capacity (e.g. Gamberale, 1990⁴⁰; Taylor, 2009; Xia and Frey Law, 2008; Taylor, 2016; Burnley and Jones, 2018; Potvin and Fuglevand, 2017; Steele et al., 2019)⁴¹. For cognitive tasks and self-control there are several models that are explicit in the consideration of some aspect of ‘capacity’ or ‘resource’ and, though not all conceptualise effort as being determined by task demands relative to capacity, some do (e.g. Pascal-Leone, 1970; Kahneman, 1973; Globerson, 1983; Mulder, 1986; Longo and Barrett, 2010; Kruglanski et al., 2012; Kurzban et al., 2013; Peng et al., 2018; Andre et al., 2019)⁴². Indeed, both task demands, and capacity (or ‘ability’), have been considered in discussion of the role of effort in causal ascription of behaviours (Weiner et al., 1972), in desert (Sher, 1979), and effort as an economic variable (Simon, 1991)⁴³. A non-exhaustive selection of examples of verbal definitions of *actual* effort from the literature is presented in table 1.

⁴¹ Indeed, Xia and Frew Law (2008) are explicit in their conception of how ‘brain effort’ given to drive motor tasks is a function of the task demands and capacity:

“*Residual capacity (RC) is introduced to describe the remaining muscle strength capability due to fatigue, where 0% indicates no strength reserve (not physiological) and 100% indicates full non-fatigued strength (Eq. (3)). This time-varying term can be used as a multiplier to decay maximum strength capabilities. Additionally, the central drive necessary to perform a task is modelled as brain effort (BE, Eqs. (4)), which may be used as a simple estimate of perceived exertion:*

$$RC(t) = M_A + M_R = 100\% - M_F \quad (3)$$

$$\text{If } TL \leq RC, BE = \frac{TL}{RC} \times 100\%$$

$$\text{If } TL > RC, BE = 100\% \quad (4)''$$

⁴² Kruglanski et al (2012) are also quite clear that effort (effective driving force) equals the demands (resistive force) but cannot exceed capacity (potential driving force):

“*Postulate 3: The magnitude of the effective driving force M_{DE} will be equal to magnitude M_R of the restraining force and lower or (at most) equal to magnitude M_{DP} of the potential driving force:*

$$M_R = M_{DE} \leq M_{DP} \quad (3)$$

Derivation 3 (from Postulate 3): The greater the demands of a task to be employed as means to goal attainment, the greater the individuals energy expenditures within limits of his or her potential driving force.”

⁴³ Simon (1991) considered that:

“*Specifically, the amount of effort (drive) is a function of the arithmetic difference between wealth with and wealth without the*

Table 1. Examples of existing definitions of *actual* (objective) effort.

Source	Definitions
Dewey (1897)	<i>“Practically stated, this means that effort is nothing more, and also nothing less, than tension between means and ends in action...”</i>
Globerson (1983)	<i>“For a given task demand (which is within the capacity limits of the tested children), there should be a negative correlation between the subject’s developmental Ms capacity (structural capacity limit) and mental effort exertion. That is, a child with a larger Ms capacity should exert less mental effort for the same task demand than a child with a smaller Ms capacity.”</i>
Salomon (1984)	<i>“The number of non-automatic elaborations applied to a unit of material to be learned.”</i>
Mulder (1986)	<i>“... the active involvement of subjects in the performance of mental tasks.”</i>
Backs and Seljos (1994)	<i>“Mental effort is a term used to describe the amount of information processing resources that are allocated during task performance...”</i>
Jansma et al., (2007)	<i>“We defined effort as the allocation of resources when performing a task...”</i>
Shenhav et al., (2017)	<i>“... what mediates between (a) the characteristics of a target task and the subject’s available information-processing capacity and (b) the fidelity of the information-processing operations actually performed, as reflected in task performance. The first two factors, task characteristics and capacity, determine what level of performance is attainable in principle.”</i>
Massin (2017)	<i>“.. a motor effort consists of (i) and agent exercising a mechanical force (F_1) on a body in order to make it move or stay at rest and (ii) that mechanical force being at least partly counterbalance by an opposite force (F_2): the resistive force...”</i>
Inzlicht et al., (2018)	<i>“Effort refers to... the process that mediates between how well an organism can potentially perform on some task and how well they actually perform... [and] is a volitional, intentional process, something that organisms apply, and as such, it corresponds to what organisms are actively doing and not what is passively happening to them.”</i> <i>“Effort is distinguishable from demand [original authors emphasis] or difficulty: effort corresponds to the intensity of mental or physical work that organisms apply towards some outcome, whereas demand of difficulty refers to a property of the task itself (e.g. holding seven items vs three items in working memory) ...”</i>
Steele et al., (2019)	<i>“The intensity of effort during exercise can be defined in relation to the current ability to meet the demands of the task being attempted...”</i>

An important distinction between the effort experienced by non-conscious objects such as in materials mechanics, and conscious organisms intentionally attempting performance of tasks, has also been noted by many: that it involves *intent* by an organism i.e. an agentic self⁴⁴. However, I contend that, at least for *actual* effort, there is no need for a *conscious* actor to be

present. That is to say *actual* effort is something that can be ‘experienced’ by both conscious and non-conscious things. There merely has to be the *directional* ‘intent’ of an action towards a goal (i.e. attempted task performance): the *thing* (actor) has to *do a thing* (task).

opportunity in question, considered relative to the persons current wealth. Formally

Drive-Effort Measure = expected likelihood of a positive response to a given opportunity by an individual of nation

$$= a \left[\frac{W_{n+1} - W_n}{W_n} \right]$$

⁴⁴ Indeed, folk concepts of intentionality see ‘effort’ as being a ‘symptom’ of intent (Malle and Knobe, 1996)

I wish to offer an explicit conceptual definition which, similarly to in materials mechanics, permits this distinction between absolute task demands and effort (and between *actual*, and *perception of*, effort), but holds that absolute task demands relative to current capacity to meet those demands (i.e., *relative* task demands) are in essence what determine *actual* effort. As such, when absolute demands increase such that they represent a greater relative demand, or when a reduction in capacity is present, there similarly is an increase in relative task demands and thus the objective effort required also increases.

A definition of 'actual' effort

Considering the above distinction, I offer the following definition:

Effort; *noun*

That which must be done in attempting to meet a particular task demand, or set of task demands, and which is determined by the current task demands relative to capacity to meet those demands, though cannot exceed that current capacity.

To relate back to a phrase used earlier, effort is in essence what is required *to do a thing*. In this sense I am labelling the action of doing something as the 'task' and claiming that the intentional attempt to perform a task is the necessary and sufficient condition for effort. In this sense, demands and capacity are both necessary and sufficient conditions for effort: a task imposes demands if attempted and, while task demands exceeding capacity can be attempted, capacity must be some positive value greater than zero to allow any attempt to be made. I am in this definition taking as primitive the ideas 'task demands' and 'capacity to meet those demands', following Wacker's (2004) terminology for the terms comprising conceptual definition.

This in essence means that these terms are assumed to be understood and not need defining. Although, conceptually in their regard we might say that there is some 'stuff' that is necessary to be met when tasks are attempted (demands), and some 'stuff' that actors must have to attempt to perform a task (capacity).

This definition is clear in how it presents effort as a concept that relates the absolute task demands to the current capacity to meet those task demands thus in essence equating *actual* effort to the *relative* task demands i.e., they are logically interchangeable. Though this definition can in theory be used to determine the *actual* effort required for a given task *a priori*, effort by its nature teleological in that no effort is 'experienced' unless there is an 'intentional' attempt to perform a task⁴⁵. The definition can be applied to both physical and cognitive⁴⁶ tasks; any kind of task really. That is to say it is agnostic of the specific nature of the task⁴⁷, and is in essence anchored with a ceiling relating to the point at which, assuming genuine intentional attempts to meet them, it is no longer possible to meet the task demands (i.e. demands exceed capacity).

In considering the set theoretical approach suggested by Markus (2008)⁴⁸ regarding the definition of variables, we might define *actual* effort as a concept (i.e., a population-independent variable) as follows:

Effort (concept)

$E_A(i, t, C_A, D_A, w, T_{Any})$ is the actual effort for any individual i at time t where $C_A(i, t, x_C)$, and $D_A(i, t, x_D)$ are the actual capacity and actual demands respectively, and x_C and x_D are the magnitudes of those respectively for individual i at time t , where w denotes all possible states of affairs (i.e. combinations of i, t, C_A , and D_A), and T_{Any} denotes the boundary conditions noting it as intensional to all possible types of tasks.

⁴⁵ Note here that effort, which can be determined *a priori*, is distinguished from any resultant behaviour itself (i.e. the task performance). Even if it weren't attempted, a task *would* still require effort to perform, and this *would* be 'experienced' if that attempt (try) were made.

⁴⁶ Some models of objective effort have included two 'types' of effort. For example, Mulder's (1986) model considers 1) attention demanding controlled information processing, and 2) a person's requirement to change their current energy resource state towards that which is optimal for the task. However, in the context of effort within a capacity model (i.e. that as a relative variable it can only be allocated up to and not exceeding 100%), these two 'types' might instead be considered as separate task demands that both require effort to achieve.

⁴⁷ Indeed, in Massin's (2017) definition of a 'force' based account he argues that this, along with 'goal-directedness' and 'resistance', are key ingredients of efforts. But he extends 'force' to include physical and cognitive forces. Thus, to my interpretation, he appears to be using all of these terms in a non-committal agnostic manner. A number of others also imply that effort is a universal applied to various attempted task performances (Dietrich, 2003; Dietrich and Sparling, 2004; Franconeri et al., 2013; Preston and Wegner, 2009).

⁴⁸ Though notably Dubin (1969) considers what is in essence a set theoretical approach also in distinguishing between the class considered as a unit to be used in theory, and the individual members of that class.

Conceptually then we have a set of hypothetically infinite size that describes all *possible* efforts; we could from it generate any logical proposition of values for the primitive units it contains, and the resultant value ascribed to its function expressed from 0 to 100% to any degree of precision imagined. This definition is, by its nature, a derived ratio given that capacity and demands have natural origins: capacity can be zero, as can demands (Stevens, 1946). In fact, it could be expressed as a percentage:

$$\begin{aligned} D_A \leq C_A &\rightarrow E_A = \left(\frac{D_A}{C_A} \right) \times 100\% \\ D_A > C_A &\rightarrow E_A = 100\% \end{aligned}$$

Equation 1.

This is also useful for the extension of the definition to a construct (i.e., a population-dependent variable). In essence, any given individual at any given time only has one effort level (which is comprised of their capacity and the task demands), but more than one person can share the same effort level. Markus (2008) notes that “... *the definition of a construct necessitates the stipulation of an origin, however arbitrary to identify the scale of the construct. It then becomes possible to give a construct a formal definition.*” When we extend the concept of *actual* effort (E_A) defined above to a population-dependent set describing only combinations of all individuals, times, capacities and demands that exist empirically, we merely remove the w and T_{Any} terms, and can denote it as $E_A'(i, t, C_A, D_A)$. Denoting the C_A and D_A terms in a ‘non-committal’ way also presents value in making clear and directing operationalisation which is considered a virtue of ‘good’ concepts (Gerring, 1999). As such, the capacity is always defined in relation to the *nature* of the task being attempted and what demands it requires. In a way this deals with the issue faced by many resource or capacity based models of effort in determining *what* the ‘resources’ or ‘costs’ of effort are⁴⁹. The task demands may be a combination of physical, cognitive, or self-control based and thus we might consider the ‘net’ demands and the ‘net’ capacity to meet them. Either way, they are always specific to the given task, and effort is merely a relational unit denoting the ratio of specific

task demands to the capacity to meet those specific demands⁵⁰. The operationalisation and measurement issue then merely becomes how to identify valid empirical indicators of capacity and demands; this is probably easier in some tasks than others, but we might consider some simple examples.

In a physical task the role of differential demands and capacity are easily considered in that *actual* effort is determined by the task demands relative to the current capacity to meet task demands. As such, if two individuals were attempting to pick up the same specific absolute load (e.g. 80 kg) the stronger of the two would initially require less *actual* effort to complete this task. If they had both performed prior tasks that had resulted in a reduction in their maximal strength, then each would require a greater *actual* effort to complete the task than compared with when their capacity was not reduced. And further, if both continued performing repetitions of this task their maximal strength might continue to reduce insidious to continued attempts to maintain a particular *absolute* demand, and thus require an increasingly greater *actual* effort with every individual or continued attempt to meet the task demands. Correspondingly, if the absolute task demands were increased then both individuals would also require greater *actual* effort to complete the task. Yet for both, the continued attempted performance of the task with fixed absolute demands and insidious reduction of capacity or the increase of absolute demands, task performance would be capped by their maximum capacity at which maximum effort is required. With training though that maximum strength might be increased such that a given absolute task demand now represents relatively less and so requires less *actual* effort. Further, biomechanical alterations to the task might reduce the absolute demands and thus the *actual* effort⁵¹.

Similar examples could be provided for cognitive tasks. For example, if two individuals were attempting to hold a fixed number of items in their working memory, the one who has the larger working memory of the two would require less *actual* effort to complete this task. However, both individuals would again require greater *actual* effort to do so in the presence of lingering reduction in cognitive capacity from prior tasks, or from continued attempts to meet the task demands, or from increased absolute task demands

⁴⁹ It is worth being explicit here; even though some use ‘resources’ and ‘capacity’ differently, I am in essence treating them as synonyms.

⁵⁰ In fact, Skott (1997) has argued “*The analysis [of effort] can proceed on the basis of any given cardinal representation of effort*” even in the “*absence of natural units*”.

⁵¹ For example, it is quite common to observe individuals performing resistance exercises who ‘loosen’ their form as they fatigue in essence reducing the demands of the exercise through altered kinematics, and with this ‘sloppy’ form can continue performing the exercise longer than had they maintained the same form.

(i.e., more items to be held in working memory). Again, training may also improve maximal capacity. Also, cognitive processing alterations (i.e., heuristics; Shah and Oppenheimer, 2008) might reduce task demands and thus the *actual* effort⁵².

Some have suggested that certain tasks might not be considered effortful even though they are difficult; at least when difficulty is considered as the probability of success. For example, considering Westbrook and Braver's (2015) neuroeconomic account, Massin (2017) offers the example of trying to hit a bullseye but points out that, though efforts are accompanied by success/failure conditions, these do not determine the magnitude of those efforts. I believe it is possible to subsume even this example into the current definition of *actual* effort⁵³. Arguably, one could *try harder*; that is to say employ more actual effort (concentrate more, apply greater control over fine motor action etc.) which might arguably strain the limit of their ability (capacity) to perform the task and thus make it require more *actual* effort. But, though such effort might increase the probability of their success (or not), if they have a particularly low ability their probability of success will still likely be low.

Indeed, by way of demonstrating its task agnostic nature further, it could even be applied to tasks performed in imaginary worlds as permitted intensionally by our conceptual definition. Let us explore some thought experiments in this regard. For example, McCoy and Ullman (2019) recently considered people's judgements of the effort that might be required for wizards casting spells in a world where spells required an amount of 'magic points' to be cast. Each spell was judged to require a specific absolute number of magic points with some spells being judged as requiring less effort than others. But it could also be said that people would likely judge more powerful magic users (for example an arch-mage) with greater capacity for magic points, to require less effort to attempt to perform any given spell compared to a weaker magic user (for example a neophyte) with lesser capacity for magic points (Ullman, 2019 – personal communication). Returning to Massin's (2017) suggestion that "*Effort is not a planet*"; though I agree, we could imagine a planet that 'experienced' effort. In the Marvel Comics universe there is a character called (somewhat aptly given the

present topic) Ego the Living Planet. He is incredibly powerful, albeit limited in his capacity. As such, his attempts to perform tasks (e.g. control and transform his atmosphere or surface, generate energy blasts etc.) must place demands on him that cannot exceed his capacity, but could be expressed relative to his capacity. Thus, we could imagine Ego as 'experiencing' *actual* effort⁵⁴. Massin (2017) also argues that "*Spontaneous muscle contractions, such as cramps, or externally generated muscle contractions, do not count as efforts...*". Yet, I would disagree noting that, while such actions do not generate an accompanying *perception* of effort (Pageaux et al., 2015), they do require *actual* effort; the task is *actually* attempted and performed by the stimulated muscle, and cannot be performed in a manner that exceed the capacity of that which performs it.

Not only is such formalisation of the concept of effort like this useful for operationalisation, but it also presents a clear means by which the inclusion of the concept in theories can lead to formal model development and derivation of its propositions through mathematical or computational modelling (Dubin, 1969; Guest and Martin, 2021; Borsboom et al., 2021; Navarro, 2021; Haines et al., 2021). Thus, combined we might benefit from the stronger coherence between the propositions from theories including effort, and resultant operationalisation of hypotheses for testing such theories.

As noted, I am considering the tradition of Theory-Theory of concept formation (Murphy and Medin, 1985), and indeed we might consider the graphical depiction of this concept of effort here (Glymour, 2001)⁵⁵. If some task attempt is necessary and sufficient for effort then we can trace an arrow from D_A to E_A and, given that capacity interacts with demands to determine the magnitude of effort, we denote C_A as a moderator intersecting the arrow leading from demands to effort (Weinberg, 2007). Figure 3A depicts this. However, given that we know empirically that capacity is typically not a fixed value and often changes during attempted task performance itself (i.e. fatigue occurs), we could also trace an additional line between D_A and C_A (Figure 3B), and even consider the rate at which this occurs i.e., some 'fatigability' coefficient (Figure 3C).

Formalisation of models can support simulation of their propositions which often produce results

⁵² Like the notion of reducing demands through biomechanical alteration of physical tasks.

⁵³ Though even if it were not, I personally find it hard to believe anyone would think that such a task required literally zero effort and so maintain that intentional attempt to perform a task is the necessary and sufficient condition for effort.

⁵⁴ Arguably as a conscious being we could also imagine him having a corresponding *perception* of that effort if he had the appropriate system to produce such a phenomenology.

⁵⁵ Though we should perhaps be cautious of using traditional approaches such as structural equation modelling to examine relationships for definitional concepts such as this (Trafimow, 2013; 2015).

Figure 3. Directed acyclic graphs depicting effort as a causal model where A) shows that while demands cause effort they are moderated by capacity, and both B) and C) show that the imposition of demands can also affect capacity with the latter including a fatigability factor to moderate this. Note: D_A = actual task demands; C_A = actual capacity to meet task demands; E_A = actual effort.

unexpected given purely verbal expressions of a theory (Fried, 2021). We could for example, considering the definition of effort given here, examine how it might be expected to change over time given continued attempted task performance and some assumption regarding the change in capacity as a result of this continued attempted task performance.

For the sake of this example, let's grant an assumption of a proportional relationships between the derivative of capacity ($\frac{dC_A}{dt}$) and effort at the preceding time ($E_{A,t-1}$). We could simulate computationally⁵⁶ and then graphically depict the relationships between task demands and effort at a given time (t), as well as the change in capacity and thus effort across given static absolute task demands over time⁵⁷. Figure 4 shows: (A) the increased effort required with increased task demands (note the example assumes a capacity of

100 AU); (B) the increase in effort with continued time attempting the task at those fixed absolute demands; and (C) the drop in current capacity to meet those demands (i.e. 'fatigue'⁵⁸ [F_A] which in essence could be considered merely the change in capacity of the opposite sign: $\frac{dC_A}{dt} = -\frac{dF_A}{dt}$). Thus, *relative* task demands become progressively greater (hence the increased effort), due to the decrease in capacity, up to the point of momentary task failure⁵⁹. However, effort cannot exceed 100% and so, when attempting a task of demands equal or greater than capacity (in this example an initially maximal demand task), the decay in capacity becomes linear. Figure 4D shows the four-dimensional relationships between capacity, demands, time, and effort. Considering the example of an initially maximal demand task, as capacity drops the demands that can be met also reduce; theoretically a maximal task could be

⁵⁶ See accompanying online materials for code (<https://osf.io/p75m2/>).

⁵⁷ In a brief discussion of effort and fatigue (at least in reference to the limitations of 'resource based accounts'), Massin (2017) suggests that we should not prejudge a relationship between the two in any definition of effort. He offers an example of a being with an "infinite amount of energy at his disposal – a being who therefore never gets tired" and that such a being, while empirically impossible, should not be metaphysically impossible or precluded by a definition of effort. But such a being is possible with my definition. Their *actual* effort for continued attempted performance of any given task would remain constant with time as their capacity never reduced. We might liken them to a videogame character who has a 'power bar' representing their capacity to perform special actions and which depletes each time they use one. A cheat code might enable them to perform such actions without the power bar ever reducing. But low-level special actions are still relatively speaking low effort, and vice versa.

⁵⁸ Note that here I have explicitly chosen to use the term 'fatigue'. In fact, at least with respect to *actual* fatigue I feel it is very appropriate given that the term is also used in materials mechanics and is thus similar to the abductive analogy provided regarding effort (<https://uk.comsol.com/multiphysics/material-fatigue> [accessed 2nd June 2020]). I am aware of the contention regarding the definition and use of this term, and the adoption of terms such as 'performance fatigability' to refer to this objective drop in capacity, whereas 'per-

ceived fatigability' is used to refer to the sensory and phenomenological state associated with it (Kluger et al., 2013; Enoka and Duchateau, 2016). Personally, I find the inclusion of the suffix "-ability" to add confusion as, at least to me, it implies the 'susceptibility' to the original noun to which it was attached. Thus, I interpret the term (at least independent of any explicit definition) to refer to tendency for an individual's capacity to reduce either in terms of magnitude, or magnitude over time (i.e. rate). Indeed, some have considered this interpretation (Hunter, 2018). Nevertheless, I will sometimes opt to use the term *actual* 'fatigue' (and the accompanying *perception* of fatigue with the same considerations for the need to separate them as with the separation of *actual* and *perceived* effort) and argue that it should just be preceded by 'magnitude' or 'rate' if that is what is being referred to. When I use the term however, I am merely alluding to a reduction in the capacity to meet a given task demand, or set of demands, and will more often than not use that language explicitly.

⁵⁹ Note that there is a need to differentiate between 'fatigue' and 'failure' which, at least in kinesiology, is not often done (Enoka and Duchateau, 2008; Steele et al., 2017). Failure occurs at the point during attempted task performance at which task demands exceed current capacity. Fatigue, conversely, is the reduction in the capacity to perform the task. Thus, while fatigue maybe an ongoing *process*, failure is better considered an *event*. Further, reaching task failure does not mean that fatigue is necessarily maximal, nor even substantial.

Figure 4. The relationships between demands, capacity, time, and effort, given the definition proposed across varying fixed absolute task demand examples (10%-90% of initial capacity) and an initially maximal task. Panel (A) shows the relationship between demands and effort; Panel (B) shows the change in effort over time given continued attempt to perform a task of fixed absolute demands; Panel (C) shows the change in capacity over time given continued attempt to perform a task of fixed absolute demands (note, where absolute task demands remain fixed, the increase in effort results from the decrease in capacity over time); and Panel (D) shows these relationships four-dimensionally. Note, the derivatives of demands ($\frac{dD_A}{dt}$), capacity ($\frac{dC_A}{dt}$), and effort ($\frac{dE_A}{dt}$) with respect to time are as follows: ($\frac{dD_A}{dt}$) is a constant (=0); ($\frac{dC_A}{dt}$) is $-(k * E_{A,t-1})/100$ i.e. [0,-1] where k is maximum capacity; and ($\frac{dE_A}{dt}$) is $\frac{dD_A * C_A - dC_A * D_A}{C_A^2}$ as result of application of the quotient rule.

continued until capacity is equal to zero. Similarly, we could consider a ‘supramaximal’ task (i.e. one with demands greater than capacity) could be attempted if capacity >0 and would indeed result in a maximal effort; but the task demands would not be met and thus the task would not be performed, merely attempted.

I argue that this definition is particularly useful as it permits a starting point in reality for consideration of where our *perception* of such effort might diverge from that which can be objectively defined to have been *actually* done. It should be noted that operationally, based upon this definition, without an individual actor attempting to perform an initially maximal task or continuing to the point of momentary task failure (or indeed not putting forth any effort at all – a minimum or maximum) it is difficult, and perhaps impossible, to actually know *during* attempted task performance at any given point in time precisely what a person’s required

actual effort is. Without the ability to continuously monitor during tasks the relationships between initial capacity⁶⁰ to meet task demands, and the magnitude and rate of change in that capacity, we may never really *know* empirically what the *actual* effort required is in this relative sense. However, at present I see this is a technological limitation to operationalisation and, given the conceptual definition offered, think that it is uncontroversial to work within the model that *actual* effort is in essence a latent variable that is determined by actual capacity and actual demands even if we can’t measure them directly yet in all situations⁶¹.

I don’t think that the definition of actual effort in this manner is necessarily unique. As noted, many have at least alluded to the relationships between task demands, capacity, and effort. However, I feel that the specific definition provided here could be said to be

⁶⁰ Indeed, knowing this initial capacity (or capacity at any point in time), though less of a problem when considering simple physical tasks (e.g. maximum force production, maximum speed etc.), is perhaps more of an issue as task complexity increases (even the simplest physical task can often be broken down into numerous degrees of freedom) and even more so with the complexity of most cognitive tasks and their processes. That being said, if we are good materialists, we can at least grant the assumption that even cognitive

capacity has to be limited... but we could imagine something (a ‘smart drug’ perhaps) that might enable that capacity to be increased and thus the concept is still valid in such examples.

⁶¹ However, I have in mind some operationalisations for several physical tasks and also cognitive tasks which I will present in a separate manuscript regarding descriptive exploration of effort psychophysics.

‘cleaner’ and I hope leaves less room for misinterpretation due to its explicit nature. Indeed, the avoidance of ambiguous terms and parsimony in definition are also considered virtues of ‘good’ concepts, and here I have tried to balance them against depth to maximise their utility (Gerring, 1999; Wacker, 2004). One could demur with my definition given that as a theory of effort it is unfalsifiable; that is to say it is axiomatic as opposed to assumptive (Trafimow, 2013). But, given its other apparent virtues, I see little reason to balk at it in this regard or to avoid its inclusion in wider substantive theories as an auxiliary. The application of this conceptual definition might assist researchers in operationalisation both in measurement and manipulation. Better manipulation of the *actual* effort required during tasks will aid in understanding the role that effort plays in determining behaviours and responses across fields of inquiry and help with testing theories that include it. Indeed, effort is often considered as an ordinal variable and manipulated as such in experimental studies. However, understanding effort objectively as a continuous ratio variable might also allow for a finer grained understanding of where, when, and why discordance exists between this and the subjective experience (*perception*) of that effort. That is to say it might enhance our ability to build and test a psychophysical model of effort. Further, not only does a clear definition of *actual* effort permit greater ability to understand its role in behaviour and responses, but it also allows consideration of the combined and differential influences that both *actual* effort, and the *perception* of it, impart in theories. Thus, its overall usefulness among other virtues (Gerring, 1999; Wacker, 2004) might be considered sufficient to overlook the fact of its unfalsifiability (Trafimow, 2013).

Having offered a definition, I now move away from the *actual* effort required and done for attempted task performance and to the phenomenology of that concept for conscious actors. However, before doing so it is necessary to highlight the distinction between sensation and perception as it could be said the former bridges the concepts of *actual* - and *perception of* - as we discuss them here.

Sensation and perception

Many people when referring to ‘effort’ use either ‘sensation of’ or ‘perception of’ seemingly under the assumption that these are terms that might be used interchangeably. I argue this is not the case and as such, prior to moving to discuss a definition of *perception* of effort it is necessary to highlight the difference between ‘sensation’ and ‘perception’. Michel Cabanac, in his essay “*What is sensation? Gnoti se auton*” (Cabanac, 1995), discussed the difference between these two concepts referring to definitions from Levine and Shefner (1981) as follows:

“[sensation is]... the process of detecting a stimulus (or some aspect of it) in the environment...”

And,

“[perception is]... the way in which we interpret the information gathered (and processed) by the senses...”

Summing this up they suggest that “*In a word, we sense the presence of a stimulus, but we perceive what it is.*” For reasons that will become clear in the following discussion and will hopefully convince the reader this is more than simply a semantic issue, I consider the conscious experience of effort to be a *perception*⁶² that likely arises from a myriad of underpinning physiological *sensations* which in many cases relate to the *actual* effort required, though as I have noted may not always exist in congruence; that is to say, the sensory stimuli resultant from some *actual* effort, may or may not result in a *perceptual* representation of that effort which is accurate. They are sufficient, but not necessary.

To illustrate the relationships between the concepts we are defining and discussing here – *actual* effort, *sensations* or the detection of effort being made, and *perception* of effort – I offer the analogy of an unconscious robot actor⁶³ who can ‘experience’ the former two though cannot ‘interpret’ them, compared to a conscious human actor who experiences these in addition to conscious awareness of effort being exerted (figure 5). The unconscious robot may have a maximum

⁶² Some might argue ‘interoception’ is more accurate, but I use perception broadly to cover both intero- and extero-ception.

⁶³ I know I said earlier we would avoid zombies (a usually sensible idea). But if you’re a fan of philosophical zombies feel free to

swap out the robot for that instead. The point made remains the same.

Figure 5. The unconscious robot in this example, despite ‘experiencing’ the same *actual* effort as the conscious human, does not have a perceptual experience of the intentional attempted performance of the task e.g. lifting the weight, or recalling from memory. Note, quotes are taken from Levine and Shefner (1981).

capacity to attempt to perform a particular task, for example lifting a weight or recalling from memory. The robot may also be programmed to attempt to perform this task. That is to say, it *intentionally* does so (even though it is not conscious of this intent which is programmed). The *actual* effort required by the robot to attempt to perform the task is a function of the task demands relative to its capacity. Further, similarly to a conscious human, the robot can be programmed such that its maximum capacity reduces as it continues to attempt to perform a task over time (i.e., it fatigues). As such, with time on task whereby the absolute demands remain the same, the relative demands will increase and thus the *actual* effort required will increase. We can consider this example with (i.e., the robot may have some sensors monitoring demands and changes to capacity resultant from fatigue, and thus have a composite signal generated for the relative demands ‘experienced’ at any given point during attempted task performance i.e., *actual* effort) or without ever invoking any sensory apparatus to detect the stimulus that the intentional attempted task performance produces, and certainly without any perceptual apparatus that can interpret or represent any sensory information generated. The robot ‘experiences’ the *actual* effort required irrespective of any degree of sensory or perceptual awareness. Contrastingly, the conscious human upon intentionally attempting to perform the task will generate sensory signals relating to this⁶⁴, and this sensory information can

be interpreted to generate a conscious experience i.e., *perception*. Considering this, although many use the phrase ‘sense of effort’, I will utilise ‘*perception of effort*’ in the interest of accuracy and now look to discuss and present an appropriate conceptual definition for the *perception of effort*.

Perception of (subjective) effort

Unlike *actual* effort which can be objectively defined independently of any conscious actor, the *perception* of effort requires a conscious organism to experience “something it is *like*” to experience effort (Nagel, 1974). Therefore, though *actual* effort can be determined objectively, even *a priori* to intentional attempted task performance (i.e., what effort would be needed *if* you attempted the task) given we know the task demands and capacity of the actor, the *perception* of effort is unknown (though can of course be anticipated and predicted) until it is experienced by a conscious organism. Some have argued that phenomenal experiences, including that of effort or even consciousness itself, do not require explanation; they are merely epiphenomenal to other biological activity (Kinsbourne, 1996; Pinker, 1997). But, as Preston and Wegner (2009) have noted, there are functional benefits to this phenomenological experience of effort; feedback on task difficulty, prompting behaviour changes, indication of authorship of actions etc. Further, there is no need to understand the underlying biology that gives

⁶⁴ As noted, there is historical and continuing debate regarding exactly what the sensory signals are.

rise to such ‘epiphenomena’ if we are content to be operationalist in this regard and any psychological constructs are instead thought of merely as placeholders for neurophysiological mechanisms (Rorty, 1977)⁶⁵. Though some researchers are interested in uncovering these mechanisms that ‘translate’ the objective reality of effort into its phenomenology, many researchers are interested in both objective and subjective effort *without* the need to know what’s going on in the ‘black box’. They wish to understand the functional relationships between the objective and the subjective, in addition to their independent and joint effects on behaviours, adaptations etc. So, it is not my intention here to discuss *how* actual effort during tasks gives rise to a perception of that effort; responsibilities such as this and discussion of how other conscious content arises can be left to others (Searle, 1998; Morsella et al., 2016; Humphrey et al., 2020)⁶⁶. Instead, again I merely intend to provide some definition of the concept such that we have a start and end point within a system that might not only assist those interested in examining that ‘black box’ of mechanisms, but that a definition of *perception* of effort might better assist those interested in understanding that phenomenology specifically.

One issue we face with the consideration of the *perception* of effort is that, though we might be able to ‘know’ that *actual* effort is occurring even as third person observers, the precise phenomenology and magnitude to any third person observer remains unknown until that experience is communicated behaviourally. As noted, I wish to avoid engaging purely in philosophical analysis from the armchair to determine conceptual definitions and indeed feel this is most certainly required for any definition of a conscious experience. Any definition for such a concept should in some way be linked to a well described phenomena. Thus, we must have some approach to taking ‘first person’ behavioural data, such as self-reports⁶⁷ or other behavioural consequences, and from them interpreting from a third person perspective to draw inferences regarding phenomenology. Daniel Dennett (1991; 2003) has

called such a method Heterophenomenology (“phenomenology of another, not oneself”) wherein “... *basically, you have to take the vocal sounds emanating from the subjects’ mouths (and your own mouth) and interpret them!*”. He states that:

*“You are not authoritative about what is happening to you, but only about what seems to be happening in you, and we are giving you total, dictatorial authority over the account of how it seems to you, and **what it is like to be you.**”*

Dennett dislikes the use of ‘lone wolf autophenomenology’ where the subject and the experimenter are one and the same person. Others such as Max Velmans (2006) have proposed an approach called Critical Phenomenology which is reflexive, unlike Dennett’s approach, and he argues that even third person reports from experimenters are ultimately based upon their first-person experiences. Instead, he argues first- and third-person methods should be employed conjointly to provide triangulation of evidence⁶⁸; indeed, Velmans argues that experimenters do this frequently particularly in psychology:

“Do psychologists ever use first-person methods (in isolation, or in combination with third-person methods)? Of course we do. When setting up a laboratory experiment, say on perception, the very first thing one usually does is to try the experiment on oneself.”

I must confess, I feel some affinity with this approach similarly to the affinity I feel with Massin’s (2017) armchair philosophising; that is to say, in thinking through this topic I have done much of this self-experimentation myself⁶⁹. Gualtiero Piccinini (2010) has attempted to improve upon Dennett’s method of Heterophenomenology to incorporate the self-measurement of first-person data. He argues that scientists should in es-

⁶⁵ Indeed, Rorty (1977) notes this is no different than the parallel consideration of Mendel’s use of ‘gene’, and further notes that “...*if the body had been easier to understand, nobody would have thought that we had a mind*”.

⁶⁶ Although I do think that robust exploration of the psychophysical relationships between *actual* effort, and *perception* of effort, are fundamental to understanding the sensory factors that might mediate these relationships.

⁶⁷ Note, a ‘self-report’ need not be a verbal report, nor does it even need to be communicated in any specific lexicon. In fact, Dennett (1991) suggests we must grant that some aspects of ‘what it is like to be you’ may be ineffable: “*What better grounds could we have*

for believing that you are unable to describe something than that (1) you don’t describe it, and (2) confess that you cannot? Of course you might be lying, but we’ll give you the benefit of the doubt.” (Dennett, 1991, pp 96-97).

⁶⁸ Arguably this suggests he is in favour of simple first-person experiments and the use of intuitions regarding perceptual phenomena.

⁶⁹ In fact, during the various ‘lockdowns’ as a result of the Coronavirus pandemic I’ve given much time to developing experimental paradigms for exploring the psychophysics of effort using myself as the subject... and much to her chagrin, my wife. I jest of course... she was more than happy to participate.

sence use the best evidence they have which might include first-person data, but that we should be cautious and reserved in what we can infer from it:

“According to the self-measurement methodology of first-person data, scientists treat subjects issuing first-person behaviours as a self-measuring instrument. It is the scientist’s responsibility to insure that the instrument is calibrated and set up properly and that the measurement is carried out correctly. It is also the scientist’s responsibility to determine what can and cannot be reliably measured by the instrument under the relevant circumstances. That being said, heterophenomenology got two important points right: first-person behaviours are not always a reliable window into the mind, and their use as evidence ought to be a form of third-person science.”

As such, in developing a definition of the *perception* of effort from empirical data we need to consider the approach taken to measure this phenomena, and thus the ‘training’ involved in eliciting first-person data regarding it whether this is as a third-person observer, or from self-measurement. These considerations may be particularly important given that it is not immediately obvious whether perceptual phenomenology is ‘thin’ or ‘thick’; that is to say either exhausted by low-level properties directly sensed, or whether it includes higher level properties such as potentials, causal relations, kinds, and functions (Masrour, 2011; Nanay, 2012). Considering the lack of consensus on the precise neurophysiological mechanisms that might give rise to a *perception* from sensory information that accompanies *actual* effort, it is difficult to say which of these, ‘thin’ or ‘thick’, effort might fall under. Yet, it has been argued that even conceptual experiences that are initially post-perceptual⁷⁰, could become part of the perceptual experience (Nanay, 2012)⁷¹. Such, cognitive infiltration has implications relating to the instruction and training of subjects to elicit first-person data regarding their phenomenological experience. I, for example, have spent many years thinking about this topic of effort and trying to attend very closely to the phenomenological experience during tasks of all kinds; thus, it might not be surprising that it is now a quite

salient part of my perceptual phenomenology, or at least it appears to be.

Though, even if such ‘cognitive infiltration’ is not something which happens and effort indeed falls within our perceptual experiences, our gestalt phenomenology is filled with many perceptions at any given instant. Yet, given aspect perception, though they may fill our ‘perceptual field’ we may experience each with differing degrees of salience (Davies, 2011)⁷². Thus, though some may have interest in understanding this gestalt whole, there must also be consideration of the separation of each perception within the phenomenological experience in order to obtain first-person data of the greatest ‘precision’ and understand the composition of the whole⁷³. Recall again that such differentiation is also a virtue of ‘good’ conceptual definition (Gerring, 1999; Wacker, 2004).

Similar to other conscious personal experiences such as taste, pleasure/pain, and wellbeing (Moskowitz & Meiselman, 1977; Bartoshuk, 2014; Krueger & Stone, 2014), psychophysical approaches have been used in attempts to relate subjective personal experiences of effort to objective physical processes (Borg, 1998). However, due to the fact that self-report or other behaviours are the data generated from this, it is not possible to completely ascertain the extent to which any measure of *perception* of effort obtained is truly reflective of the perceptual or conceptual processes underlying the experience of the *actual* effort required or done (Gameberale, 1990). Because of this required step in the process of measuring *perception* of effort (a subject providing a rating, or displaying some other behaviour), careful consideration must be given to exactly how a definition of it is formed. The subject must understand what it is they are being asked to provide a rating of, or attend to, in order for that to be a valid reflection of the desired concept i.e., *perception* of effort (Moore et al., 2018; Halperin and Emanuel, 2020). Further, considering additionally the nature of our definition of *actual* effort, and the relation of this to *perception* of that effort through sensory apparatus, it seems that any definition of the *perception* of effort (particularly because it must be provided to subjects or at least encapsulated in what a subject is asked to provide a rat-

⁷⁰ Recall that Dunn et al. (2016) have suggested effort is a meta-cognitive evaluation.

⁷¹ Nanay (2012) gives the example of a chess master who has spent such time training the conceptualisation of a particularly strategy for an opening that it becomes automatic and part of their perceptual experience of the board.

⁷² In physical tasks the notion of whether perception of effort can be considered ‘gestalt’ has been specifically questioned (Hutchinson and Tenenbaum, 2006).

⁷³ Though, if the phenomenology of perception during attempted task performance is similar to that of visual perception, binocular rivalry might suggest that we cannot actually perceive this gestalt whole at any given instance.

ing of) should as closely as possible reflect this pathway and thus the subjective nature of the specific objective concept.

Thus, in this section I will first discuss existing definitions of the *perception* of effort, in addition to some discussion of scales and instructions often used in intentional attempted task performances both physical and cognitive, noting what I believe are some of the issues they produce. Then I will offer my definition of the *perception* of effort which I feel is an appropriate corollary of the definition of *actual* effort. That is, the two concepts whilst clearly differentiated, are unified in that *perception* of effort is the imperfect reflection of *actual* effort much like a reflection in moving water. I will note here in advance that I think this definition of *perception* of effort is inherently weaker than the one offered for *actual* effort by dint of the fact that it is defining an aspect of phenomenology.

Existing definitions of 'perception' of effort

Various verbal definitions for the *perception* of effort during both physical and cognitive tasks have been offered from a range of authors and some of the most prominently used and cited have been included in Table 2. While many offer value when it comes to the understanding and measurement of someone's perception of effort, I feel that many suffer from shortcomings that might impact their use as conceptual definitions. Indeed, as will be clear, many fall short of the virtues of 'good' concepts (Gerring, 1999; Wacker, 2004). Many of these issues are particularly evident from examination of the approaches used in combination with such definitions, to measure perception of effort.

As noted already there is the issue of some referring to a 'sense of' effort when it is perhaps more appropriate to refer a 'perception of' effort. Secondly, there is the issue of the terms 'effort' and 'exertion' being used interchangeably (as evident from some even using the terms in description of one another). In fact, sometimes these definitions are used to refer to effort and in others exertion, or even both within the same text. This presents issues particularly for those for whom English is not their first language and in an extension of the lexical fallacy arguments could support a case for dropping the terms in favour of a new label (e.g. *Horme*). There is also the issue of descriptions including reference to things such as 'heaviness', 'fatigue', 'self-efficacy', or things that could perhaps be grouped as 'discomfort' (i.e., 'strain'). Indeed, many

definitions appear to describe some gestalt experience. However, as noted, though humans experience multiple perceptions simultaneously during attempted task performance, they are evidently capable of differentiating these as separate dimensions of their overall experience and doing so conceptually presents value for empirical work, theory building, and theory testing. Thus, as mentioned I wish to focus my conceptual definition on the perception of 'effort', how it is independent of other perceptions, and will briefly highlight some of the issues caused by the conflation included in many existing definitions.

Perception of 'exertion' or 'effort'?

This problem of synonymy is one that is particularly evidenced in the field of kinesiology and in the study of physical tasks. In fact, this internal debate could be argued to be a major barrier in the advance of interdisciplinary work between kinesiology and other fields interested in effort. Abbiss et al. (2015) have argued that perception of 'exertion' and perception of 'effort' are not interchangeable concepts, defining the former as "*the amount of heaviness and strain experienced in physical work*", and the latter as "*the amount of mental or physical energy being given to a task*." However, I believe an issue arises with insistence on using both terms, *despite* offering differing conceptual definitions of them, when considering that in many languages the two translate as synonyms⁷⁴. Table 4 presents translations of either term in 88 different languages highlighting where they do, and do not, translate *from* English as synonyms in the target language.

For example, though English is my first language, for many researchers with whom I have collaborated regarding effort in physical tasks it is not. These interactions have highlighted the issues of translation into their own languages. For example, in Portuguese both 'exertion' and 'effort' translate as 'esforço'. In French, both translate to 'effort'. In Italian, both translate as 'sforzo'. In German, both translate to a 'anstrengung'; and further, I am informed, to add to the potential confusion, 'schwer' is a word often used interchangeably to refer to something requiring a high actual and/or perception of 'effort' or that is particularly 'heavy' – a problematic conflation that is explained further below. The use of the terms as synonyms in some languages might create issues in attempting to measure either described concept, or indeed in the interpretation of the literature pertaining to either, when this involves

⁷⁴ A point that Abbiss et al. (2015) raise and then appear to promptly ignore.

Table 2. Existing definitions of *perceived* (subjective) effort

Source	Definitions
Borg (1962)	<p><i>“the feeling of how heavy, strenuous and laborious exercise is”</i></p> <p>And,</p> <p><i>“the sensation from the organs of circulation and respiration, from the muscles, the skin, the joints and force”</i></p>
Gamberale (1990)	<p><i>“...the perception of effort should be interpreted as constituting a ‘summing up’ of the influence on the organism from all structures under stress during physical work.”</i></p>
Noble and Robertson (1996)	<p><i>“the subjective intensity of effort, strain, discomfort, and/or fatigue that is experienced during exercise”</i></p>
Burgess and Jones (1997)	<p><i>“Effort as an efferent perception may be defined as how hard one tried when carrying out a motor task.”</i></p>
Taylor (2009)	<p><i>“...the sense of effort gives a perception of the strength of muscle contraction relative to the total strength of the muscle.”</i></p> <p>And,</p> <p><i>“...a perception of the proportion of total muscle strength being used.”</i></p>
Preston and Wegner (2009)	<p><i>“The particular feeling of energy that is being exerted... accompanied by a sense of strain and labour, that intensifies the harder a person tries”</i></p>
Marcora (2010)	<p><i>“the conscious sensation of how hard, heavy, and strenuous a physical task is”</i></p>
Kirschner and Kirschner (2012)	<p><i>“...how hard a person tried to actively process presented information... a combination of perceived demand characteristics, perceived self-efficacy, and level/depth of information processing such that the first two influence the last which determines the amount of invested mental effort”</i></p>
Dunn et al. (2016)	<p><i>“...conceptualizing effort is to liken it to a type of general metacognitive evaluation of perceived task demand... In this vein, we can consider an individual’s metacognitive evaluation of demand as akin to a type of metacognitive experience (e.g. perceived effort)”</i></p>
Taylor (2016)	<p><i>“...sense of effort, which reflects the relative strength of a muscle contraction as a proportion of that muscle’s maximum force output...”</i></p>
Radel et al. (2017)	<p><i>“Mental effort is a feeling of strain occurring while investing a limited energetic resource to perform a mental task, due to the mobilization of controlled cognitive processing.”</i></p>
Halperin and Emanuel (2020)	<p><i>“The process of investing a given amount of one’s perceived physical or mental resources out of the perceived maximum to perform a specific task”</i></p>

Table 3. Translations of ‘effort’ and ‘exertion’ across different languages.

Language	Ways to say effort	Ways to say exertion	Match O/X
<i>European Languages</i>			
Albanian	përpejke	tendosje	X
Basque	ahalegin	exertion*	N/A
Belarusian	высілак	напружанне	X
Bosnian	napor	napor	O
Bulgarian	усилие	усилие	O
Catalan	esforç	esforç	O
Croatian	napor	napor	O
Czech	snaha	námaha	X
Danish	indsats	anstrengelse	X
Dutch	inspanning	inspanning	O
Estonian	pingutus	pingutus	O
Finnish	ponnistus	ponnistus	O
French	effort	effort	O
Galician	esforzo	esforzo	O
German	Anstrengung	Anstrengung	O
Greek	προσπάθεια (prospátheia)	προσπάθεια (prospátheia)	O
Hungarian	erőfeszítés	erőfeszítés	O
Icelandic	átak	áreynslu	X
Irish	iarracht	exertion*	N/A
Italian	sforzo	sforzo	O
Latvian	pūles	piepūle	X
Lithuanian	pastangos	įsitempimas	X
Macedonian	напор	напор	O
Maltese	isforz	strapazz	X
Norwegian	anstrengelse	anstrengelse	O
Polish	wysiłek	wysiłek	O
Portuguese	esforço	esforço	O
Romanian	efort	efort	O
Russian	усилие (usiliye)	напряжение (napryazheniye)	X
Serbian	напор (napor)	напор (napor)	O
Slovak	snaha	námaha	X
Slovenian	trud	naporu	X
Spanish	esfuerzo	esfuerzo	O
Swedish	ansträngning	ansträngning	O
Ukrainian	зусилля (zusylyla)	напруга (napruha)	X
Welsh	ymdrech	ymdrech	O
Yiddish	מַחְצָה	אַרבעט	X
<i>Asian Languages</i>			
Armenian	ջանք	լարում	X
Azerbaijani	səy	güc	X
Bengali	প্রচেষ্টা	উদ্যম	X
Chinese Simplified	功夫 (gōngfū)	用力 (yòngli)	X
Chinese Traditional	功夫 (gōngfū)	用力 (yòngli)	X
Georgian	ძალისხმევა	დაძრავს	X
Gujarati	પ્રયત્ન	પ્રયત્ન	X
Hindi	प्रयास है	तनाव	X
Hmong	dag zog	tom	X
Japanese	努力	努力	O
Kannada	ಪ್ರಯತ್ನ	ಪರಿಶ್ರಮದಿಂದ	X
Kazakh	күш салу	жүктемесін	X
Khmer	កិច្ចខិតខំប្រឹងប្រែង	ខំប្រឹង	X
Korean	노력 (nolyeog)	노력 (nolyeog)	O
Lao	ຄວາມພະຍາຍາມ	ກາບອກແຂງ	X
Malayalam	(ശ്രമം	കറവ്	X
Marathi	प्रयत्न	श्रम	X
Mongolian	хүчин чармайлт	хүчлээд	X
Myanmar (Burmese)	ကြိုးစားအားထုတ်မှု	ခေတ္တခဏ	X
Nepali	प्रयास	exertion	X
Sinhala	උත්සාහයක්	ඔප්පීමේත්	X
Tajik	кушишҳои	кушиши	X
Tamil	முயற்சி	உழைப்பு	X
Telugu	ప్రయత్నంతో	కృషిచేసిన	X
Thai	ความพยายาม	การออกแรง	X
Turkish	çaba	çaba	O

Table 3. Continued.

Urdu	کوشش	تیشرم	X
Uzbek	harakat qilish	qizg'inlik	X
Vietnamese	cố gắng	Sự gắng sức	X
<i>Middle-Eastern Languages</i>			
Arabic	majhud) مجهود	majhud) مجهود	O
Hebrew	מִשָּׁרָף	מִשָּׁרָף	O
Persian	تلاش	اعمال زور	X
<i>African Languages</i>			
Afrikaans	poging	inspanning	X
Chichewa	khama	thukuta,	X
Hausa	} o } arin	exertion*	N/A
Igbo	mgbaļ	exertion*	N/A
Sesotho	boiteko bo	Mokhathala	X
Somali	dadaal	dirqin	X
Swahili	juhudi	exertion*	N/A
Yoruba	akitiyan	işákuṇ	X
Zulu	umzamo	ukuzikhandla	X
<i>Austronesian Languages</i>			
Bisaya	paningkamot	paningkamot	O
Tagalog	pagsisikap	pagpupunyagi	X
Indonesian	upaya	pengerahan tenaga	X
Javanese	gaweyan	kaluwehan	X
Malagasy	ezaka	ezak'izy	X
Malay	usaha	melakukan senaman	X
Maori	kaha	tautooraa	X
<i>Other Languages</i>			
Esperanto	fortostreĉo	penego	X
Haitian Creole	efò	efò	O
Latin	conatus	scientibus Lilybaei abstulisti	X
No. Matches (O)			29
No. Differences (X)			54
Percentage of Languages with Matches			34.94%

Note: Translations were drawn from <https://www.indifferentlanguages.com/>

Some languages most commonly adopt the English word as a 'loan word' and these are indicated by *

those whose language treats the words as such. Pageaux (2016) has argued that, considering many within the literature do in fact use the two terms as synonyms already, and that many languages do the same, it may be best to instead use the terms interchangeably⁷⁵. Instead, the descriptors of other phenomenological aspects associated with exercise (such as 'strain') might be better termed as 'pain' or 'discomfort'⁷⁶. Following from this disagreement within the literature my research group has also been suggested a differentiated approach to the terminology should be used (Steele et al., 2017b). 'Effort' and 'exertion' are used by some interchangeably, but by others they are not, so such an approach might avoid confusion in communication⁷⁷. As most consider

perception of 'effort' to refer in some way to the *subjective* component relating to the attempt to meet the demands of a task (whether physical or cognitive), and that 'exertion' appears to be often used in reference to the perception of *other* aspects during those attempts, the term 'effort' might be more felicitous with respect to the former (but that 'exertion' not be used interchangeably with it), and 'discomfort' (or another contextually appropriate term e.g. 'pain', 'fatigue', 'force/load/weight/demand') for the latter. This approach deals with the potential operational issues of separating the two variables for measurement, and in such a way as to avoid issues in certain languages upon translation; and, would assist in avoiding unnecessary

⁷⁵ He also suggests utilising the definition provided by Marcora (2010); though, both I and others (Halperin and Emanuel, 2020) find this definition to include unnecessarily misleading terms.

⁷⁶ Although, 'pain' has been reported as perceptually distinct from 'discomfort' during exercise (Hamilton et al., 1996) and so the latter may be preferable for such exercise induced perceptions unless injury itself has occurred.

⁷⁷ Indeed, even recent texts where the authors note this distinction between 'effort' and 'exertion' the terms are still used interchangeably without sufficient care as to when either is supposed to be appropriate (Hutchinson and Tenenbaum, 2019)

confusion in interpretation of the literature around this area.

Further problems with definitions, and measures, of perception of effort: Descriptors and anchors

As noted above, many of the definitions offered for perception of effort utilise other terms as descriptors that could cause confusion for those being asked to offer an appraisal of this; and indeed, may be separate perceptions entirely. Further, many of these descriptors have been directly utilised in self-report tools (and their instructions) used to measure perception of effort⁷⁸.

'Heavy', 'Heaviness', or perception of absolute task demands

Use of the term 'heavy' is a particular issue for attempted physical task performances which often involve actually lifting weights of different magnitudes. Many definitions used in fields studying these tasks, along with the tools used to elicit self-reports⁷⁹ utilise descriptors that could be interpreted by someone as referencing perceptions of weight, or load, experienced⁸⁰. Considering the definition of *actual* effort proposed, we can of course acknowledge that an increase in the weight used in a physical task will mean a greater effort is required and thus likely elicit a greater perception of effort. In fact, these scales have good construct validity when considered with reference to the weight/load used unsurprisingly (Andersen et al., 2010; Buckley & Borg, 2011; Colado et al., 2012; Hollander et al., 2015; Lins-Filho et al., 2012; Pincivero, 2011; Gearhart et al., 2001; Gearhart et al., 2002; Lagally et al., 2002a)⁸¹.

However, as mentioned, the *actual* effort required to attempt a task also rises over time, even when

an absolute submaximal demand (i.e., weight/load/power/speed) is used, due to a reduction in the capacity to meet task demands (i.e., fatigue). Indeed, studies show that for physical tasks this also manifests in an increased *perception* of effort over time (Hortsmann et al., 1979; Noakes, 2004; Marcora & Staiano, 2010; Buckley & Borg, 2011; Pincivero, & Gear, 2000; Pincivero et al., 2004; Testa et al., 2012). This increasing perception of effort with continued time on task also occurs in cognitive tasks⁸² performed at fixed absolute demands due to the reduction in capacity (i.e. fatigue) that occurs (Wright et al., 2008; Hockey et al., 2013; Richter et al., 2016; Bijleveld, 2018; Bambragh et al., 2019). As such, we would expect *actual*, and thus *perception* of, effort to differ independently of the submaximal absolute demands of the task as a result of the reduction in capacity (fatigue) experienced during continued attempted task performance⁸³. In fact, this is in essence what we might expect if the *perception* of effort were a corollary of *actual* effort given the models depicted in figure 3. That is, effort is not dependent only on the value for demands as they are moderated by capacity.

For example, a single instantaneous task attempt performed with say, 80% of a person's maximum capacity, will require a greater *actual* effort, and likely produce a greater *perception* of effort, compared to a single instantaneous task attempt performed at 50% of their maximum capacity. However, if the task attempt with 50% were repeated or continued to a point of momentary task failure (i.e., the point at which, despite attempting to do so, a person can no longer meet the task demands⁸⁴), we would expect a greater *actual* effort to be required, and thus likely a greater *perception* of effort, than that produced by the single task attempt at

⁷⁸ I first became cognizant of many of these issues in the work on resistance training that my research group conducts (Steele, 2014; Steele et al., 2017b).

⁷⁹ For example, the Borg 6-20 Category Scale, Borg Category-Ratio-10 Scale, OMNI scale etc.

⁸⁰ For example, Borg's scale (1998) uses "Hard (heavy)", "Weak (light)", "Strong (heavy)" and the adult OMNI Scale, developed for use specifically with resistance training, adds to this by using specific images which depict an increasingly heavier load on the barbell being held by the avatar (Robertson et al., 2003).

⁸¹ And also, other physiological measures such as electromyographic amplitude, heart rate, and blood lactate when performing resistance training (Andersen et al., 2010; Hollander et al., 2015; Pincivero, 2011; Lagally et al., 2002b; Colado et al., 2012; Robertson et al., 2003).

⁸² Though, in certain cognitive tasks there can be a short-term reduction in perceived effort with time on task which is thought to be

due to a 'learning' effect, and development and application of heuristics to reduce processing demands (Shah and Oppenheimer, 2008; Bambragh et al., 2019).

⁸³ Further reason to argue against the inclusion of descriptors relating to the 'heaviness' of task demands when attempting to define perception of effort, at least for attempted physical task performance, is that not only is the actual task demand (i.e. weight/load) independent of the actual and perceived effort, but also that the perceptions of effort, force, and heaviness are phenomenologically distinct and indeed neurophysiologically distinct mechanisms exist for the sensory stimuli that the latter perceptions represent (Taylor, 2009; Taylor, 2016; Proske and Allen, 2019). In fact, interesting work has shown this distinction using the size-weight illusion (Burgess and Jones, 1997; Buckingham et al., 2014).

⁸⁴ Note, I am aware here that, with respect to attempted task performance by conscious actors such as humans, this 'momentary task failure' may or may not actually coincide with the intersection of actual task demands and actual task capacity. Indeed, many argue

80%. The reduction of capacity that occurs with continued task attempts influences the *actual* effort required and thus should influence the *perception* of effort experienced. Yet if descriptors relating to the absolute task demands (e.g. weight/load in the case of a physical task) are used when attempting to measure *perception* of effort we may instead be asking persons to rate the perception of absolute demands being used in the task instead (i.e. its ‘heaviness’)⁸⁵.

‘Fatigue’, ‘Self-efficacy’, and perception of capacity to meet task demands

As already noted, fatigue is a term often used for the reduction in capacity to meet task demands and which interacts with absolute task demands to determine the *actual* effort required. The *perception* of effort is directionally (albeit seemingly coarsely) related to this and, during continued task attempts at fixed absolute demands, increases as a function of time due to the reduction in capacity that occurs (i.e., fatigue). *Actual* fatigue is merely capacity to meet task demands expressed with an opposite sign (i.e., a *decrease* in the capacity to meet task demands of a certain magnitude is the same as an *increase* in fatigue of a certain magnitude), and thus *perception* of fatigue is the *perception* of this changed capacity.

However, a related concept is ‘self-efficacy’ which refers to an individual’s belief in his or her capacity to execute behaviours necessary to meet specific task performance demands (Bandura, 1977; 1986; 1997). Indeed, self-efficacy is essentially the *perception* of an individual’s capacity to meet task demands. Thus, ‘perception of fatigue’ and ‘self-efficacy’ are extensionally equivalent in that they both refer to the same thing: *perception* of capacity to meet task demands⁸⁶.

During continued attempted task performance the change in capacity to meet task demands and effort

are related; but, upon task disengagement the *actual* effort, and also the *perception* of effort, experienced drop immediately to zero; whereas the reduction in capacity to meet task demands, although often transient, may *actually*, and be *perceived* to, last past this point. Thus, though effort, both *actual* and the *perception* of, is influenced by the capacity to meet task demands, they are not the same thing. Indeed, the *perception* of capacity to meet task demands (whether termed ‘fatigue’ or ‘self-efficacy’) should be considered distinct from the *perception* of effort.

Perception of fatigue is something that is often measured as a state variable in response to, or during, task performance and indeed is often related to perception of effort; that is to say the greater the perception of fatigue, the greater the perception of effort (Benoit et al., 2019; Mickelwright et al., 2017; Milyavskaya et al., 2018; Greenhouse-Tucknott et al., 2019; Fernandez et al., 2020; Whitaker et al., 2019). Similarly, self-efficacy⁸⁷ has been examined and found to be related to perception of effort as a trait variable⁸⁸ (i.e. typically the greater the self-efficacy, the lower the perceived effort; Kukla, 1972; Ford and Brehm, 1987; McAuley and Courneya, 1992; Rudolph and McAuley, 1996; Pender et al., 2002; Sarrazin et al., 2002; Yoshida et al., 2002; Hu et al., 2007; Pinxten et al., 2014; Malik et al., 2020); though has sometimes been measured as a state variable which reduces in response to continued attempted task performance (Hall et al., 2005; Wrightson et al. 2019)⁸⁹, and has also been manipulated where studies have found increasing/decreasing self-efficacy decreased/increased perception of effort (and even volitional performance) respectively (Weinberg et al., 1979; 1980; 1981; Feltz and Riessinger, 1990; Fitzsimmons et al., 1991; Hockey, 1997; Kivetz and Simonson, 2003; Muraven et al., 2006; Hutchinson et al., 2008; Cameron et al., 2019; Mlynski et al., 2020). Indeed, further highlighting the extensional equivalence be-

that in such conscious actors it is more likely that task disengagement (i.e. the voluntary withdrawal of ‘trying’) occurs prior to this and instead when the actor reaches the level of *perception* of effort they are willing to put forth (which may or may not be maximal), or *perceives* their capacity has reached its limit relative to the task demands (Wright, 2008; Marcora and Staiano, 2010; Richter et al., 2016).

⁸⁵ Hysteresis models are also of interest to consider here. For example, in a stepwise or ramp task whereby absolute demands increase up to a point, and then following this reverse (i.e. the absolute task demands decrease symmetrically), on the latter stage the perception of effort is higher than during the former due to the residual drop in capacity that occurred (Montull et al., 2020).

⁸⁶ Wright et al. (2018) also appear to allude to this equivalency, albeit not explicitly.

⁸⁷ It is worth noting that there is considerable variation across studies in how ‘self-efficacy’ has been measured; some clearly ask regarding perceived capacity to meet task demands, others ask things such as perceived ability to tolerate the other perceptions experienced during attempted task performance like discomfort.

⁸⁸ Perhaps more akin to initial ‘rested’ maximal capacity to meet task demands.

⁸⁹ Though notably, both Hall et al. (2005) and Wrightson et al. (2019) reported that the relationship during certain physical task performances between self-efficacy and perceived effort broke down at very high relative task demands (endurance exercise above in the heavy/severe ‘intensity’ domains).

tween these two concepts, several studies show that fatigue and self-efficacy are also associated; though this is in clinical populations and looking at ‘state’ measures (Findley et al., 1998; Akin and Guner, 2019). However, Stephan et al. (2016) have posed an ‘allostatic self-efficacy’ model whereby perception of fatigue⁹⁰, particularly chronic fatigue and depression, is viewed as a metacognitive phenomenon: “...a set of beliefs held by the brain about its own functional capacity...”.

Of course, *actual* capacity influences *perception* of effort (Rudner et al., 2012) which is perhaps to be expected if we assume that people’s *perceptions* of their capacity are related to their *actual* capacity. However, despite people’s perceptions of capacity being *directionally* associated with their actual capacity, these also seem to be rather coarse grained for both maximal capacity (Wisen et al., 2002; Bindemann et al., 2014; Brewer and Olsen, 2016; Gjestvang et al., 2017) and in predictions of remaining capacity during attempted task performance (at least for physical tasks; Steele et al., 2017a; Hackett et al., 2012; Hackett et al., 2016; Altoé Lemos et al., 2017; Zourdos et al., 2019; Armes et al., 2020; Emmanuel et al., 2020).

‘Strain’, ‘Discomfort’, ‘Pain’⁹¹

As noted earlier, at least lexically, the perception of effort should also be considered differently from perception of discomfort during attempted task performance. Indeed, where scales and instructions are used for self-reporting perceptions of effort or behaviours are used as empirical indicators for it but do not make explicit this distinction, there is the potential for individuals to mar their reports or behaviour with the discomfort experienced. Yet, in both physical tasks and cognitive tasks individuals are able to differentiate and separately attend to the perceptions of effort and discomfort experienced (Tenenbaum et al., 1999; Steele et al., 2017b; Fisher et al., 2017a; Fisher et al., 2017b; Hsu et al., 2017; 2018; Stuart et al., 2018; Fisher et al., 2018; Bambragh et al., 2019). Indeed, with appropriate scales

and descriptions, even the perception of effort due to the task of performing respiration can be differentiated from the unpleasant discomfort associated with perception of air hunger or breathlessness (Lansing et al., 2000).

A definition of ‘perception of’ effort

As a result of many of these considerations, I have attempted to offer a conceptual definition of *perception* of effort that addresses the issues raised, and that is in keeping with what I think this perception is likely attempting to provide; that is, in essence, a conscious representation of the *actual* effort involved in attempted task performance. My current definition of *perception* of effort is thus:

Perception of effort; *noun*

The perception of that which must be done in attempting to meet a particular task demand, or set of task demands, and which is determined by the perception of current task demands relative to the perception of capacity to meet those demands, though cannot exceed that current perception of capacity.

I believe that this definition overcomes many of the issues noted whereby prior definitions, and the operationalisations produced from them, have often been marred by inappropriate descriptors. As a phenomenological variable I feel it is appropriate in that it possesses:

- Quality; meaning that, though it may be related to, it is distinct from other concepts (e.g. perception of task demands, perception of capacity to meet task demands, perception of discomfort etc.).
- Intensity; meaning that it has a magnitude.
- Direction; meaning that it is ‘aimed’ at the task being attempted.

⁹⁰ They opt to use the terms ‘tiredness’ and ‘fatigue’ to refer to what might be considered either acute or chronic reductions in perception of capacity (self-efficacy) respectively. They note that this is usually task specific (as self-efficacy is normally conceptualised) and in most cases this is transient and behavioural adaptation will shift self-efficacy back in the other direction. But, in extreme cases of chronic reduction (chronic fatigue/depression) they pose this reduction can become more general and lead to impact on self-efficacy in other tasks.

⁹¹ I note that some may see the absence of discussion regarding affective valence to be of concern given the discussion of what are often viewed as inherently negatively valenced experiences; for

some this includes the experience of effort, though as noted it is not so simple (Inzlicht et al., 2018). The absence of discussion of valence here is partly because it is not clear to me what is the more appropriate approach to its conceptualisation. It is commonly defined with respect to degrees of pleasure or displeasure (Schroeder, 2004); but this is not the only way of conceptualising it and some have defined it as purely an indicator/representation of value (Caruthers, 2011). Nevertheless, irrespective of the framework chosen for its conception, it isn’t clear whether valence falls within our interoceptive phenomenology as *what* we experience itself; or, if instead it is more a colour of *how* we value what we do experience (Serban, nd.).

- Duration; meaning that it can be experienced over time.
- Hedonicity/affectivity; meaning that it can elicit emotions.
- Valence; meaning that it can have either a positive or negative value ascribed to it.

This definition relates to the definition offered for *actual* effort. Indeed, it could be said that it is merely the *perceptual* form of our *actual* effort definition i.e., the perception of task demands relative to the perception of capacity to meet those task demands. Indeed, as noted, perception of effort may be a meta-cognitive process (Dunn et al, 2016). Thus, we could follow the same set theoretical approach (Markus, 2008) and define it as a concept:

Perception of effort (concept)

$E_P(i, t, C_P, D_P, w, T_{Any})$ is the perception of effort for any individual i at time t where $C_P(i, t, x_C)$, and $D_P(i, t, x_D)$ are the perception of capacity and perception of demands respectively, and x_C and x_D are the magnitudes of those respectively for individual i at time t , where w denotes all possible states of affairs (i.e. combinations of i, t, C_P , and D_P), and T_{Any} denotes the boundary conditions noting it as intensional to all possible types of tasks.

Again, we have conceptually a set of hypothetically infinite size that describes all possible *perceptions of effort*. Further, this can be extended to a construct definition – $E_P'(i, t, C_P, D_P)$ – merely by again removing the w and T_{Any} terms. Thus, perception of capacity and perception of demands are always defined in relation to the *nature* of the task being attempted. Of course, similarly to our actual effort definition, this definition is, by its nature, a ratio given that perception of capacity and perception of demands have natural origins, and thus it could be expressed as a percentage:

$$\begin{aligned} D_P \leq C_P &\rightarrow E_P = \left(\frac{D_P}{C_P} \right) \times 100\% \\ D_P > C_P &\rightarrow E_P = 100\% \end{aligned}$$

Equation 2.

Similarly, to the definition of *actual* effort provided, this definition of *perception* of effort is by no means unique as for both physical (Halperin and Emmanuel, 2020) and cognitive tasks (Kirschner and Kirschner, 2012) there have been similar definitions. Nevertheless, I hope that this definition is again very clear in its derivation and assumptions and could be said to be ‘cleaner’. Of course, I hope its application is useful for researchers interested in understanding the subjective dimension of effort in conscious actors. As noted, not only do clear definitions of both *actual* and *perception* of effort in this way permit operationalisation including finer grained control and manipulation of the variables within studies, but the clear conceptual differentiation of the two permits deeper examination of where, when, and why discordance exists between them.

All the examples I offered in the section regarding *actual* effort and its definition can be extended here with *actual* merely replaced by *perception* of⁹². Equally, so too could figure 3 and figure 4. However, as noted the perception of effort appears at best a coarse-grained representation of actual effort which is probably a result of the introduction of ‘noise’ into the signal from both the sensory systems, and the perceptual system. As such, although the directional patterns of perception of effort often follow those we would expect based upon actual effort, they are ‘fuzzy’ and inaccurate representations of reality. Thus, before concluding, as initially promised I want to offer some brief thoughts on the reunification of *actual* and *perception of effort* here in a possible⁹³ psychophysical model, and to highlight why I think that this work holds value for future empirical work, theory building, and theory testing through consideration of the operationalisation step from conceptual definition.

Reuniting Actual, and Perception of, Effort

As noted, clear conceptual definition holds considerable value for theory building and testing of course in aiding with operationalisation and measurement. But, in particular it offers value in supporting formal theory development and derivation of propositions through mathematical or computational modelling (Dubin, 1969; Guest and Martin, 2021; Borsboom et al., 2021; Navarro, 2021; Haines et al., 2021). As I have

⁹² As this piece is already long enough, I’ll let you, the reader, imagine that for yourself and save the space on the page.

⁹³ Note that I am not proposing this as being a model with any known degree of verisimilitude, nor one which I have yet set about

testing systematically. Further, it is by no means the only model which could be produced from the concepts presented in this work. It is merely illustrative.

The final simulated operationalisation of our psychophysical model of actual effort ~ perception of effort

Figure 6. Output of the generative model of effort psychophysics outlined in Equation 3 with slight overestimation bias (left) and underestimation bias (right) in the self-reporting of perception of effort.

alluded to, I speculate the *actual* effort involved in attempted task performance is separate but gives rise to the *perception* of that effort.

In figure 4 earlier I presented what could be considered the underlying idealised actual effort for a range of task demands over time; the effort we could know if we had, in Paul Meehl's parlance, the knowledge of Omniscient Jones i.e., perfect knowledge of reality as it is. This is what, given the definitions provided (and of course the assumption in that particular model for how capacity decays), we would determine effort to be if we had the values for actual capacity and demands at a given time for a given individual attempting to perform a task. However, we do not ever have this information. Instead, we must operationalise our concepts and take observations of them; observations which are subject to 'noise'. Similarly, the manner in which the underlying *actual* effort gives rise to the *perception* of that effort is also subject to 'noise' though independently. In our case, we might assume that the 'noise' occurs in the perception of demands and capacity, and these imperfect representations are then meta-cognitively evaluated to result in the perception of effort (Dunn et al., 2016). Lastly, as explained, we cannot directly measure this phenomenological experience but instead must rely on self-report or other behavior. Actually, like other incongruences between actual and perception such as in the Dunning-Kruger effect, there may also be the potential for a bias factor to influence

the measurement we obtain through rating or behaviour (Haines, 2021).

Taking these considerations, we could lay out the following formalisation of this model:

$$\begin{aligned} D_{A,obs} &\sim \text{Normal}(D_A, \sigma_{D_A}) \\ C_{A,obs} &\sim \text{Normal}(C_A, \sigma_{C_A}) \\ E_{A,obs} &= \frac{D_{A,obs}}{C_{A,obs}} \end{aligned}$$

$$\begin{aligned} D_P &\sim \text{Normal}(D_A, \sigma_{D_P}) \\ C_P &\sim \text{Normal}(C_A, \sigma_{C_P}) \\ E_P &= \frac{D_P}{C_P} \end{aligned}$$

$$E_{P,obs} \sim \text{Normal}(E_P + b, \sigma_{E_P})$$

Equation 3.

Where the symbols for actual and perception of demands and capacity are the same as in Equations 1 and 2, and the observed counterparts of these are denoted by superscripted 'Obs', 'noise' parameters are denoted by the letter σ and the bias factor is denoted by the letter b . Taking the simulated idealised data from earlier in figure 4, we get the following results from this model shown in figure 6A if we assume a slight overestimation bias to reporting, and 6B if we assume a slight

Figure 7. A possible psychophysical model of effort depicted as a directed acyclic graph. Note: D_A = actual task demands; C_A = actual capacity to meet task demands; E_A = actual effort; $D_{A,Obs}$ = observed actual task demands; $C_{A,Obs}$ = observed actual capacity to meet task demands; $E_{A,Obs}$ = Observed (calculated) actual effort; D_P = perception of task demands; C_P = perception of capacity to meet task demands; E_P = perception of effort; $E_{P,Obs}$ = observed perception of effort; b = reporting bias

underestimation bias. Of course, I have arbitrarily selected values for each ‘noise’ parameter and also for bias purely for illustrative purposes⁹⁴. Figure 7 then might extend our ‘theory’ of *actual* effort (see figure 3) to a psychophysical model that includes *perception* of effort as a component conceptual ‘theory’ within. In this model, we are interested in the underlying relationship between E_A and E_P , but have to rely on the operationalisation of this through the empirical indicators of $E_{A,Obs}$ and $E_{P,Obs}$. We could also extend this model to be more in keeping with current Bayesian models of perception, whereby we might introduce priors on the perceptual parameters in the model (Knill and Richards, 1996; Vilares and Kording, 2011; Vincent, 2015).

The point here is merely to show that, given the definitions presented, we can begin to develop formal generative models from our theories for what our observations might look like if the assumptions of the model were in fact true. Thus, we have in Dubin’s (1969) terms, clear logical propositions that lead to clear hypotheses to enable us to test our theories. Hypotheses are merely the operationalisations of propositions from formal theories or models.

Given that effort as noted is a concept often included in various theories and models across a number

of fields, I believe that such formalisation of the concept will aid with better formalisation and testing of these theories. Further, an obvious first step is in developing a robust theory of effort psychophysics, by which I mean a robust understanding of the nature of the relationship between *actual* effort and the *perception* of that effort.

I have deliberately maintained depth in the conceptual definition of both actual and perception as a noted virtue of ‘good’ concepts (Gerring, 1999; Wacker, 2004) by way of making them intensional to *any* species of task. Thus, beginning with these concepts logically leads to the development of a ‘general’ psychophysical model that has the proposition that the relationships are similar in shape across different tasks i.e., its domain, or boundary conditions are necessarily wide. Such a model would be interesting to explore systematically through the selection of a large set of different tasks across different domains, and modelling these as random variables to draw broad generalisable conclusions regarding effort psychophysics (Yarkoni, 2021). However, as Massin (2017) has noted, there may in fact be different species of effort, and thus empirical exploration may reveal that there are indeed quantitatively different relationships between *actual* effort and

⁹⁴ See code in online materials <https://osf.io/p75m2/>

the *perception of* that effort for different tasks. Theory development and iteration should rely on empirically observed quantitative relationships and not merely some presumed qualitative differences between tasks or a ‘feeling’ that they should differ (Eronen and Bringmann, 2021). This is what Chang (2004, 2016) refers to as ‘epistemic iteration’. This iteration and possible contraction of the boundary conditions for a psychophysical model could also extend to populations of actors⁹⁵, or environmental conditions and interventions as noted in the section on perceptual illusions of effort.

I have also not considered the problem of level of analysis (Eronen, 2019; Fried, 2021), though I have alluded to the idea of ‘net’ task demands throughout. Most tasks that actors attempt to perform can be broken down from their gross levels to lower and lower levels⁹⁶; it may be turtles all the way down! Whether it is fruitful to explore for example the nature of lower component levels of actual effort for a given task and their relationship to perception is of course something that can only be answered through developed understanding of the ‘black box’ of sensory signals. Arguably, this could just be considered an extension of the discussion above regarding boundary conditions. Although, there are arguments for maintaining a practical pluralism (Eronen, 2019), and this seems prudent given the typical theories that employ effort as a concept. On these theories then, we should consider finally why the formalisation argued for here is worthwhile.

Effort... in Theory and Practice

“In theory there is no difference between theory and practice, while in practice there is.”
(Benjamin Brewster, 1882. *The Yale Literary Magazine*)

It has recently been argued that psychologists⁹⁷ are often not yet ready to begin testing the hypotheses that their theories imply⁹⁸ (Scheel et al., 2021). In part, this is thought to stem from the lack of formalisation of

theories, and indeed deeper than that, the building blocks of those theories: concepts. As noted, there is interest in the employ of effort across diverse fields and within many theories (e.g. Rosenbaum & Gregory, 2002; Parfitt and Hughes, 2009; Smirnaul et al., 2013; Pageaux, 2014; Fisher and Steele, 2014; Bigler et al., 2014; de Morree and Marcora, 2015; Abbiss et al., 2015; Shepherd, 2016; Cha et al., 2015; Shadmehr et al., 2016; Pageaux, 2016; Steele et al., 2017; Cos et al., 2017; Morel et al., 2017; Shenav et al., 2017; Massin, 2017; Picou et al., 2017; St Clair Gibson et al., 2018; Inzlicht et al., 2018; Charness et al., 2018; Scarton et al., 2019; Andre et al., 2019; Steele et al., 2019; Halperin et al., 2020; Cheval and Boisgontier, 2021). Yet, it could be argued that in many of these areas the theories employing it are ‘immature’, lacking in a strong derivation chain leading from concepts to relationships/laws and boundaries denoting theories, to models and logical propositions, to operationalisation and measurement and highly specific hypotheses that might serve as severe tests of the substantive theory (Dubin, 1969; Meehl, 1990; Mayo, 2018; Guest and Martin, 2021; Navarro, 2021; Fried, 2021; Borsboom et al., 2021; Scheel et al., 2021). Returning to the earlier parable “Chaos in the Brickyard” (Forscher, 1963) employed by Knudson (2019) regarding terminology, in the context of theory driven research and the derivation chain, not only could we say we have unconnected piles of ‘bricks’, but we could argue that many of these ‘bricks’ (concepts) show evidence of poor craftsmanship.

Many theories that attempt to employ the concept ‘effort’ are unclear in exactly what they mean by this. This absence of clear conceptual definition extends to lack of clarity whether theories refer to effort as an objective, or subjective phenomena. Do theories propose that *actual* effort or the *perception* of effort, or both, impact things such as: selection and initiation of behaviour (i.e. task attempts); behavioural persistence

⁹⁵ For example, recent work suggests there may be differences in perception of effort between those with and without chronic low back pain (Coppieters et al., 2021), and of course there is clear evidence of this in schizophrenia (Lafargue and Franck, 2009; Gerrans, 2015),

⁹⁶ Take for example a simple task like attempted performance of elbow flexion to lift a weight. We could consider the net capacity and demands of that system with respect to lifting weight, or step down to the level of individual muscular contributions (biceps brachii, brachioradialis) and their capacity to produce force and the individual force demands placed on them, and onward down to individual myofibril level at each level considering the demands being

placed on that level and its capacity to meet them. For each we could then calculate the actual effort required, but should not presume the extent to which any given level(s) are causative with respect to the perception of effort.

⁹⁷ And I would extend that to the wider fields interested in effort.

⁹⁸ Note, here I am setting aside what Paul Meehl often refers to as technological research (e.g. treatment effects, predictive models etc. [though notable these could act as tests of theory where they are indeed consequent to propositions implied by the theory]) and referring to theory-driven research (Meehl, 1990).

in attempted task performance and task attempt cessation⁹⁹; the underlying mechanisms involved in carrying out task performances; how people adapt to the continued attempted performance of task behaviours etc. Clear concepts by necessity are the foundations of the derivation chain for good theory building and testing. Further, it is these which lead to valid operationalisation and measurement (Dubin, 1969; Gerring, 1999; Wacker, 2004). The definition of actual effort employed here leads to a quite simple and logical approach to its operationalisation; that is, the nature of the task under consideration dictates what should be considered the demands and thus the capacity. In essence, we have a kind of simple ‘face validity’ to the operationalisation of any empirical indicator of these two properties from which to determine the relational unit of actual effort. As Dubin (1969) notes:

“... the traditional view of validity has little to recommend it except in the limiting case where we can consider invalid those empirical indicators producing artificial values. The idea that any empirical indicator may be created that meets both the necessary and sufficient conditions of the definitions of a theoretical unit suggests that the problem of validity may be further simplified. As we shall presently see, many theoretical units have the potential of being measured by a large number of empirical indicators. In the face of this, and providing each empirical indicator satisfies the necessary and sufficient conditions defining the unit, it seems pointless to be concerned about the traditional issue of validity.”

Thus, operationalisation of actual effort is a simple case of considering whether a given empirical indicator meets the necessary and sufficient conditions defining the concept. I have suggested that an obvious first step in theory building from the concepts defined here is a general psychophysical model of effort. In fact, I think this will also present practical value for those wishing to test theories employing effort as a concept, whether objective or subjective, particularly with respect to measurement.

For example, researchers should probably consider whether capturing measurements of the perception of effort are in the interest of understanding effort

phenomenology specifically, or in gaining a measurement that is a ‘proxy’ empirical indicator of the actual effort required. That is, whether *perception* can act as a valid operationalisation of *actual*. In this respect it is worth noting it has been said that “*Psychophysical measures are inherently subjective and therefore are suspected to lack validity...*” (Hutchinson and Tenenbaum, 2019). Indeed, I have previously thought that they can only really be thought to lack validity if the intention is to measure something other than the subjective experience; though of course there is no guarantee either that the ‘rating’ we obtain is in fact a valid reflection of the phenomenology it is intended to represent. In all regards, caution in interpretation is encouraged when it comes to phenomenology. That being said, practically, and from the consideration of the two concept and construct definitions I have provided, it is possible, given that they are both ratios, for perfect collinearity along the identity with the same mean and standard deviation. If this were the case empirically in a given context then we would be able to say that both *actual* and *perception* of effort has *strong identity*. However, the more coarsely grained collinearity between the two constructs that has been observed empirically, at least up until now, could be said to reflect *weak identity* (Markus, 2008). Thus, development of a highly corroborated psychophysical model of effort would present value for researchers testing models, particularly if it meant that we could employ transformations of perceptual measures as valid operationalisations of actual effort. For example, a theory interested in *actual* effort, albeit in tasks where at present technological advancements limit the direct observation of capacity for the task at a given time (e.g. most cognitive tasks), might still be able to test hypotheses by operationalising *actual* effort as a rating of effort from the actor. Of course, such value may not manifest from development and testing of a psychophysical model; we may be left finding that *perception* of effort is so coarse grained that it is not considered a valid operationalisation of *actual* effort for practical means. Thus, it is worth touching on some final considerations for practical measurement of phenomenological experience relating to clear definitions.

As noted, a critical lens must be applied to any first-person data (Dennett, 1991; 2003; Velmans, 2006;

⁹⁹ The wording task ‘attempt’ cessation is deliberately chosen here such that, when considering conscious actors, it makes more sense to speak in this way to differentiate the questions “*why did they stop?*” and “*why couldn’t they continue?*”. The former here is

framed as being a question of the actors *choice* to cease the task attempt, whereas the latter is such that the task was still *being attempted* but they could no longer meet its demands and is a question about what led to a reduction in capacity such that this was the case.

Piccinini, 2010). Definitions are of particular importance when generating self-reports given that, absent the provision of a clear definition from the researcher, people often apply their own idiosyncratic definitions (Dunning et al., 1989; Dunning and McElwee, 1995). Further, with respect to perception of effort, as highlighted people can often conflate other salient perceptions in their self-reported ratings. In addition, despite the effort of attempted task performances being independent of their success/failure (Massin, 2017), people often apply substitution heuristics¹⁰⁰ whereby they answer regarding their perception of how *well* they perform (Picou et al., 2017; Moore and Picou, 2018). Peer presence may also impact upon ratings of perception of effort (Winchester et al., 2012; Minett et al., 2021)¹⁰¹. Indeed, it is unknown if the mere act of *asking* someone to provide rating of their phenomenology actually changes the experienced phenomenology (Ariely, 1998); thereby invalidating the self-report for its presumably intended purpose before it is even made (assuming the intention is to operationally measure phenomenology). Evidently, it is impossible for us to ever *know* the phenomenology of anyone other than ourselves. But there are likely things that can be done to ‘calibrate’ our self-reporting instruments (participants) as best as possible such that they provide the best measurements of the phenomena we are interested (Piccinini, 2010).

Considering the conceptual definition provided, I would argue that appropriate instruction and anchoring is required as some minimum for accurate measurement of perception of effort. Hopefully, it has been made clear that, without instruction, persons typically anchor their perception of effort upon their other salient perceptions substituting or mixing the ratings provided. An appropriate top anchor of maximal effort in relation to the absolute task demands is likely needed and I would contend that anchoring should be per-

formed in relation to the task demands using either descriptive explanation, past experience and memory¹⁰², experiential procedures, or all of these. If the task is to maintain a particular absolute demand for an extended period of time for example this might require some explanation of the notion of ‘task failure’ (i.e. the point at which despite attempting to do so you can no longer maintain the task demands) again specifying what those demands are.

If it is of interest to also examine other perceptions (i.e. ‘heaviness’, ‘fatigue’, ‘discomfort’), which some theories may also include, then these should be appropriately differentiated from perception of effort and full details provided of their operationalisation. However, if applying several scales consideration should be made for issues of scale burden and how this may impact ratings given by participants. I would encourage instead replication of individual perception of effort response effects with certain experimental conditions before then applying that experimental paradigm to examine new perceptual measures as dependent variables. That way you can have at least some confidence of the stability of the perception of effort under those experimental conditions and then examine other perceptions in relation to them.

In some cases, researchers may be interested in capturing measures of first-person perceptions of *third-persons*. For example, it may be of interest to understand how well not only our own perceptions of effort are reflective of the actual effort required for tasks, but also our perceptions of *others* (Steele et al., 2017b; Ibbotson et al., 2019)¹⁰³. Another interest might be in the prediction¹⁰⁴, anticipation, or remembering of attempted task performances and their phenomenology (Höst and Wohlin, 1997; Hsu et al., 2018; Dunn et al., 2017; Bambragh et al., 2019).

Lastly, irrespective of exactly how perceptions are captured by researchers I would strongly encourage fully reporting the scale used and the administration

¹⁰⁰ There is a beautiful irony in this: because answering regarding the *perception* of effort is difficult (the meta-cognitive process of relating perception of demands and perception of capacity is perhaps inherently ‘costly’ itself), a more accessible and easier question is answered in order to reduce the effort.

¹⁰¹ Winchester et al. (2012) for example found that men performing the same absolute demand treadmill task (20 minutes at 60% of their peak treadmill speed) reported higher ratings of perception of effort when observed by a male, and lower when observed by a female, compared to a control condition. Considering the task performed meant that the *actual* effort required was the same every time it seems that either the observer did genuinely influence participant’s *perceptions* of effort such that they no longer were accurate reflections of the *actual* effort required, or that participants

were dishonest in their reporting for psychosocial reasons relating to the observer.

¹⁰² An example might be asking participants to imagine the most demanding version of the specific task they think they would be capable of doing and then to consider how demanding it is to complete the task in relation to that.

¹⁰³ Relatedly, research has examined people’s perceptions of others capacities (i.e. team self-efficacy; Feltz et al., 1989; Parker, 1992) and people’s perceptions of the capacity of robots compared to their actual capacity (Cha et al, 2015).

¹⁰⁴ Or even the impact that predictions of effort may have upon the perception of effort when actually experienced.

procedures, including anchoring, instructions to participants, and the timings and environments when ratings were captured, so that readers can fully understand exactly what was measured and how. Independently of the considerations discussed in this paper, open and transparent reporting would likely result in far clearer interpretations of research going forwards, be a big step towards improving our understanding of these areas, and may aid in the development of better psychophysical scales for the measurement of perception of effort across task modalities.

Summary and Conclusion

Considering the historic and recently renewed growth in interest regarding ‘effort’, the purpose of this manuscript was to consider and define ‘effort’ during attempted task performance; hopefully, in a successful attempt to bring clarity to the topic, and permit unification of the concept across different fields of inquiry. In doing so I have argued for a distinction between the *actual* effort required, and the *perception* of that effort, during intentional attempted performance of tasks, as separate concepts. Further, I have followed a set theoretical approach to defining both *actual* effort and *perception* of effort as both *concepts* and *constructs*, in addition to couching these definitions within the tradition of Theory-Theory. Lastly, given the proposed necessity of the separation of *actual* effort and the *perception* of that effort, I considered their proposed reunification after formal conceptual definition arguing for psychophysical model development of these formal concepts, and its value to aid in theory building and operationalisation of hypotheses for theory testing.

Hopefully, one personal goal has also been achieved in producing this manuscript: I have made my own current conceptualisation and understanding of effort clear to myself, and to other researchers. At the very least, my own subsequent empirical work on the topic can be considered in light of it.

In terms of future research regarding *actual* effort and *perception* of effort, the conceptual definitions and considerations for measurement presented might better enable an understanding to be developed of where perceptions are, or are not, accurate reflections of reality (i.e., the psychophysical nature of effort), the reasons for this¹⁰⁵ and the implications of this. Further, researchers might explicitly look to understand both the independent and combined impacts of both objective

and subjective dimensions of effort in: selection and initiation of behaviour (i.e. task attempts); behavioural persistence in attempted task performance and task attempt cessation; the underlying mechanisms involved in carrying out task performances; how people adapt to the continued attempted performance of task behaviours etc. Whatever specifically is pursued, hopefully deeper conceptual work aids interpretation of subsequent empirical work, theory building, and theory testing on the topic.

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¹⁰⁵ For example, is it because the perception of task demands, or the perception of capacity, are inaccurate reflections of reality?

When, where, and why do errors influence the representation of effort in perception?

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