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REVIEW ARTICLE

When is Learning "Effortful"? Scrutinizing the Concept of Mental Effort in Cognitively Oriented Research from a Motivational Perspective

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Abstract

In the context of instructional design and self-regulated learning research, the notion of mental effort allocation, monitoring, and control has gained increasing attention. Bringing together a cognitive perspective, focusing on Cognitive Load Theory, and a motivational perspective, merging central accounts from Situated Expectancy Value Theory and Self-Determination Theory, we plea for a three-fold conception of effort that clearly distinguishes the different psychological sources of experiencing and allocating effort in learning environments: effort-by-complexity, effort-by-need frustration, and effort-by-allocation. Such a detailed conception has important implications for how effort should be studied and how it can be influenced by instructional support or by the learning individual itself. A first conclusion we draw is that cognitively oriented research needs to be careful when taking students' self-reports on the "effortfulness" of a task as an indication of the object-level cognitive requirements of the task, as such appraisals may also reflect the affective-emotional requirements of task execution as well as motivational beliefs regarding the likelihood of success and meaningfulness of a task. A second conclusion is that instructional procedures rooted in cognition-oriented theory ideally are complemented by motivation theory to support student learning optimally.

Keywords Cognitive load · Cost · Mental effort · Motivation

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Nothing comes from nothing! This proverb, perhaps like no other, depicts a currently highly influential line of psychological research. The notion of effort allocation, monitoring, and control has gained increasing attention from different research traditions (i.e., Cacioppo et al., 1996; Dreisbach & Fischer, 2015; Duckworth et al., 2019; Miele & Scholer, 2018; Shenhav et al., 2017). One particularly productive field has been cognitively oriented research on instructional design and self-regulated learning (de Bruin et al., 2020, 2023; Koriat, 2012, 2018; Seufert, 2018, 2020). In this literature, it is argued that the amount of *mental effort* devoted to productive learning activities as well as its monitoring and control by students themselves are essential to learning.

But what do scientists exactly mean when they refer to the concept of effort, for example, by claiming that learners can keep performance at a constant level with increasing task complexity (if not totally overwhelmed), by investing more mental effort (Sweller et al., 1998), by stating that learning is facilitated by *desirable difficulties* that require more mental effort (Bjork, 1994), or by postulating that exerting mental effort *is aversive* (Shenhav et al., 2017)? And what do students mean when stating that schooling is *exhausting* or that they *tried hard* to understand some learning material (Salomon, 1984)? Bringing together a cognitive and a motivational perspective, we plea for a three-fold conception of effort in contexts of learning in formal settings (e.g., school, college) that clearly distinguishes the different psychological sources of experiencing and allocating effort.

Such differentiation may enrich cognitively oriented research because cognitive load appraisals, as the most common approach to operationalize mental effort (e.g., Scheiter et al., 2020), are seen to reflect the cognitive resources *allocated* or *invested* by the learning individual to accommodate task demands (e.g., Hoch et al., 2023). Yet, this conception inherently intertwines motivational processes—determining for example the selection and persistence of behavior as well as its affective-emotional quality (Rheinberg et al., 2000; Vollmeyer & Rheinberg, 2000)—and the actual cognitive learning processes, without explicating the conceptual and methodological implications of this blending. Conceptually, when not being explicated, this blending may lead to an underestimation of motivational processes in learning. This may be the case, for example, when overlooking that there may be qualities of the effort experience that have nothing to do with the cognitive processing demands of a task per se, and when overlooking that every sort of cognitive processing presupposes some sort of motivational activation (cf., Hofmann et al., 2012). Methodologically, motivational processes of learning behavior should be better separated from its cognitive processes, for example, to study the role of the former as a cause for invalid cognitive load appraisals (cf., Scheiter et al., 2020).

What Is Effort and Why Should We Distinguish Different Conceptions?

Effort is a very widespread concept when it comes to formal learning. Most students would probably agree that learning at school is effortful and that it requires some sort of effort to learn new content and receive good grades, although they sometimes, and knowingly, avoid those learning activities that would be particularly effective (cf., Bjork et al., 2013). Similarly, most scientists seem to agree that effort is crucial for learning (cf., de Bruin et al., 2023; Metcalfe, 2011), and students' efforts to learn are highly valued by teachers (Matteucci et al., 2008). Yet, despite this seemingly common understanding, there is considerable conceptual confusion and inconsistency when it comes to pinning down effort as a concept of scientific study (cf., Shenhav et al., 2017).

In the following, we use the distinction between data-driven and goal-driven factors of effort experience and allocation (Baars et al., 2020; Koriat et al., 2006, 2014) as a starting point to elaborate on a three-fold effort conception that we use to illustrate the tension between motivational and cognitive conceptions of effort. According to Hoch et al. (2023), goal-driven effort refers to the mental effort an individual decided (or is willing) to invest (see also Scheiter et al., 2020), whereas data-driven effort refers to the mental effort an individual faces while dealing with task requirements. However, beyond this useful distinction, the term effort has at least three fundamentally different meanings—both in psychological research and in the lay world—that often get mixed up but should be clearly separated.

In a first meaning, effort indirectly reflects the difficulty or complexity of a problem (i.e., *effort-by-complexity*, see Table 1). From this perspective, lifting a stone of 20 kg requires objectively more physical effort than lifting a stone of 10 kg of the same size and haptic texture under similar conditions, and lifting the same stone 10 times or for 10 s is more effortful than lifting it 5 times or for 5 s. Similarly, solving a problem that includes three interrelated variables is typically seen to require more mental effort than a related problem that includes only two of these variables (e.g., Heitmann et al., 2018), and solving 10 math problems in 60 min is more effortful than solving five problems of the same kind in 30 min. This effort conception is a close analogy to the concept of work in physics. It refers to the *object-level* processing requirements of a task, hence, data-driven sources of effort experience being central also in cognitive load research (Sweller et al., 1998, 2019). The more complex, difficult, or time-consuming the problem, the more mental effort it requires to solve it (e.g., Bjork, 1994; Paas et al., 2003). As displayed in Table 1, we could infer this kind of effort specifically by asking a student during or after a task "How difficult is/was this task for you?" or, more ambivalently for a layperson, by "How much *effort* do/did you have to invest in order to solve the task?" (cf., Hoch et al., 2023).

In a second meaning, effort refers to how strenuous or aversive a person experiences task execution (i.e., *effort-by-need frustration* in Table 1). For example, learners working on a certain task as part of their homework may experience this task as exhausting, annoying, inconvenient, or stressful. Hence, in this sense, effort refers to the negatively valenced *affective-emotional* processing requirements of learning (e.g., Feldon et al., 2019). Notably, these affective-emotional processing requirements are also data-driven, as they arise directly from task execution. However, as we argue later, they are of a different kind compared to object-level processing requirements, as both have different psychological conditions of origin. We may infer this state of affair more specifically by asking "How strenuous is/was working on that task for you?" rather than by asking, more ambivalently for a layperson, "How *effortful* is/was it for you to work on that task?" Notably, different to what may be the case for the first effort conception, effort-by-need frustration is nothing

Table 1 Different conceptions and operationalizations of (mental) effort

Effort concept	Meaning	Practical implications	Ambivalent item example[a]	More specific item example
Effort-by-complexity	Object-level processing demands	Intrinsic/germane load needs to be *adapted* to prior knowledge to support learning; extraneous load needs to be *low* to support learning	How much effort do/did you (have to) invest in order to solve the task?	How difficult or complex is/was this task for you?
Effort-by-need frustration	Negatively valenced affective-emotional processing demands	Need frustration needs to be *low* to support learning; need satisfaction needs to be *high* to support learning	How effortful is/was it for you to work on that task?	How strenuous is/was working on that task for you?
Effort-by-allocation	Self-initiated effort	Expectancy and value beliefs need to be *high* to support learning	How much effort are you willing to/have you invested in the task?	How important/meaningful is it for you to work on that task? (value belief); how confident are you that you can solve the task? (expectancy belief)

Note: [a]By referring to the general term "effort," examples in this column are phrased ambivalently on purpose to illustrate the benefit of a more nuanced phrasing in line with our three-fold effort conception (see column on the far right) that is per se required to learn. Rather, it may even impair learning because it indicates suboptimal motivational processes (e.g., Dreisbach & Fischer, 2015; Ryan & Deci, 2020, see below for more details from the perspective of Self-Determination Theory) or even a behavioral tendency to withdraw (e.g., Watson et al., 1999).

Notably, when tasks are perceived as either subjectively very complex, highly aversive, or both, it requires good reasons and a certain kind of optimism to face these difficulties and to persist in deliberate cognitive operations. This assumption brings us to a third conception of effort, reflected also in the goal-driven effort interpretation (Hoch et al., 2023; Koriat et al., 2006) or the distinction between active and passive cognitive load (Klepsch & Seufert, 2021). In this conception, effort refers to the initiation, intensity, and persistence of learning-related behavior (i.e., *effort-by-allocation* in Table 1), as a direct outcome of momentary motivation (e.g., Salomon, 1984; Schnotz et al., 2009). This effort conception is quite different from the first two conceptions, as it does not refer to the characteristics of the learning task at hand, but rather to students' self-initiated effort allocation to deal with these requirements (see also Heider, 1958; Muenks et al., 2016).

Generally, people are willing to allocate effort when they are sufficiently motivated (Vollmeyer & Rheinberg, 2000). More specifically, it is typically assumed that students' expectancy and value appraisals concerning a certain task, as specified in Situated Expectancy Value Theory (SEVT, e.g., Eccles & Wigfield, 2020) determine, for example, (a) whether students learn or do something else, (b) how concentrated they are during learning, (c) which learning strategies they apply, (d) how they react to setbacks, and (e) how persistently they learn (see below for more details). We can infer learners' value beliefs, for example, as a close antecedent of effort allocation (Dietrich et al., 2017) by asking directly "How important/meaningful is it for you to work on that task?" instead of asking more broadly for a layperson "How much *effort* are you willing to/have you invested in the task?" A specific example of expectancy beliefs would be "How confident are you that you can solve the task?" From this perspective, effort-by-allocation seems to be an essential requirement to learn effectively for many students and in many situations.

The third effort conception becomes especially crucial in contexts where learners (have to) deal with evolutionary novel knowledge, such as the acquisition of reading and mathematics in school, which supposedly cannot be "acquired on the fly" (e.g., Geary, 1995; Geary & Xu, 2022). Its importance is even amplified from a self-regulated learning perspective, when it is up to the students how (much) they learn (Bjork et al., 2013; Paas et al., 2005), such as when doing homework. However, in these contexts, it is also of particular importance not to mix the three effort conceptions, theoretically and methodologically, because different theoretical and practical implications follow from each conception.

As indicated by the high similarity of the item examples presented in the fourth column of Table 1, we need to be precise to distinguish the three conceptions. This is of particular importance for laboratory-based metacognition research, where students' appraisals of ongoing task performance have been found to be crucial for self-regulated learning (e.g., Hui et al., 2022); yet such appraisals are not always valid (Hoch et al., 2023; Scheiter et al., 2020). In addition, although effort-by-complexity and effort-by-need frustration may be often confounded when learning at school (e.g., working on a mathematics problem has a high object-level requirement *and* is experienced as aversive by many students), this must not be the case for all learning settings. Finally, distinguishing the three effort conceptions would help to interpret effective instructional design interventions, for example, by explicating the motivational mechanisms of presenting a meaningful rationale for strategy use (e.g., Ariel & Karpicke, 2018; Hui et al., 2021b).

Generally, learning environments could be optimized to reduce unnecessary effort-by-need frustration and to foster effort-by-allocation for a task with a given object-level requirement (i.e., effort-by-complexity). Effort-by-complexity and effort-by-need frustration may also interact, insofar as repeated setbacks while working on certain tasks likely lead to increasing aversion over time (Brandstätter & Schüler, 2013). This experience, in turn, could influence students' expectancy and value appraisals, and consequently, their self-initiated effort allocation (i.e., effort-by-allocation) in subsequent similar tasks (Dreisbach & Fischer, 2015; Feldon et al., 2019). However, this argumentation does not mean that working on tasks with increasing complexity automatically becomes more aversive with time (e.g., Heitmann et al., 2022).

Given these (and other) complex patterns of interaction, an integrated perspective on (mental) effort is crucial to better understand and support learning processes. Hence, it is sensible to bring together cognitive and motivational perspectives on the effects of learning-task requirements and on how effort experience and allocation can be explained. Although fruitful insights are likely to be mutual, we will focus here on how the cognitive perspective on mental effort during learning, that is, effort-by-complexity, may profit from a motivational perspective, that is, by taking effort-by-need frustration and effort-by-effort-allocation more explicitly into account. Our analysis points to some conceptual inconsistencies and blind spots as well as to methodological challenges when relying on laboratory research and learners' self-reports to infer internal processes. Eventually, educational practice may profit from such a detailed conception, as cognitive and motivational interventions do not always converge in their practical implications.

A Cognitive Load Perspective on Effort-as-Complexity

From a Cognitive Load Theory perspective, mental effort is closely related to the object-level processing requirements of a learning task. Irrespective of whether the most recent version of Cognitive Load Theory, which distinguishes mainly between intrinsic and extraneous cognitive load (e.g., Sweller et al., 2019), or the previous version, which distinguishes between intrinsic, extraneous, and germane cognitive load (e.g., Sweller et al., 1998), is used, the view on sources of processing requirements is similar. Specifically, two main factors are identified that determine the processing requirements of a learning task: (a) the number of idea units and the degree to which the idea units need to be related to each other in order to reach the learning goal or solve the task (intrinsic cognitive load), and (b) cognitive processes that are required due to a suboptimal design of the learning task and material (extraneous cognitive load). Both factors arise from the task design itself and hence, effort-by-complexity can be conceived as a facet of data-driven effort (cf., Koriat et al., 2006, 2014; Scheiter et al., 2020).

When learners experience this kind of effort to be high, it is sometimes argued that this would indicate that the learning task entails high potential for knowledge construction. For example, in the literature on *desirable difficulties* (e.g., Bjork, 1994; McDaniel & Butler, 2011), it is highlighted that learning tasks such as retrieval practice tasks or interleaved practice, which, in comparison to common learning activities such as restudy or blocked practice, pose more challenging processing requirements, are, at least in the long-run, more effective (see also Roelle et al., 2022; Richter et al., 2022).

However, the effort that learners experience could be related either to learners' activities in dealing with suboptimal task design (extraneous cognitive load) or to effective learning activities that contribute to learning (intrinsic/germane cognitive load). Furthermore, even when it mainly reflects learners' execution of effective learning activities, learners who indicate higher effort would not necessarily be expected to outperform those learners who indicated lower effort. For example, when learners with low prior knowledge can hardly cluster idea units, they experience high intrinsic load and likely learn less than learners with high prior knowledge (e.g., Sweller et al., 1998). Hence, prior knowledge can substantially affect the degree to which certain processing requirements induce intrinsic/germane cognitive load (e.g., Chen et al., 2017a, 2017b; Roelle & Berthold, 2013; Sweller et al., 2019), and higher levels of experienced mental effort can reflect both a higher degree of executed effective learning activities or lower prior knowledge (note that in certain circumstances, higher prior knowledge can also enhance intrinsic cognitive load, see Endres et al., 2022). Hence, although a certain degree of cognitive processing is vital to any learning task, high effort-by-complexity would not necessarily be indicative for better learning outcomes or task performance.

The fact that learning requires some sort of cognitive processing in response to a task's complexity (i.e., effort-by-complexity), at first glance renders it understandable that the phrase "no pain, no gain" is increasingly used in educational contexts (e.g., Metcalfe, 2011; see also de Bruin et al., 2023). The potential benefits of performing a learning task for learning outcomes (i.e., the gains) can be expected to increase with the degree to which learners respond cognitively to the object-level processing requirements of the task. However, it is important to highlight that the outlined effort-by-complexity conception of mental effort does not entail any assumptions concerning learners' affective-emotional phenomenology during learning. Hence, whether learners experience effort-by-complexity as painful, or at least as unpleasant, and hence, something to be avoided, cannot be derived from the theoretical foundations of the effort-by-complexity conception of mental effort. Rather, a motivational perspective on effort anticipation and experience is helpful to understand when and how potential pain comes along with the cognitive processing of a learning task.

A Motivational Perspective on Effort-by-Need Frustration and Effort-by-Allocation

Motivational concepts have been part of research on self-regulated learning from the very beginning. For example, it is typically emphasized that learners self-regulate cognitive, emotional, and motivational aspects of learning, and it is acknowledged that motivation plays a role in all phases of self-regulated learning (Boekaerts, 1995; Pintrich, 2004). In addition, it has been proposed that mental effort investment is determined by motivational appraisals concerning the learning material and its interaction with personal characteristics (Paas et al., 2005; Salomon, 1984; Schnotz et al., 2009). More recently, it has been suggested that cognitive load can be reconstrued as a specific kind of motivational cost, thereby shaping future motivational beliefs (Feldon et al., 2019, see our following description of effort-by-allocation for more details).

For further elaborating motivational factors in the present context, we need to shortly recap two major theoretical accounts on learning motivation: Self-Determination Theory (SDT, e.g., Ryan & Deci, 2020) and Situated Expectancy Value Theory (SEVT, e.g., Eccles & Wigfield, 2020). We refer to these approaches, (a) because they are both highly influential in the domain of educational psychology, (b) because they prototypically illustrate the richness and diversity of motivation approaches by highlighting either the relevance of affect-based motivation processes grounded in momentary need satisfaction (SDT) or the relevance of future-directed cognition-based appraisals (SEVT), and (c) because they prototypically reflect effort-by-need frustration (SDT) and effort-by-allocation (SEVT) as we understand it.

Effort-by-Need Frustration from a Self-Determination Perspective

SDT is a theoretical framework that has been applied to educational contexts for many decades. Its sub-theories and basic tenets are described elsewhere in detail (Deci & Ryan, 1985; Ryan & Deci, 2020). Here, we focus on SDT ideas that inform our understanding of when and why learning feels aversive. In this regard, it is critical that SDT assumes three fundamental psychological needs to be satisfied so that individuals can exploit their natural potential to grow and to learn. These are the needs for competence (i.e., need to interact with the environment competently and effectively), autonomy (i.e., need to be able to act independently and free from external pressure), and social relatedness (need to build and maintain trusting and supportive relationships, Deci & Ryan, 1985).

Need satisfaction is deemed critical for self-determined behavior, meaning that behavior is regulated either by intrinsic (i.e., learning because it is fun) or identified (i.e., learning on the bases of personal value and meaning) types of regulation in contrast to introjected (i.e., learning out of guilt) and external (i.e., learning to obtain rewards or avoid punishment) types of regulations, with the first two regulation types underlying autonomous motivation and the latter two regulation types underlying controlled motivation (Deci & Ryan, 2000; Howard et al., 2021). The distinction between autonomous and controlled motivation is even more critical in SDT than the more well-known distinction between intrinsic and extrinsic motivation. Self-determined forms of extrinsic motivation, such as existent in identified regulation, are assumed to be similarly beneficial to learning as intrinsic regulation. A recent meta-analysis corroborates these ideas by yielding distinct patterns for autonomous and controlled forms of motivation with respect to indicators of academic success, persistence, and well-being (Howard et al., 2021).

One important idea in the present context is the assumption that learning contexts can both foster and frustrate need satisfaction and consequently, can contribute to how attractive or aversive learning is experienced (cf., Bartholomew et al., 2011; Vansteenkiste & Ryan, 2013). For example, if students are confronted with learning materials that are too easy or difficult given their previous knowledge, their need for competence is likely to be frustrated, which should become manifested in a momentary state of aversion (e.g., boredom, overload, anxiety). Similarly, even if their need for competence is fulfilled (or at least not frustrated), their need for autonomy may be frustrated by learning environments that do not offer any degrees of freedom or their need for relatedness may be frustrated by a teacher who does not care about the teacher-student as well as student–student relationships. From the SDT perspective, it becomes obvious that learning can feel “effortful,” or at least not “effortless,” because of many different reasons that do not fall into the effort-by-complexity category. As these reasons are nevertheless related to features of the learning task and its context at hand, effort-by-need frustration can be conceived as a facet of data-driven effort as well (cf., Grund et al., 2018; Koriat et al., 2006).

Effort-by-Allocation from an Expectancy-Value Perspective

From a SEVT perspective (Eccles & Wigfield, 2020), effort-by-allocation is the outcome of future-directed expectancy and value appraisals concerning a specific task or activity, such as working on a math problem. The more likely a person deems it to be able to solve a task (i.e., expectancy belief) and the higher the incentives for solving the task are judged (i.e., value belief), the more willing the person should be to start the task and to persist even in the face of challenges. In other words, the more “effort” the person is willing to invest, where the term effort refers to a latent, mediating variable between the motivational appraisals and any kind of learning activity directed towards working on the learning task at hand (e.g., time spent on a task, learning strategies applied, cf., Vollmeyer & Rheinberg, 2000). That is, any kind of cognitive operation that is deliberately executed to work on a learning task requires effort-by-allocation.

There have been many different types of expectancies and values proposed (see Eccles & Wigfield, 2002), among which the regulation types specified in SDT correspond to “reasons” (or values) for engaging in learning activities (Grund, 2013; Grund & Fries, 2012). SEVT also considers motivational costs as negative valences to be considered when weighing expectancy and value prior to task execution. Eccles & Wigfield (1995) suggested three types of costs: (1) *Effort cost* refers to the a priori perception of how much effort it would require to complete a task of a given difficulty. Note that this concept is similar to the effort-by-complexity conception presented above, despite the fact that it refers to students' difficulty *perceptions* rather than the *actual* object-level processing requirements as determined by the nature of the task itself.[1] (2) *Opportunity cost* refers to those incentives that are anticipated to be lost by engaging in a specific task. For example, the idea of motivational interference stresses that students often miss out highly valued leisure activities when they decide for learning (Fries et al., 2008; Grund & Fries, 2012; Grund et al., 2014), which may lead to poor performance and impaired well-being. (3) *Emotional costs* refer to the "psychological costs of pursuing the task, particularly anticipated anxiety and the emotional and social costs of failure" (Eccles & Wigfield, 2020, p. 5). Here, there is a link to effort-by-need frustration, as it is likely that such appraisals are grounded in previous aversive or unsatisfying learning experiences. This idea was emphasized by Feldon et al. (2019), who proposed a transmission of current effort experiences to future expectancy and value beliefs. For example, when learning is experienced as particularly strenuous, this experience could reduce the belief that one can solve similar tasks and/or the perceived value of these tasks.

The concept of effort-by-allocation bears much similarity to the concept of goal-driven effort (Koriat et al., 2006). However, a motivational perspective on effort experience and allocation provides some additional insights by highlighting the functional role of motivational processes in the course of learning behavior from its onset via its execution until its termination (Feldon et al., 2019; Schnotz et al., 2009) and by highlighting potential interactions between different kinds of effort as reflected in the different effort conceptions. This can be illustrated by the following example.

Imagine a young student reluctant to do homework one evening after school, when asked to do so by her parents. For her, the idea of doing homework under the present conditions is highly aversive. Apparently, it would require a lot of "effort" to do so. She indicates that she does not want to study just because "she has to" (e.g., her parents urge her to do so), which may reflect a frustration of her need for autonomy (i.e., high effort-by-need frustration), which may have, in turn, resulted in low expectancy and value appraisals (i.e., low effort-by-allocation). Surprisingly (at least to her parents, one of whom is the first author of this text), she volitionally completed her homework early the next morning before school as part of a "game" she invented (pretending to her parents that some gnome did the homework for her). Through this change in context, need frustration was gone (i.e., low effort-by-need frustration), although the object-level requirements (i.e., effort-by-complexity) of the task remained the same. Psychologically, however, the task definition in terms of task-related expectancies and values (i.e., effort-by-allocation) changed in the eyes of the student, from controlled to autonomous motivation, with all the cognitive, emotional, and behavioral consequences, such as deeper level processing of

[1] This critical distinction obviously becomes blurred when object-level processing requirements are assessed via self-reports as common in metacognition research (Scheiter et al., 2020). Yet, this is a methodological problem, whereas we are here referring to a conceptual distinction.

the learning material (Vansteenkiste et al., 2004) and higher academic persistence (Howard et al., 2021).

Integrating Cognitive and Motivational Perspectives on Effort Experience and Effort Allocation: Lessons to be Learned

The notion that (formal) learning is effortful is quite suggestive. From the perspective of cognitive load, some kind of cognitive processing needs to be done with new learning content in order to make sense out of it and to enrich prior knowledge. As instructional psychologists, we cannot take this demand away from the students. But how do we get students to do so? And at what potential costs? Explicating some of the motivational processes that seem to be essential when looking at (mental) effort may help to get to better answers to such questions.

From a motivational perspective on effort, it is important to distinguish the direct experience of aversion during learning from the expectancy that learning will be difficult, aversive, or both. Experiencing aversion is likely to be grounded in need-related aspects such as the frustration of the needs for competence, autonomy, or relatedness (Deci & Ryan, 2000). By contrast, expectancy and value appraisals are likely to be not only based on the actual difficulty or complexity of a given task but also on previous learning experiences in similar situations, personal characteristics, and the psychosocial environment students are embedded in (Eccles & Wigfield, 2020). Both appraisals, in turn, should determine whether and how persistent a student works on a given task.

Feldon et al. (2019) noted a commonality between CLT and the concept of motivational costs as specified in SEVT. They suggested to "conceptualize cognitive load as task-specific cost" (p. 328), which allows to integrate the study of mental effort in motivation theory. This idea is suggestive, as it may help to understand the motivational underpinnings of learning behavior, for example, the conditions under which students are willing to apply certain learning strategies and, therefore, to *invest* mental effort. However, the model is less helpful when it comes to pinning down and differentiating the specific task requirements that make learning "effortful." To do so, we believe it is also crucial to differentiate effort-by-complexity (i.e., object-level task requirements) and effort-by-need frustration (i.e., affective-emotional task requirements).

In the following, we first elaborate on how differentiating between effort-by-complexity and effort-by-need frustration could help to prevent a negative view on learning more generally. We then explore in detail the conceptual and methodological implications of differentiating all three effort conceptions for cognitive load research before we describe some practical implications derived from motivation theory.

Learning Does Not Have to be Painful to be Effective—It Can Even be Joyful

The phrase "no pain, no gain" is often used, for example, by parents and teachers who are confronted with children who are reluctant to work on a given task. The phrase is also related to the concept of desirable difficulties, which require learners to execute learning activities that they perceive as unfavorable or unpleasant (see de Bruin et al., 2023), and it resonates in Geary's (e.g., 1995) claim that evolutionary novel knowledge acquisition happens less effortless than language acquisition. From a motivational perspective, however, this phrase leads to some frowning, on the basis of many findings in research on intrinsic or autonomous (learning) motivation (e.g., Howard et al., 2021; Ryan & Deci, 2020), flow (e.g., Csikszentmihalyi & LeFevre, 1989; Shernoff et al., 2003), situational as well as personal interest (e.g., Hidi & Harackiewicz, 2000; Hidi & Renninger, 2006), and need for cognition (e.g., Cacioppo et al., 1996; Colling et al., 2022), to name just a few.

What these approaches have in common is the opposite of a "no pain, no gain"-stance towards learning: they characterize learning attempts, in the positive case, as connected to functional states of positive affect—even enjoyment—despite sometimes (or even because) high object-level processing demands. Need for cognition, for example, refers to "an individual's tendency to engage in and enjoy effortful cognitive endeavors" (Cacioppo et al., 1996, p. 197). In addition, flow is characterized by the "subjective state that people report when they are completely involved in something to the point of forgetting time, fatigue, and everything else but the activity itself" (Csikszentmihalyi et al., 2005); this flow state is assumed to be likely when both task demands and individual abilities are high (Csikszentmihalyi & LeFevre, 1989), that is when individuals just yet experience control over their (learning) behavior despite high object-level processing demands. Notably, as illustrated also by research on interest and autonomous motivation, we are talking here about highly functional forms of learning behavior that go hand in hand with high-quality learning (e.g., Howard et al., 2021; Rheinberg et al., 2000; Schiefele, 2009; Schiefele & Csikszentmihalyi, 1995; Vansteenkiste et al., 2004; Vollmeyer & Rheinberg, 2000).

From these perspectives, experienced effort-by-need frustration, or "pain," neither can be a necessary requirement of high-quality learning nor should it be tolerated as a typical concomitant of it. In addition, motivation research emphatically shows that feelings of aversion are not a natural consequence of high task complexity. Rather, when effort-by-need frustration is high, these affective-emotional processing requirements place an unnecessary extra burden on students that, similar to extraneous load—to borrow a term from CLT—, can limit their possibilities to deal with the object-level requirements of the task. Such potential extra burden calls for educators to think about how learning environments can be motivationally optimized beyond the instructional design aspect as specified, for example, by CLT (van Merriënboer & Sweller, 2005). Only when motivational problems inducing extraneous load are avoided, instructional design features may be fully effective. Notably, the first and primary goal of motivation interventions rooted in SDT is not to reduce effort-by-need frustration, that is, negative affect or avoidance tendencies (Watson et al., 1999). Rather, the goal is to promote positive affect and approach tendencies, for example, by a way of teaching that focus on supporting both students' need for competence and autonomy (e.g., Raufelder & Kulakow, 2021; Reeve & Cheon, 2021; Ryan & Deci, 2020).

Conceptual Implications for Cognitive Load Theory

Cognitive Load Theory does not focus on motivation. In the foundational and highly cited theory article by Sweller et al., (1998; Google Scholar 7880 citations; 5/21/2023), the notion of "motivation" can be found just twice. In addition, motivation was only mentioned in the context of very specific considerations, that is when discussing a potential disadvantage of the otherwise recommended study of worked examples (i.e., in initial skill acquisition: worked examples outperform problem-solving). In the authors' update of this article ("Cognitive Architecture and Instructional Design: 20 Years Later"; Sweller et al., 2019), the term "motivational" can be found twice, but only in the reference list (i.e., in the titles of two cited articles).

Nevertheless, a careful reading of not only the major theoretical assumptions but also of considerations that might seem to be peripheral shows that even in the seminal empirical article from 1985 on the worked example effect—the first effect postulated by Cognitive Load Theory—learners' motivation was regarded as essential. Sweller & Cooper (1985) have written about a potential disadvantage of studying worked examples as follows:

> Problem solving is more motivating probably because it requires activity (…). It is possible to read a worked example and assimilate nothing if motivation is low. This problem was mitigated in Experiment 2 by alternating worked examples with structurally identical conventional problems. It was assumed that motivation, while reading a worked example, would be increased by the knowledge that a similar problem would need to be solved immediately afterwards" (p. 69).

Hence, motivational processes underlying effort-by-allocation are considered crucial so that the learners exploit the learning opportunities provided by worked examples.

However, Sweller et al., (1998, 2019) did not consider motivation when theoretically explaining the worked example effect. Similar cases can be found, for example, for the variability effect (i.e., learning from variable problem situations is beneficial) and for assumptions about complex learning in the course expertise development (e.g., van Merriënboer & Sweller, 2005). As the main purpose of Cognitive Load Theory is to explain instructional design effects through the amount of working memory resources that are used or required, this lack of a focus on motivation should not be considered a significant omission. However, the lack of considering motivation may become problematic when effects of attempts to increase germane cognitive load and hence to foster the usage of "effortful" learning strategies such as retrieval practice or elaboration activities are interpreted (e.g., Hübner et al., 2010; Hui et al., 2021a; Roelle et al., 2017). As such interventions do not address factors related to effort-by-complexity, CLT is not well-suited to explain the found intervention effects. Rather, such interventions try to increase effort-by-allocation. They aim at changing students' expectancy and value beliefs, for example, by offering an additional compensation (i.e., something meaningful or "valuable") to those whose learning outcomes ranked in the top 50% (Hui et al., 2022) or by providing performance feedback after strategy use (Hui et al., 2021a), the latter presumably affecting their expectancy beliefs (see section "Promoting Learning Behavior From a Motivational Perspective" for further explanations).

The outlined findings suggest that even in studies that are framed by Cognitive Load Theory—or that are related to effects postulated by this theory—it is frequently, at least implicitly, assumed that learners' expectancy and value beliefs are sufficiently high to execute learning activities for the cognitive-load-inspired instructional design effects to occur. Otherwise, effort-by-allocation is missing so that learning opportunities are not exploited. However, such motivational processes are hardly considered in their theoretical framework. Yet, the implicit assumption that the learners are sufficiently motivated to learn is not necessarily justified, neither in laboratory instructional design research nor in "the wild" of formal schooling.

In many typical instructional design studies, the learning content and the learning outcomes are "low-stakes," that is, they are relatively meaningless to the participants. Learning about the toilet flush system (a content repeatedly used in multimedia learning research; e.g., Mayer et al., 2005), about different types of mushrooms (e.g., Abel, 2023), or about social norms (e.g., Waldeyer et al., 2020) can of course be of interest for some learners to some degree. However, at least in lab-based instructional design research, the learning content is often explicitly designed such that students can hardly have any substantial prior knowledge, and the content is not aligned with students' curriculum in school or at university. It is reasonable to assume that under these conditions, students' expectancy beliefs, value beliefs, or both will be low and so will be effort-by-allocation. Consequently, it is difficult to draw definite conclusions in these circumstances about favorable task design for practice settings, in terms of the object-level processing requirements (i.e., effort-by-complexity). However, such conclusions about recommendable task design are targeted in instructional design research (e.g., Ariel & Karpicke, 2018, Endres et al., 2021; see also Nückles et al., 2020).

Admittedly, there are also several studies that investigate procedures to enhance learners' execution of activities with high processing requirements in authentic contexts (e.g., Broeren et al., 2023; Chen et al., 2017a, 2017b; Zepeda et al., 2015). In these authentic settings, it is reasonable to assume that learners show substantial effort-by-allocation. However, these studies scarcely aim at investigating the potential moderating role of the level of effort-by-allocation for optimal task design from an effort-by-complexity-perspective. Hence, it may remain unclear whether the *optimal* effort-by-complexity and the concomitant task design determined in laboratory studies depend on the level of effort-by-allocation. For example, the worked example effect might not fully evolve if the learners are not motivated to carefully study the examples (see Hilbert & Renkl, 2009). Similarly, the variability effect (Paas & van Merriënboer, 1994; like the interleaving effect elicited by intermixing different task types) might not occur if students are not motivated to compare adjacent tasks to induce rules (see Ziegler et al., 2018).

Methodological Implications for Cognitive Load Theory

From a methodological point of view, it would be useful to implement measures that can help to differentiate between the three effort conceptions. Currently, such attempts focus on different kinds of cognitive load (e.g., Brünken et al., 2010; Klepsch et al., 2017; Paas et al., 2003) or differentiate only effort-by-complexity and effort-by-allocation-like concepts (Klepsch & Seufert, 2021). However, measuring and clearly differentiating effort-by-need frustration from effort-by-complexity would be of particular importance for cognitive load research, because it may help to locate critical motivational hindrances to learning that are not due to the object-level cognitive requirements of a learning task. This does not necessarily require the development of new instruments. Rather, researchers could rely on existing ecologically momentary measures of need satisfaction (e.g., Jang et al., 2009; Neubauer & Voss, 2018) and general affect (e.g., Grund et al., 2022) alongside more traditional cognitive load measures to separate effort-by-complexity and effort-by-need frustration statistically. Alternatively, the items presented in the rightmost column of Table 1 may serve as a starting point for more tailored developments.

The importance of a comprehensive measurement that is able to differentiate cognitive and motivational sources of effort experience and allocation becomes particularly obvious by attempts to use physiological parameters such as heart rate (Brünken et al., 2010; Paas & van Merriënboer, 1994) as indicators for cognitive load. Physiological arousal has a clear affective-motivational core (Richter & Slade, 2017). Therefore, a multi-facet, multimodal assessment of effort, integrating differentiated self-reports and physiological indicators seems indicated, ideally in real-time (Trull & Ebner-Priemer, 2013), as problems of introspection and hence, the validity of effort-related self-reports, probably become more relevant in hindsight.

In the absence of such comprehensive procedures, it is not clear whether higher levels of mental effort that are experienced (or reported) during certain generative learning activities are due to the object-level processing requirements of the respective activities (i.e., effort-by-complexity) due to affective-emotional factors (i.e., effort-by-need frustration), due to low expectancy and value beliefs (i.e., effort-by-allocation), or a combination of these variables. Future research should therefore aim at developing and testing models that acknowledge interactive processes among all three effort conceptions to better integrate cognitive and motivational processes of learning.

Promoting Learning Behavior from a Motivational Perspective

Practical recommendations rooted in CLT focus on the object-level requirements of the learning material, that is, they aim at dealing with effort-by-complexity (in particular by reducing extraneous demands). For example, worked examples replace problem-solving tasks or text, and picture elements are spatially integrated to ease finding relations between information sources (Sweller et al., 1998, 2019). From a self-regulated learning perspective, it was also proposed that learners should be meta-cognitively informed about the benefits of effortful learning strategies (Ariel & Karpicke, 2018; Carpenter et al., 2017; Eitel et al., 2020; Hübner et al., 2010; Roelle et al., 2017; see also de Bruin et al., 2023). Recently, cognitive load research also acknowledged that “informed self-regulation” can moderate the effects of instructional design features by postulating "self-management effects" (e.g., Castro-Alonso et al., 2021; Eitel et al., 2020).

Both kinds of intervention strategies (i.e., CLT design and providing metacognitive information) could also be interpreted as motivational in nature. Firstly, when learning tasks and materials are tailored to meet the cognitive learning prerequisites of an individual (e.g., Heitmann et al., 2018, 2021; Raaijmakers et al., 2018; Schwonke et al., 2006), this adaptation may not only optimize effort-by-complexity but also reduce effort-by-need frustration, and subsequently build effort-by-allocation for similar tasks in the future, as learners' need for competence might get satisfied. Consequently, when learners report lower intrinsic load for adaptive versus non-adaptive practice quizzing (Heitmann et al., 2021), part of this introspection may reflect lower effort-by-need frustration. This interpretation is supported by Heitmann et al.'s (2021) finding that students in an adaptive practice quizzing group, but not in a non-adaptive practice quizzing group, also reported a higher "motivation" compared to a note-taking control group.

Secondly, the abovementioned metacognitive information interventions try to foster self-regulated learning by informing about the instrumental benefit of a certain learning strategy for fostering conceptual learning and understanding. In Heckhausen's (1977) cognitive model of achievement motivation, this strategy refers to strengthening students' *action-outcome expectancy* (i.e., the perceived likelihood that a certain action leads to a certain outcome), but it does not change anything substantial about the task values differentiated in SEVT. Since expectancies and values are typically seen to spur motivation in a multiplicative way (Meyer et al., 2019; Nagengast et al., 2011; Trautwein et al., 2012), metacognitive information interventions may not suffice to increase effort-by-allocation in the laboratory, and particularly not in real-life learning situations. Learners could be completely convinced that a certain learning strategy is effective to foster learning (i.e., high action-outcome expectancy, Heckhausen, 1977), for example, because they had received performance feedback (Hui et al., 2021a); as long as the learning outcome (e.g., correct answers in a post-test) and its designated consequences (e.g., knowledge gain, praise from parents, job opportunities) are meaningless to them, effort-by-allocation will still be low. In the study of Onan et al. (2022), in which learners were provided insight into their learning gains when performed interleaved rather than blocked practice, for instance, this notion could explain why learners' decisions whether to perform blocked or interleaved practice were hardly affected although the insight into their learning gains likely increased the expectancy that interleaving would foster learning. Future interventions in the context of self-regulated learning should therefore incorporate ideas from motivational interventions that try to increase the intrinsic, attainment, or utility value of a certain task or learning material (Hulleman & Barron, 2016; Hulleman & Harackiewicz, 2009; Hulleman et al., 2010).

Ideally, these effort-by-allocation interventions are combined with interventions aiming at reducing effort-by-need frustration (or strengthening positive affect). SDT offers a comprehensive perspective in this regard, as the theory highlights that students not only need to feel competent during learning but also self-determined (and socially related) to become autonomously motivated and hence, get into a highly functional learning state (Deci & Ryan, 2000; Ryan & Deci, 2020). In particular, the need for autonomy may be frustrated when learners are guided very closely in experimental settings or when certain learning strategies are simply imposed on them without further explanation. Somewhat paradoxically, such unfavorable motivational conditions do not necessarily impair participants' learning when tasks are rather meaningless to them. However, in real-life learning environments, where students are expected not only to acquire new content knowledge but also to develop personal interest, at least in some domains, and more generally a positive stance towards the concept of lifelong learning, satisfaction of the need for autonomy seems crucial. Future research should therefore scrutinize in more detail to what extent effort-by-need frustration reflecting frustration of the need for autonomy can explain difficulties in self-regulated learning (see also Nückles et al., 2010; Udvardi-Lakos et al., 2023). In the same spirit, researchers and practitioners should be aware of different instructional goals (e.g., motivated and persistent learning vs. short learning success) and unintended side effects of an instructional intervention. For example, they should consider the risk that a very close instructional guidance can spur reluctance and reduce motivation on the learners' side (see, e.g., Nückles et al., 2010) due to a frustrated need for autonomy. They should also consider that their educational efforts may be in vain when they try to promote the use of effective learning strategies by offering certain incentives without ensuring that the learning task itself is personally meaningful to students (e.g., autonomous motivation, Howard et al., 2021).

Quite incidentally, the distinction between the three effort conceptions and their interplay has the potential to question our common understanding of self-regulated learning and the practical implications derived from it. For example, assuming effort-by-allocation is low, that is, when either students' expectancy or value beliefs, or both, are low, or when students learn out of controlled versus autonomous reasons, to what extent can we then assume "self-regulation" when participants and students comply with the demands of a task and apply certain learning strategies? Similarly, in terms of efficiency, do we not have to ensure effort-by-allocation on an institutional level (e.g., in schools) when we train self-regulation strategies to students and when we expect students to apply these strategies? This issue becomes particularly relevant when it comes to motivation regulation strategies (Trautner & Schwinger, 2020; Wolters, 2003). Assuming effort-by-need frustration is high and effort-by-allocation low, should we then expect that it is the student's responsibility to deal with such difficulties in learning?

Conclusion

Cognitive and motivational perspectives on learning often seem to coexist separately. In the context of research on mental effort, this is particularly surprising because motivational processes can make dealing with apparently strenuous tasks seemingly easy, even joyful so that learning must not even be perceived as "effortful" by students. Even if this advantageous constellation is not given, the deliberate activation of effective learning activities should be dependent on a certain degree or kind of motivation, particularly when looking at self-regulated learning activities outside the laboratory. Therefore, the primary goal of this contribution was to call for theoretical and methodological considerations of motivational processes in research on cognitive load and, probably, on cognitively oriented instructional design more generally, either in terms of the motivational beliefs that precede the use of effective learning activities, that is, effort-by-allocation, or in terms of the need-relevant aspects of the learning environment that render the use of these learning activities more or less aversive, that is effort-by-need frustration. Of course, being adequately motivated itself is not a sufficient condition to foster learning, but it might be an important prerequisite, which is typically not acknowledged in cognitively oriented approaches.

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