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Cognitive Load Theory: How Many Types of Load Does It Really Need?

Slava Kalyuga

Abstract Cognitive load theory has been traditionally described as involving three separate and additive types of load. Germane load is considered as a learning-relevant load complementing extraneous and intrinsic load. This article argues that, in its traditional treatment, germane load is essentially indistinguishable from intrinsic load, and therefore this concept may be redundant. Contrary to extraneous and intrinsic load, germane cognitive load was added to the cognitive load framework based on theoretical considerations rather than on specific empirical results that could not be explained without this concept. The design of corresponding learning activities always required methods and techniques external to the theory. The article suggests that the dual intrinsic/extraneous framework is sufficient and non-redundant and makes boundaries of the theory transparent. The idea of germane load might have an independent role within this framework if (as recently suggested by John Sweller) it is redefined as referring to the actual working memory resources devoted to dealing with intrinsic rather than extraneous load.

Keywords Cognitive load theory · Germane load · Intrinsic load · Working memory load

Cognitive load theory (CLT) is a learning and instruction theory that describes instructional design implications of a model of human cognitive architecture based on a permanent knowledge base in long-term memory (LTM) and a temporary conscious processor of information in working memory. Essential characteristics of working memory are its limited capacity and duration. We can consciously process no more than a few items at a time for no longer than a few seconds. If these limits are exceeded, working memory becomes overloaded and learning inhibited. CLT makes specific instructional design prescriptions for managing working memory load as a key issue for successful learning and performance (see Sweller 2003, 2004, 2008 for reviews of the major features of human cognitive architecture and their general instructional implications; Paas *et al*. 2003, 2004; Paas and van Merriënboer 1994b; Sweller *et al*. 1998; van Merriënboer and Sweller 2005 for reviews

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S. Kalyuga (✉)
School of Education, University of New South Wales, Sydney, Australia
e-mail: s.kalyuga@unsw.edu.au

of specific instructional methods; and Mayer 2005, 2009; Mayer and Moreno 2003 for reviews of multimedia learning applications).

Most current descriptions of CLT consider three types of cognitive load: intrinsic, extraneous, and germane load. *Intrinsic load* is described as the load caused by the internal complexity of the learning materials that is measured by the degree of interconnectedness between essential elements of information that should be considered in working memory at the same time (element interactivity) (Sweller 1994). An element or a chunk of information for particular learners and specific tasks is determined by the organized knowledge structures (schemas) the learners hold in their long-term memory base. With the development of expertise, the size of a person’s chunks increases: many interacting elements for a novice become encapsulated into a single element for an expert. For example, expert chess players in the classical experiments of De Groot (1965) and Chase and Simon (1973) recalled greater numbers of figures from real game situations than novices due to larger chunks (figure patterns) in their knowledge base.

The magnitude of intrinsic cognitive load experienced by a learner is determined by the degree of interactivity between essential elements of information relative to the level of learner expertise in the domain. Managing intrinsic load for a specific learner by instructional manipulations requires modifying the nature of the learning task. For example, intrinsic load can be reduced if the original task is simplified by omitting some elements and relations at the initial stages of instruction or is replaced with a relatively simpler task. Segmenting the original task and pre-training learners in the required basic concepts and procedures are two other empirically tested methods for managing intrinsic load. In all these cases, the learner would face modified learning tasks that are different from the original one. Therefore, even though it could be influenced by instructional design, intrinsic load is traditionally regarded by CLT as related to the nature of the learning task and the level of learner expertise and independent of the specific instructional design methods applied to the task.

If interacting elements of information need to be processed simultaneously in order to comprehend a task or situation, they can generate high levels of intrinsic cognitive load. When learners attend to those elements and attempt to mentally establish connections between them in working memory, they actually experience intrinsic cognitive load. Without considering the active processing of these essential elements and connections between them by a learner with a specific knowledge base, the element interactivity would remain a characteristic of the complexity of the task (relative to the learner’s level of expertise). It would indicate only a potentially expected magnitude of intrinsic cognitive load for a specific person rather than its actual level (Kalyuga 2007). Because intrinsic load is essential for comprehending the material and constructing knowledge structures, it is vital to provide all the necessary resources to accommodate this load without exceeding the limits of working memory capacity.

Extraneous cognitive load is associated with cognitive processes that are not necessary for learning and are invoked by suboptimal instructional designs, for example, performing search-and-match operations that are not relevant to learning or processing redundant information. Extraneous load is imposed by the cognitive activities that a learner is involved in because of the way the learning tasks are organized and presented, rather than because the load is essential for achieving instructional goals (Sweller *et al*. 1990; Sweller and Chandler 1994). For example, when some interacting textual and graphical elements in instructional materials are separated over distance or time, their integration might require intense search processes and the recalling of some elements of information while other elements are attended and processed. Such processes might significantly increase unnecessary demands on working memory (a split-attention effect).

CLT was originally developed to suggest means for reducing extraneous cognitive load in learning (Sweller 1988). The concept of extraneous cognitive load is central to this theory and has generated the majority of cognitive load effects investigated within this theoretical framework. This concept was then followed by the concept of intrinsic cognitive load when in some experiments variations in extraneous cognitive load produced no expected instructional effects. It became clear that explaining these empirical results required a new concept associated with the levels of intrinsic complexity of learning tasks or the levels of element interactivity. Extraneous cognitive load effects such as the worked example, split-attention, or redundancy effects were not demonstrated under the conditions when intrinsic cognitive load was low. They were only demonstrated when intrinsic cognitive load was high (Sweller 1994).

The concept of *germane cognitive load* was added to CLT at a later stage (Sweller *et al.* 1998). However, in contrast to intrinsic load, germane cognitive load was introduced not because there were unexplained empirical findings that demanded a new concept. It became increasingly clear that, in general, cognitive load did not always interfere with learning but was also necessary for learning. No meaningful complex learning would be likely to occur without effortful cognitive processing and associated working memory load. However, both the extraneous and intrinsic types of load were treated at that time as the load that needed to be reduced to avoid a cognitive overload. Therefore, it seemed theoretically plausible to introduce a separate type of load to account for the intentional cognitive effort leading to learning and the corresponding learning-relevant demands on working memory. It was suggested that germane cognitive load should be increased in order to enhance learning. Since then, germane load has been traditionally associated with the effortful construction and automation of organized knowledge structures or schemas and the corresponding cognitive activities that directly contribute to learning (Sweller *et al.* 1998).

By definition, extraneous load must always be reduced or, if possible, eliminated, but this does not necessarily apply to intrinsic load. For intrinsic load, a clear understanding that it should be properly managed (increased or decreased), rather than always decreased, came later. It was realized that such management required selecting learning tasks that are not too complex relative to learner levels of expertise but, on the other hand, not so simple as to no longer be sufficiently challenging and motivating within the available cognitive capacity (e.g., see Schnotz and Kürschner 2007, where this procedure is related to the Vygotskian zone of proximal development).

According to the traditional definition of germane cognitive load as a load that is essential to learning via schema acquisition and automation, intrinsic cognitive load, it can be argued, should be considered as the most important part of it. Intrinsic load is associated with processing the essential interacting elements of information and their relations that define the corresponding schematic structures. Thus, the cognitive load that directly contributes to schema acquisition ("good" load) may fit the traditional definitions of both intrinsic and germane load equally well. According to these definitions, germane load effectively duplicates intrinsic load and cannot be essentially distinguished from it. In contrast, extraneous ("bad") load is easily distinguished as it is always associated with a diversion of cognitive resources to activities that are irrelevant to learning.

Empirical Evidence Related to Germane Cognitive Load

As mentioned in the previous section, intrinsic and germane types of load were originally introduced in CLT in different ways. In contrast to intrinsic load, the introduction of germane cognitive load was based on purely theoretical considerations rather than on a specific need to deal with unexplained empirical results. Therefore, it is not a surprise that, in comparison with concepts of extraneous and intrinsic load, the concept of germane load has not been quite as constructive in CLT, especially in terms of its specific explanatory or predictive roles. Whereas CLT has been instrumental in developing many new instructional techniques or cognitive load effects associated with *reducing* cognitive load (mostly extraneous, but also intrinsic), within its own framework, it generated only a few new techniques that were considered as methods for increasing germane cognitive load. Among the best known are self-explanations of worked example steps (Renkl and Atkinson 2003) and studying examples with different rather than similar surface features to enhance the transferability of acquired knowledge (Paas and van Merrienboer 1994a).

Even these few techniques were related to germane load mostly in a post hoc manner and usually had precursors that were developed outside of a cognitive load framework. For example, the method of varying surface features and conditions of problems used in worked examples was preceded by a contextual interference effect when using either blocked or random sequences of problems during learning motor tasks (e.g., Shea and Morgan 1979). Similarly, using prompts for self-explaining worked examples was preceded by self-explanations of problem-solving steps in Chi *et al*. (1989) or VanLehn *et al*. (1992).

The concept of germane load has also been used for mostly post hoc explanations of some aspects of learning effects observed with a number of other instructional techniques, for example, presenting multiple solution methods in worked examples (Groβe and Renkl 2006), finding and fixing errors in worked examples (Groβe and Renkl 2007), using process-oriented worked examples (Van Gog *et al*. 2004, 2006), using model's eye movements to guide learner attention when studying examples (Van Gog *et al*. 2009), using computer-assisted metacognitive support (Bannert *et al*. 2009), and others.

Within a CLT framework, there seems to have been no specific empirical studies that were deliberately designed to experimentally test the concept of germane cognitive load and results of which were actually predicted based on this concept. Rather than being an oversight in empirical research, this situation may reflect a redundant status of this concept in CLT. Whereas the concept of intrinsic cognitive load was required and used to explain why manipulations of extraneous cognitive load had no effect when using low element interactivity materials, no equivalent pressing need for the concept of germane cognitive load as an independent entity has actually existed.

In fact, the above instructional techniques that presumably generated germane cognitive load could be readily described in terms of increased intrinsic load corresponding to enhanced learning goals. For example, the effect of variability of worked examples can be associated with increased element interactivity due to considering the cross-task applicability of the solution procedures; the self-explanation effect can be related to increased element interactivity due to the prompted involvement of domain principles and relevant elements of prior knowledge. However, an increased intrinsic cognitive load was not even considered as a possible explanation at the time. The resulting overlapping definitions of germane and intrinsic cognitive load have caused a conceptual confusion when identifying different types of load both in theory and in practice.

Equally confusing is the situation with attempting to measure germane load separately from other types of cognitive load. For example, while subjective ratings of learning difficulty were reported as measures of germane load by DeLeeuw and Mayer (2008), Schwonke *et al*. (2011) used subjective ratings of learning difficulty to measure extraneous cognitive load. Gerjets *et al*. (2009) used different versions of learning difficulty scales for evaluating both intrinsic and extraneous load, and ratings of exerted mental effort were used for measuring levels of germane cognitive load.

Gerjets *et al*. (2004, 2006) evaluated all three types of cognitive load using mental effort ratings based on a modified version of the NASA-TLX items (Hart and Staveland 1988). Intrinsic cognitive load was associated with the mental effort required to deal with task demands in order to accomplish the learning task, germane cognitive load was associated with the mental effort required for understanding the contents of the learning environment, and extraneous cognitive load was associated with the mental effort required for dealing with navigational and information selection demands. However, Scheiter *et al*. (2009) later acknowledged that while the last item could be used to assess extraneous load, the mapping of the first two items onto intrinsic and germane cognitive load was less evident as the learners could not distinguish between the demands reflected by those items.

Cierniak *et al*. (2009) also used subjective ratings to measure specific load types. Ratings of difficulty of the content were used to measure intrinsic cognitive load, ratings of learning difficulty were used for evaluating levels of extraneous cognitive load, and ratings of the level of concentration during learning were used to measure germane cognitive load. Based on the analysis of their results, Cierniak *et al*. (2009) noted positive correlations between the ratings for different scales, indicating that they might have measured similar rather than different types of load.

The above examples of applying similar types of scales for measuring different types of load do not make a convincing case for valid and reliable differential measures of cognitive load. These techniques are likely to measure changes in overall cognitive load. These changes could possibly be associated with variations in a specific type of load if other types of load and levels of learner prior knowledge are kept constant. For example, by keeping constant either task complexity (intrinsic load) or characteristics of instructional design (extraneous load), such ratings could determine variations in accordingly extraneous or intrinsic load. In this way, Ayres (2006) used ratings of difficulty of computational steps in algebraic problems as an indication of intrinsic load, whereas Kalyuga *et al*. (1998) used similar ratings of learning difficulty for evaluating levels of extraneous load. However, it is impossible to experimentally manipulate the levels of presumed germane load in this way as any such changes in associated activities would also inevitably influence intrinsic load by introducing new elements of information.

Since the concept of germane cognitive load has been recently directly related to generative cognitive processing in cognitive theory of multimedia learning and attempted to be tested empirically, the following section will discuss this approach and the associated empirical results in more detail.

Triarchic Model of Cognitive Load in Cognitive Theory of Multimedia Learning

The cognitive theory of multimedia learning (CTML; see Mayer 2009 for a recent overview) applies some basic assumptions to the design of multimedia learning environments that are similar to CLT. In addition, this theory defines several types of sequential processes that are required for active learning. (a) Selecting relevant words for processing in verbal working memory and/or (b) selecting relevant images for processing in visual working memory could be followed by (c) organizing selected words into verbal mental model and/or (d) organizing selected images into visual mental model. Finally, these processes could converge into (e) integrating verbal and visual representations and learner-relevant prior knowledge structures. Within the framework of CTML, the three types of cognitive load that had been previously introduced into CLT were first discussed by Mayer and Moreno (2003). The differentiation between them was based on the three suggested kinds of cognitive processes as sources of the corresponding cognitive demands: essential processing, incidental processing, and representational holding. The types and definitions of these corresponding processes were later modified. As a result, in the most recent updated version of CTML (DeLeeuw and Mayer 2008; Mayer 2009), the three redefined types of cognitive processes—essential, extraneous, and generative—were mapped onto the three corresponding types of load in CLT. The framework is referred to as the triarchic model of cognitive load.

In the suggested mapping, extraneous cognitive processing caused by suboptimal instructional design predictably corresponds to CLT's extraneous cognitive load and is not related to any instructional goal. Essential cognitive processing is defined as processing required to represent the essential material in working memory. It is considered to be related to intrinsic load in CLT and determined by the complexity of instructional material. Essential processing corresponds to such processes of active learning as selecting relevant words and images for processing in working memory and, by itself, results only in rote learning (i.e., good retention and poor transfer performance). Generative cognitive processing is defined as processing "aimed at making sense of the essential material and that can be attributed to the learner's level of motivation" (Mayer 2009, p. 81). It is considered to be directly related to germane load in CLT. Generative processing corresponds to such processes of active learning as organizing selected words/images into verbal/visual mental models and integrating these verbal and visual representations and learner prior knowledge. When combined with essential processing, generative processing results in a meaningful learning outcome (good retention and good transfer performance).

Generally, CTML is a logically consistent and elegant theoretical model. However, it should be noted that although CLT and CTML are inherently connected by essential common assumptions (e.g., limited working memory capacity, dual-modality information processing channels, the role of LTM knowledge structures in learning), there are some conceptual differences too. Whereas CTML focuses mainly on the role of different types of cognitive processing during learning (within a limited capacity system) rather than on working memory load generated by these processes, CLT is focused primarily on cognitive load and its influence on the ability of the learner to acquire new knowledge.

CLT does not assume separate sequential cognitive processing steps for selecting and organizing information in working memory and integrating this information with LTM knowledge structures. The CLT's view on processes that generate working memory load is more in line with the theory of long-term working memory by Ericsson and Kintsch (1995). According to this theory, cognitive processes can be represented as a sequence of related states or thoughts in working memory. Each cognitive state is a result of complex sequences of activities such as temporary holding of intermediate results or activating and elaborating prior knowledge. "For each cognitive state, there are complex generation processes at various levels of analysis, ranging from the sensory to the perceptual to the conceptual. The end products of these processes are the cognitive states that succeed each other over time: the varying contents of STM [short-term memory], the changing focus of attention, and the flow of conscious experience" (Ericsson and Kintsch 1995, p. 221). According to this model, the available relevant LTM knowledge structures are inevitably and continuously involved not only in the integrating stage but also in the processes of selecting relevant information as well as its organizing.

More importantly, the essential and generative types of cognitive processing as defined in CTML may not (and do not have to) map exactly onto the CLT's intrinsic and germane types of cognitive load correspondingly. In CLT, interactions between the elements of information are principal contributors to intrinsic load. We make sense of a learning task or material and comprehend them by making mental connections between their interrelated elements and our knowledge structures (schemas) in LTM. Complex information is being understood when all the relevant interacting elements (including LTM schemas) are processed in working memory simultaneously. Information could be difficult to understand if more interacting elements need to be processed in working memory than allowed by its capacity, resulting in rote learning. Element interactivity and intrinsic cognitive load are inherently related to understanding and meaningful learning (Marcus *et al*. 1996). Whereas, in CTML, essential processing is considered as resulting only in rote learning, CLT has never associated intrinsic load with rote learning only. Therefore, it is conceivable that intrinsic cognitive load in CLT is related not only to essential processing in CTML but also to generative processing.

In support of the triarchic model of cognitive load, DeLeeuw and Mayer (2008) made an early attempt to measure separately the three types of cognitive load or, more correctly (considering CTML as the underlying theory), types of cognitive processing. As one would expect, the intrinsic and extraneous types of load were experimentally manipulated by altering the design of learning tasks (changing complexity levels of the tasks and invoking extraneous activities accordingly). In contrast, germane load was not actually manipulated by instructional design of the learning tasks but was rather assumed based on the characteristics of learners' post-test transfer performance. From the perspective of CLT, this differential approach points to the above noted difficulties in separating germane cognitive load from other types of load empirically. Distinguishing germane load based only on the learner post-instruction performance measures rather than on the characteristics of learning tasks and their design formats may also suggest that this concept need not be treated as belonging to the same category as intrinsic and extraneous load.

In the current version of CTML (Mayer 2009), as well as in other studies (e.g., Van Gog *et al*. 2008), germane cognitive load is associated with the qualitative rather than only quantitative characteristics of learning processes. According to the theoretical assumptions of CLT grounded in human cognitive architecture, the quality of cognitive processing is determined primarily by the quality of information or knowledge structures that are actually involved in such processes. A deeper level of processing involves better organized, higher-level structures (e.g., principles of a domain invoked in learners' self-explanations of problem-solving steps that evidently cause deeper levels of processing; or learner prior knowledge structures that are integrated with verbal and visual representations during generative cognitive processing in CTML). Without such structures brought from the learner knowledge base or directly provided in the instruction, the cognitive processing would likely be shallow and result in rote rather than meaningful learning. In CLT, the interactions between these structures and other elements of information in learning tasks actually contribute to intrinsic cognitive load according to its definition. There is no basic need to artificially separate factors related only to presumed germane load for explaining deep (as opposed to shallow) levels of processing that determine qualitative differences in learning.

This article argues that the concept of intrinsic load is sufficient for accounting for all the cognitive load effects that have been traditionally associated with germane load. The conceptual vagueness and redundant theoretical status of germane cognitive load, as well as the associated measurement problems, may interfere with further developments in CLT. The notion of germane load may need to be either abandoned or reconceptualized as belonging to a category of cognitive characteristics that is different from the category of cognitive load, with its role changed accordingly. To further strengthen the case against the current conceptualizations of germane cognitive load, the following sections focus on several sources of controversies associated with this concept: (1) the difference between objective characteristics of a learning task and subjective learner experiences when working on the task; (2) the difference between performance tasks and learning tasks that is used for distinguishing intrinsic and germane load in some existing approaches; and (3) the difference between considering cognitive load within a general framework of mental workload and treating cognitive load as essentially working memory load. Even though some of these issues have been discussed previously in relation with other problems, it is important to raise them again in the context of the main argument of this article.

Cognitive Load as Subjective Learner Experience

It has been mentioned above that, in the traditional descriptions of CLT, intrinsic load is often regarded as a characteristic of learning materials determined by their complexity relative to the level of prior knowledge of potential learners. However, cognitive load by its nature is always a feature and a result of actual human cognitive processes or “the subjective reflection of complexity” (Beckmann 2010). Even though these processes are directly influenced by learning materials and learner prior knowledge, it is what the learners actually do in their minds that determine the magnitude of this load. If they are mentally establishing essential connections between interacting elements of information in working memory and connect them with available knowledge structures in long-term memory, these processes constitute when and how learners build new knowledge structures and learn. These activities generate intrinsic load actually experienced by the learners (Kalyuga 2007). By traditional definition, these activities are also associated with germane cognitive load, thus making the distinction between these two allegedly different types of load vague. Accordingly, the traditional view that all three types of load (intrinsic, extraneous, and germane) are independent and comparable and add up to an overall cognitive load is questionable.

Still, the notion of additive independent sources of intrinsic, extraneous, and germane cognitive load is extensively used in the field. Any meaningful learning as construction and strengthening of organized knowledge structures (schemas) is often associated with germane load. However, if germane load is treated in the traditional way as any learning-relevant load, developing methods for increasing germane cognitive load is essentially equivalent to developing any effective instructional methods that enhance learning, no matter which theoretical framework is used. With this approach, any effective instructional techniques that originated within various theoretical frameworks can be potentially presented as germane-load-enhancing methods and thus associated with CLT. Such post hoc associations may result in a circular logic with no real explanatory power (meaningful learning is improved because of increased germane cognitive load, and the increased load is germane because of improved meaningful learning). Also, such explanations may cause a diffusion of CLT in terms of its constructive capabilities in generating new instructional methods within the theory and may also result in considerable wheel reinventing.

If an instructional theory is believed to be capable of explaining any learning and instruction event, especially in a post hoc manner, it would likely lose its specificity and real predictive and constructive power. CLT has been (and hopefully will be) instrumental in explaining and predicting learning gains caused by reducing extraneous and managing intrinsic load and developing new effective and efficient instructional methods for achieving these goals. As to the effects of increasing presumed germane cognitive load, firstly, most of them are nothing else but effects of increased intrinsic load and could be fully explained by the increased intrinsic load. Secondly, there are plenty of existing instructional techniques and approaches outside of CLT that result, intentionally or not, in such increases. The theoretical perspective of embracing all those methods within a CLT framework based on the concept of germane load would potentially devalue CLT as a specific and constructive instructional theory.

Intrinsic Load as Cognitive Load Required for Achieving Specific Learning Goals

In an attempt to avoid the above dilemma and distinguish germane load more clearly from intrinsic load, many researchers (including the author of this article, e.g., Kalyuga 2007) have treated germane load not as any load that is essential to schema acquisition and automation but only as a part of this load. According to this approach, germane load is generated by intentional additional activities designed to further enhance schema acquisition beyond that associated with intrinsic load. One apparent example of this approach is the previously described triarchic model of cognitive load in CTML (Mayer 2009) in which germane load is associated with the generative processes that involve the organizing and integrating stages of active learning. These stages presumably follow the initial stage of selecting relevant information that is associated with intrinsic load.

Another specific example of this approach is provided by a traditional CLT treatment of the self-explanation effect. According to this approach, studying a worked example of a problem-solving procedure would impose a basic intrinsic load (and possibly extraneous load if the example is designed in a suboptimal way). If, in addition to that, learners are also prompted to explicitly self-explain every step of the procedure, an additional load would be generated that further enhances learning and, therefore, is considered as constituting germane cognitive load (Renkl and Atkinson 2003).

In its most explicit form, the view of germane load as an additional learning-enhancing load was articulated by Schnotz and Kürschner (2007). According to their reformulation of basic concepts, intrinsic load is regarded as the load caused by essential processing demands of basic performance tasks. In other words, it determines the lower boundary (minimum) of the processing demands involved in performance of the task that are usually topped up by the demands of learning associated with germane cognitive load. Therefore, the notion of a learning task and corresponding learning goals as opposite to a pure performance task becomes essential in distinguishing the intrinsic and germane types of cognitive load in this approach. Germane load is associated with conscious cognitive activities in working memory that are directed at intentional learning that extends beyond the activities associated with simple task performance and mostly unintentional, incidental learning (Schnotz and Kürschner 2007). Applications of learning strategies and metacognitive processes or intentional search for patterns in the learning material is provided as examples of such germane activities.

With this conceptualization, germane load is constrained not only by the available working memory capacity but also by the nature of the task itself and associated intrinsic load and by the learner's willingness to invest working memory resources into the corresponding learning-oriented activities. According to Schnotz and Kürschner (2007), the learning tasks selected for learners with given levels of expertise should impose levels of intrinsic load (or basic performance demands) that would leave sufficient working memory capacity for germane load to achieve the set learning goals. If the selected tasks are excessively difficult to perform, intrinsic load would go over the limits of working memory, resulting in failed performance and no learning. On the other hand, if the selected learning tasks are too easy, they can be performed successfully but with little learning except possible further schema automation (Schnotz and Kürschner 2007). Thus, according to this distinction, whereas intrinsic load of a task is associated with performance-only goals, germane cognitive load is associated with learning goals.

In contrast to pure performance tasks, learning tasks by definition always have specific learning goals or objectives. As discussed above, intrinsic cognitive load is not an objective depersonalized feature of the learning materials. It is always related to the specific cognitive activities involved in achieving the learning goals. Achieving the goals of some learning tasks may not require much conscious learning-directed effort, for example, when automating previously acquired solution procedures is the goal of a series of routine exercises. Such learning tasks could be very similar to performance tasks with limited (if any) explicit learning involved. However, if the goal of a learning task is constructing a schema for understanding, the learning task will require engaging intensive conscious cognitive processes in working memory.

The degree of element interactivity or connectedness between the elements of information is the most important characteristic of information that determines its complexity and influences intrinsic cognitive load. According to Sweller (1994), the level of element interactivity "refers to the extent to which the elements of a task can be meaningfully learned without having to learn the relations between any other elements" (p. 304). Thus, the notion of learning (and accordingly, the learning task with its learning goals) was implicit in the original definition of intrinsic load. Not accidentally, learning tasks rather than performance tasks were always used as illustrations of this concept, e.g., "Assume a student is learning to multiply out the b in the equation, $a/b=c$. In order to learn this process, the student must simultaneously learn that the numerator on the left side and the denominator which is not shown on the right side, remain unchanged…" (Sweller 1994, pp. 304–305).

Relating intrinsic cognitive load only to performance tasks as suggested by Schnotz and Kürschner (2007) is a rather controversial proposal. In instruction, effectively all the tasks that students are dealing with are learning tasks. For example, even such a seemingly performance-only task as $3x=4$, solve for x, when used in instruction, is essentially a learning task with a specific learning goal attached to it, such as *figure out the rule for solving such equations* (inducing a solution schema) or *apply the previously learned solution rule* (strengthening or automating a solution schema). The fact that the goal may not always be explicitly articulated to learners does not change the situation in principle. Asking students to study a worked example that demonstrates how to solve this equation would represent an explicitly stated learning task. When performing a rough preliminary evaluation of potential intrinsic cognitive load associated with the above task, the standard example-type solution steps (dividing both sides by 3, etc.) are considered when identifying interacting elements of information for a novice learner. These steps are essentially the elements of a learning task. The steps of a pure performance (problem solving) task may involve, for example, steps in applying means–ends analysis or trial-and-error attempts used by novices to solve this task.

Thus, intrinsic load is actually associated with learning tasks and achieving the corresponding specific learning goals of these tasks, such as constructing, refining, or automating schematic knowledge structures, making them more flexible and applicable in new situations, etc. Since germane load is also traditionally defined as the load leading to acquisition or automation of such schemas, it is hardly possible to effectively distinguish these two types of load by using the above macro-level distinction between performance and learning tasks. The next section will look closer at the possibility of distinguishing between germane and intrinsic load at a local micro-level of cognitive processing such as the level of working memory operation.

Cognitive Load as a Characteristic of Working Memory Operation

A substantial part of the traditional conceptualization of cognitive load theory has been based on the concepts and approaches developed earlier within a mental workload framework in the psychology of human performance in complex systems (Paas and van Merriënboer 1994b; see also Paas *et al*. 2003 for a review). This original framework does not rely on or require a specification of cognitive architecture (e.g., concepts of working memory and long-term memory) and does not consider working memory limitations as the essential characteristics of the involved processes (e.g., Xie and Salvendy 2000). Even though instantaneous (or short-term) workload was considered in the workload framework, it was not defined by the timescale of working memory processes. Based on this framework, cognitive load was defined as the load that performing a particular task imposes on the cognitive system and conceptualized in a task-based dimension (mental load as reflecting task demands) and a learner-based dimension (mental effort as the amount of cognitive resources that is actually allocated to accommodate the task demands) (Paas and van Merriënboer 1994b).

Cognitive load was also defined as essentially a working memory load (Sweller 1988). This definition is consistent with a recently adopted evolutionary view of the emergence of human cognitive architecture (Sweller 2003, 2004, 2008). According to this view, working memory is an essential component of human cognitive architecture responsible for limiting the magnitude of immediate changes to the knowledge base in long-term memory (which has analogies in other examples of natural information processing systems, e.g., restricting random mutations that change the genetic code in the process of biological evolution). If limitations of working memory capacity and duration are the cause of cognitive load, the level of working memory operation and the corresponding timescale are inevitable parts of the theoretical framework, and the time constraint is an essential and permanent factor of cognitive load.

Although it is difficult (or even impossible; see below) to provide specific numbers characterizing the timescale of working memory operation, it is generally considered as a matter of seconds. According to the classical studies by Peterson and Peterson (1959), most novel elements of information can be held in working (short-term) memory for a few seconds with almost all information lost after about 20 s, unless it is intentionally rehearsed. If the learner cannot process currently attended new elements of information within these time limits, this information will be lost, thus hindering further processing and understanding of the learning task. This scale provides a time range for actual variations of cognitive load: it could significantly change in a few seconds. Accordingly, its magnitude depends on specific cognitive processes that take place in those few seconds.

Reiterating the seemingly trivial statement that any type of cognitive load represents essentially working memory load is necessary as the timescale of working memory processes has been often ignored in CLT research. In most cases, when the concept of germane cognitive load is invoked, the corresponding activities are considered at a macro-level over prolonged periods of time rather than at a micro-level of working memory operation. For example, the variability of worked examples effect, according to which exposing learners to a sequence of varied examples and problems enhances the transferability of the acquired knowledge structures (Paas and van Merrienboer 1994a), is traditionally attributed to the additional germane cognitive load generated over a period covering the study of a series of examples. Accordingly, it is believed that the cognitive load involved in processing varying examples is higher than the load involved in processing similar examples. However, even though variability can obviously be implemented only over a series of tasks, the essential processes contributing to increased cognitive load and enhanced learning occur at the level of working memory operations involved in each task (e.g., comparing the procedure applied in the previous examples with the current one, generalizing essential components of the common procedural pattern, etc.).

There also have been recent suggestions to intentionally extend the definition of cognitive load beyond that of working memory load (e.g., Schnotz 2010; Schnotz and Kürschner 2007). For example, Schnotz (2010) suggested mental energy as a resource that is relevant to learning and from which learners draw the effort invested into cognitive processing. According to this view, the total amount of processing rather than the amount of information that needs to be kept simultaneously in working memory causes cognitive load. For example, with this approach, a long and exhausting list of second-language vocabulary items may cause a high level of cognitive load. This is clearly in contrast with the traditional CLT descriptions that often use such lists as examples of the tasks that impose low intrinsic cognitive load even though they could still be difficult tasks to learn. With this approach, extraneous cognitive load could also be associated with a waste of time and effort spent on irrelevant cognitive processing. As a result, cognitive load is viewed as effectively a load on motivational rather than cognitive resources (Schnotz 2010). Without discussing potential merits and shortcomings of this approach on its own, it is clear that it cannot be conceptually incorporated into CLT as a theory that principally defines cognitive load as essentially working memory load, especially considering that this key definition has also been recently underpinned by the adopted evolutionary perspective.

As working memory load, cognitive load is essentially a local micro-level characteristic of intensity of working memory processes dealing with interacting elements of information at a specific point of time. It is not an accumulated retrospective perception of the sum of these processes over extended periods at a later point, although these two characteristics may correlate and the latter one may provide a general indication of the magnitude of the load involved (e.g., when using post-instruction or post-test subjective ratings scales). A plausible general structure of corresponding processes as a sequence of related states or thoughts in working memory was provided by Ericsson and Kintsch (1995) (see the description quoted in the earlier part of this article). If all the processes generating a mental state exceed the capacity of working memory, cognitive overload happens. The duration of these mental states also indicates the timescale of cognitive processes relevant to CLT. Whereas new elements of information from the external environment could be held in the short-term storage only for a very limited time (a few seconds), activated relevant elements of prior knowledge from long-term memory have no such time constraints. Therefore, the magnitude of cognitive load and the actual timescale of its variations (the duration of sequential cognitive states) depend on the degree of involvement of previously acquired long-term memory knowledge structures and could vary significantly. The activated relevant prior knowledge structures in long-term memory extend the timescale and lower cognitive load.

Is it possible in principle to distinguish between cognitive activities associated with germane and intrinsic load at the above local micro-level associated with working memory operations? The particular learning-relevant cognitive activities that occur within this timescale (e.g., comparing elements of information, establishing meaningful connections between relevant interacting elements) are always related to the acquisition of specific components or aspects of organized knowledge structures (schemas), thus contributing towards achieving specific learning goals. Therefore, the associated cognitive load is essentially intrinsic load. For example, when exposing learners to a sequence of varied examples and problems (the variability of worked examples effect), the learners' activities at the level of working memory operations could involve comparing specific surface features and solution steps for a current task with previous tasks. These local operations directly contribute to achieving the corresponding learning goals of establishing common solution patterns to enhance the transferability of knowledge and thus are associated with intrinsic cognitive load.

Similarly, when explicitly prompting students to self-explain steps of worked-out solution procedures based on the principles of the domain (the self-explanation effect), the learners' activities at the level of working memory operations could involve establishing connections between specific currently processed elements of a solution procedure and elements of the corresponding domain principle. These are activities directly contributing to the learning goal (achieving deep understanding and transfer of knowledge) and thus associated with intrinsic cognitive load.

Therefore, even if at a macro-level, it seems theoretically plausible to assume that some additional activities are intentionally directed at enhancing learning by increasing germane cognitive load, such an assumption is not credible at a micro-level of cognitive processes. It is indeed impossible to effectively separate specific cognitive operations associated with intrinsic and germane types of cognitive load by defining germane load in addition to a basic intrinsic load. At a local level as the level of working memory operations (which is the basic level of cognitive load variations), any associated processes would contribute to intrinsic load involved in achieving a specific learning goal.

Implications for CLT

According to the traditional point of view, germane cognitive load is caused by cognitive activities designed to enhance learning outcomes. Even though the idea of germane load as a "good," useful, or learning-relevant load may have contributed to improving instructional methods in specific cases, loose manipulations of this concept may diffuse and devalue CLT by providing a simplistic universal explanatory framework according to which any effective instructional technique could be attributed to increased germane cognitive load. As a consequence, the boundaries of CLT are extended well beyond its actual zone of constructive applicability. This article argues against treating germane cognitive load as an independent type of cognitive load in addition to intrinsic and extraneous load.

Because of the described theoretical and empirical difficulties in separating intrinsic and germane cognitive load, returning to a simple dual division of cognitive load into intrinsic and extraneous load could provide a clear non-redundant framework and a straightforward way of approaching specific situations. In this dual framework, intrinsic load should be necessarily regarded as intrinsic to the specific learning goals rather than only to the nature of the task or material as it has often been treated in traditional CLT descriptions. The intrinsic cognitive load is associated with all cognitive activities resulting in new or modified knowledge structures in long-term memory. Such activities involve concurrent processing of interacting elements of information in working memory and integrating them with available knowledge structures in accordance with specific learning goals (e.g., comprehending a situation, performing a procedure, enhancing flexibility of knowledge for transfer in new situations, etc.).

Where does this dual framework leave the concept of germane load? As noted above, any effective instructional procedure can be actually attributed to germane cognitive load in its traditional treatment, eliminating the usefulness and constructiveness of this concept. A meaningful way of treating this concept suggested recently by Sweller (2010) is to redefine the idea of germane load as associated with working memory resources actually devoted to dealing with intrinsic cognitive load that leads to learning. In addition to such germane resources, working memory resources actually allocated to a learning task may also include extraneous resources devoted to dealing with extraneous cognitive load that is caused by inadequate instructional designs. This definition places germane and extraneous resources in a different dimension from the dimension of cognitive load with its intrinsic–extraneous dichotomy. Nevertheless, this whole detached dimension of the actually allocated working memory resources is considered within a general dual framework.

The above new definition stresses the role of the actually allocated germane resources in the learner engagement in processing relevant aspects of a task. This redefined concept of germane resources reflects exactly those aspects of learning that have attracted researchers and instructional designers to the concept of germane load in their quest to incorporate instructional methods that would motivate and engage students in learning-effective cognitive processing (e.g., generative processing in Mayer 2009). More engaged and motivated learners are able to invest more of their working memory resources into dealing with intrinsic load, leading to better learning (Schnotz 2010). With this approach, the dimension of cognitive load with its intrinsic–extraneous dichotomy is associated with the demands for working memory resources required for achieving goals of specific learning tasks or instructional episodes. Ideally, these are resources required for information processing and learning when the learner is fully engaged and committed to the learning task. The actual amount of working memory resources invested in learning activities would obviously depend on the specific level of motivation, attitudes, and other characteristics of the learner.

With this reconceptualization, extraneous cognitive load is retained in its current form. With intrinsic load, it is essential to consider all the relevant cognitive activities and structures involved in achieving specific learning goals rather than only the elements of presented information. An immediate ramification of this formulation is a radical change to the principle of additivity of different types of cognitive load. Total cognitive load would now consist of intrinsic plus extraneous cognitive load rather than additive intrinsic, extraneous, and germane cognitive load under the traditional formulation (Sweller 2010). Thus, only intrinsic and extraneous cognitive load are actually additive as there is no other comparable type of load in the same dimension. Together, they determine the total cognitive load imposed on the learner by the learning task.

The total cognitive load determines working memory resources required for processing all the involved elements of information and achieving learning goals by a fully engaged learner. However, it does not determine actually allocated working memory resources by a specific real learner in a specific learning situation. This amount of actually devoted working memory resources depends on how well and fully the actual learner is engaged in the learning environment. Also, neither the total cognitive load nor the differentiated intrinsic and extraneous types of cognitive load determine the distribution of the actually allocated working memory resources between germane and extraneous resources. If the total cognitive load (required overall working memory resources) exceeds the actually available and allocated working memory resources, the learner will fail to process all the necessary information involved in the learning task and will not achieve the learning goal.

Another ramification of the suggested reconceptualization for research in CLT is related to the issue of the measurement of cognitive load. With the new model, attempts of finding separate empirical (e.g., psychometric) measures for each of the three traditional types of cognitive load become unnecessary. Such attempts have not been very convincing so far, and it is not a surprise considering the theoretical problems with distinguishing germane cognitive load discussed in this article. What is required in experimental studies according to the revised model is the ability to differentiate between only two types of cognitive load, intrinsic and extraneous load. This could be achieved by appropriately manipulating the design of learning tasks. For example, for a particular sample of participants, the intrinsic cognitive load could be kept constant between experimental conditions when alternative learning tasks are designed to achieve exactly the same specific learning goals. The observed changes in performance and/or measures of cognitive load could be attributed to variations in extraneous load between experimental conditions. Of course, the techniques for measuring cognitive load need improvements. The majority of measures supporting cognitive load interpretations of empirical results have been based primarily on learners' subjective ratings that may not be particularly reliable. Cognitive load theory would definitely benefit from exploring other more reliable and unobtrusive methods for gathering empirical evidence to support its theoretical constructs.

Implications for Instructional Design

One of the main implications of the suggested reconceptualization of the types of cognitive load for instructional design is affirming the boundaries of applicability of CLT. Avoiding or reducing working memory resources devoted to activities that are not associated with learning is the primary aim of applying a cognitive load perspective to instructional design. Therefore, CLT methods and techniques (usually referred to as cognitive load effects) should be primarily used in instructional design for reducing extraneous cognitive load as much as possible so that less working memory resources would be required for dealing with information that is extraneous to learning. Then, as a consequence, a greater part of working memory resources could be potentially available for dealing with intrinsic load associated with learning.

If instructional design causes high levels of extraneous cognitive load, the share of available working memory resources devoted to dealing with this load (extraneous resources) could become excessively high, thus reducing the share of germane resources for dealing with intrinsic cognitive load. A range of various CLT methods have been experimentally proven to be effective in reducing extraneous cognitive load. However, ensuring that sufficient germane resources are actually devoted to learning requires appropriately engaged learners. This is undoubtedly a critical issue in teaching and learning, but it cannot be resolved solely within a CLT framework and requires specific methods and techniques external to CLT. Unsurprisingly, the attempts to deal with this issue within CLT by relying on the concept of germane cognitive load have not been very productive. They mostly resulted in the previously mentioned simplistic post hoc explanations and trivial instructional prescriptions that could lead to disappointments in the theoretical power and practical value of CLT. The power and value of any theory are best realized in the actual boundaries of its applicability.

Another aim of CLT as an instructional theory is to reduce intrinsic cognitive load in situations where the minimized extraneous cognitive load does not improve learning because insufficient working memory resources are left for dealing with the learning task.

The changes to intrinsic load are always associated with corresponding alterations in learning goals. When intrinsic load needs to be decreased, the modified goals may involve learning simplified procedures or concepts, partial schemas, or just learning by rote at the initial stages. In contrast, extraneous cognitive load can be reduced by instructional designers by modifying instructional procedures and techniques without altering the learning goals.

The traditional concept of germane cognitive load has been associated with learning-enhancing increases in cognitive load. According to the proposed modified model, such increases could be described in terms of the increased intrinsic cognitive load caused by the corresponding alterations in learning goals. An implication for instructional design is that when evaluating intrinsic cognitive load, learning tasks should be approached in terms of the entire array of cognitive activities required for achieving specific learning goals rather than be separated into some basic activities (e.g., related either to basic performance-only goals or to essential processing only) and additional learning-enhancing or generative activities.

In general, the following three related levels of analysis could be used in instructional design. The first is the objective level of learning materials and assumed learner expertise. The degree of element interactivity could be estimated theoretically based on relations between the elements of information involved in the learning tasks or materials. In this estimate, levels of learner expertise should be taken into account based on the expected relevant patterns of knowledge the assumed learners have in their long-term memory.

The second level of analysis is associated with intrinsic and extraneous cognitive load experienced by a fully engaged ("ideal") learner. This level corresponds to the previously described dimension of cognitive load and determines working memory resources that are required for achieving specific learning goals. At this level, complex sequences of related cognitive processes of sensory, perceptual, and conceptual nature result in corresponding cognitive states in working memory. Because of the complex character of these experienced cognitive activities, a precise theoretical estimate of cognitive load at this level is not possible. However, more importantly, it could be controlled by applying the evidence-based instructional methods and techniques that have been experimentally proven by research in CLT and CTML. Also, if required, cognitive load could be inferred and compared using experimental instructional manipulations and the available cognitive load measurement tools (e.g., subjective rating scales or dual-task techniques).

This level is the main area of applying CLT in instructional design. However, when selecting optimal learning tasks and materials, the objective indicators of their complexity based on the theoretically estimated levels of element interactivity (the first level of analysis) should be used for a preliminary evaluation of expected cognitive load. In the existing studies, the theoretical estimates of cognitive load based on the levels of element interactivity have been very rough, approximate, and not considering many contributing factors. Therefore, it is essential to develop more specific and refined guidelines and procedures for making estimates of cognitive load based on the varying degrees of element interactivity, as well as to establish the strength of correlations between these estimates and actual objective measures of cognitive load.

The above two levels of analysis in instructional design could be fully accomplished based on CLT and its methodology. The third level is associated with actual levels of learner engagement with the learning environment. This level corresponds to the dimension of working memory resources that are actually devoted to dealing with cognitive load. Instructional design issues at this level of analysis require specific methods and techniques that may not be available in CLT and are external to CLT.

Conclusion

In the last decade, virtually every published article related to CLT has described three additive types of cognitive load—intrinsic, extraneous, and germane load—usually treating them as well-established and indisputable facts. This article provided some arguments in favor of abandoning this framework along with the principle of additivity of the above three types of cognitive load. The proposed modification removes the concept of germane load as an independent type of cognitive load in line with intrinsic and extraneous load and effectively returns to the dual framework. All learning-relevant cognitive activities are considered as related to specific learning goals and associated with intrinsic cognitive load.

However, following Sweller (2010), the idea of germane load could be redefined as germane resources in a separate dimension associated with actually allocated working memory resources. The development of effective learning environments that enable learners to devote maximum of their working memory resources to achieving learning goals requires the creativity and skills of instructional scientists and designers that stretch outside the boundaries of CLT. The role of the methods and techniques developed by CLT is to provide effective means for, firstly, reducing extraneous cognitive load in any learning situation and, secondly, managing intrinsic cognitive load depending on the availability of working memory resources.

The envisaged benefits of this model are in (a) making the framework of CLT more straightforward and transparent by abandoning the apparently redundant concept of germane cognitive load, (b) affirming the boundaries of CLT to prevent its diffusion caused by using this theory to explain instructional events outside of the area of CLT applicability, and (c) making unnecessary the development of separate empirical measures for the three types of cognitive load. Because of its successful development and expansion over the last two decades, many educational researchers have started to regard CLT as a theory that can explain any learning and instruction event. As a result, the theory could be in danger of becoming too amorphous and vague. This article has been inspired by the desire to clarify its basic concepts and limits of applicability in order to keep the theory precise and constructive.

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