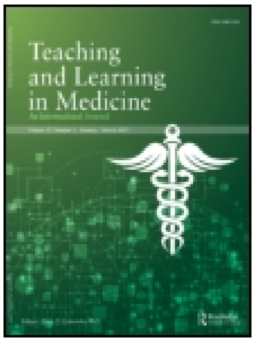

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Teaching and Learning in Medicine

An International Journal

ISSN: 1040-1334 (Print) 1532-8015 (Online) Journal homepage: http://www.tandfonline.com/loi/htlm20

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To cite this article: John Q. Young, Olle ten Cate, Patricia S. O'Sullivan & David M. Irby (2016) Unpacking the Complexity of Patient Handoffs Through the Lens of Cognitive Load Theory, Teaching and Learning in Medicine, 28:1, 88-96, DOI: 10.1080/10401334.2015.1107491

To link to this article: http://dx.doi.org/10.1080/10401334.2015.1107491

Published online: 19 Jan 2016.

TEACHING AND LEARNING IN MEDICINE
2016, VOL. 28, NO. 1, 88–96
http://dx.doi.org/10.1080/10401334.2015.1107491

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OBSERVATIONS

Unpacking the Complexity of Patient Handoffs Through the Lens of Cognitive Load Theory

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ABSTRACT
Issue: The transfer of a patient from one clinician to another is a high-risk event. Errors are common and lead to patient harm. More effective methods for learning how to give and receive sign-out is an important public health priority. *Evidence*: Performing a handoff is a complex task. Trainees must simultaneously apply and integrate clinical, communication, and systems skills into one time-limited and highly constrained activity. The task demands can easily exceed the information-processing capacity of the trainee, resulting in impaired learning and performance. Appreciating the limits of working memory can help identify the challenges that instructional techniques and research must then address. Cognitive load theory (CLT) identifies three types of load that impact working memory: intrinsic (task-essential), extraneous (not essential to task), and germane (learning related). The authors generated a list of factors that affect a trainee's learning and performance of a handoff based on CLT. The list was revised based on feedback from experts in medical education and in handoffs. By consensus, the authors associated each factor with the type of cognitive load it primarily effects. The authors used this analysis to build a conceptual model of handoffs through the lens of CLT. *Implications*: The resulting conceptual model unpacks the complexity of handoffs and identifies testable hypotheses for educational research and instructional design. The model identifies features of a handoff that drive extraneous, intrinsic, and germane load for both the sender and the receiver. The model highlights the importance of reducing extraneous load, matching intrinsic load to the developmental stage of the learner and optimizing germane load. Specific CLT-informed instructional techniques for handoffs are explored. Intrinsic and germane load are especially important to address and include factors such as knowledge of the learner, number of patients, time constraints, clinical uncertainties, overall patient/panel complexity, interacting comorbidities or therapeutics, experience or specialty gradients between the sender and receiver, the maturity of the evidence base for the patient's disease, and the use of metacognitive techniques. Research that identifies which cognitive load factors most significantly affect the learning and performance of handoffs can lead to novel, contextually adapted instructional techniques and handoff protocols. The application of CLT to handoffs may also help with the further development of CLT as a learning theory.

KEYWORDS
cognitive load theory; handoffs; instructional design

Introduction

Transfers of patients from one physician to another (handoffs) are pervasive[1] and occur with increasing frequency, in part due to the restriction of resident duty-hours in Europe in 1998[2] and in the United States in 2003[3] and 2011.[3] At the same time, these transitions pose serious risks to patient safety because handoffs are often accompanied by communication failures, which lead to medical errors and harm to patients.[4–6]

Given this potential for harm, considerable attention has focused on interventions to improve patient safety during handoffs,[7–9] many of which have been adapted from industries such as nuclear power and space aviation in which transition errors have high consequences.[10] These best practices employ structured communication protocols such as face-to-face and written sign-out to facilitate information transfer. These protocols typically include several other features, such as interactive questioning, the use of mnemonics and standardized templates, and distraction-free settings.[11]

The Institute of Medicine has recommended[12] and the Accreditation Council for Graduate Medical Education now mandates[13] handoff training for residents. Published model curricula utilize multimodal instructional

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methods, including lecture, simulation, and feedback, to teach the bundle of best practices just described.[8,9] Recently, implementation of this type of curricula in multiple pediatric hospitals yielded significant improvements in educational and clinical outcomes.[14] To further advance patient safety during handoffs, the application of cognitive theories of learning can help identify the diverse challenges trainees face when executing handoffs. Insights from this analysis can advance handoffs research and the design of instructional interventions.

The overarching goal of a handoff is to transfer responsibility for a patient's care and, in so doing, to create a shared mental model between the giver and receiver.[15] This shared model represents a mutually negotiated understanding or representation of the patient's clinical condition that enables the receiver to effectively assume responsibility for that patient's care. For students and residents, conveying the facts or learning a handoff protocol, such as the mnemonic to use during the verbal sign-out, represents only part of the challenge. Sense-making or appropriately contextualizing, processing, understanding, and communicating the clinical information necessary to establish a shared and accurate mental model is an additional and even more complex task.[16] The required knowledge, skills, and attitudes cross multiple domains, including clinical, communication, and systems. To succeed, the learner must simultaneously apply and integrate these multiple sets of knowledge, skills, and attitudes into one time-limited and highly constrained activity.[8] The quantity and complexity of the information transferred can exceed the learner's working memory, which can lead to errors and harm to patients.

Our instructional techniques must appreciate and address this complexity. Cognitive load theory (CLT) has particular relevance to complex learning tasks, such as handoffs,[17,18] with its emphasis on optimizing learning by managing working memory resources. First described by Sweller in 1988,[19] medical educators have given CLT increasing attention.[20,21]. Although CLT has not to date been applied to handoffs,[22] a CLT-based exploration of how handoffs impose mental workload can inform future research and the development of new instructional strategies for handoffs. In this article, we begin by briefly summarizing CLT and then use CLT to identify and categorize factors that affect cognitive load and learning and performance during a handoff. We end by exploring the implications of the analysis for future handoff research and instructional design.

Summarizing cognitive load theory

CLT builds upon a model of human memory developed by Atkinson and Shiffrin[23] that includes three subsystems of memory (sensory, working, and long-term memory).[24] Sensory memory perceives visual and auditory information. This subsystem has enormous capacity but can retain any given piece of information for only a brief time (less than 0.25 to 2 seconds).[25] Most perceived information does not reach conscious awareness. This can give rise to inattentional blindness where, for example, a person focused on a monitoring task (e.g., counting the number of times players in white pass the basketball) will not notice an unexpected object (e.g., a gorilla that walks through the middle of the game).[26] When our attention raises sensory information to awareness, the information enters the domain of working memory (WM). WM (re)organizes the information into packages to facilitate efficient storage as schemata in long-term memory (LTM). LTM has theoretically limitless capacity in terms of duration and volume, but a route map, built of meaningful connections, is required to find the information. WM encodes the information with this route map, which enables retrieval when the information is needed in the future.

When learners focus attention on sensory information, such as the words of a colleague presenting sign-out information on a patient admitted with sepsis, the information moves to WM. Unlike sensory and LTM, WM is finite—WM can hold only a limited number of independent information units at a time (4 to 7$\pm$ two)[27,28] and can actively process (i.e., organize, compare, and contrast) no more than two to four elements at any given moment.[29,30] In addition, WM can retain an information element for a few seconds with almost all information lost after 30 seconds unless it is actively refreshed by rehearsal (e.g., repeating to oneself an important lab value or pager number that one has verbally received until one is able to write it down). CLT identifies three types of cognitive load that consume limited WM resources:

1. *Intrinsic load*—load associated with the task (intrinsic to task)—processing is required to make sense of the information relevant to the task.
2. *Extraneous load*—load not essential to the task (extrinsic to task)—processing is not required to make sense of the relevant information but induced by the design of the task (e.g., how information is presented) or the environment (e.g., background noise).
3. *Germane load*—load imposed by the learner's deliberate use of cognitive strategies to reorganize information in order to refine existing schemata and enhance storage in LTM.

The amount of WM used during a handoff is the sum of these three types of cognitive load. In addition, CLT highlights that WM has partially independent channels for auditory and visual information, which means that WM can handle more information elements when the information is distributed between the two channels.[31,32] The two major learning processes in CLT are schema construction and automation, which occur at the interface of WM (especially germane load) and LTM. Learners construct schemata (in acquiring medical skills also referred to as *illness scripts*[33]) during knowledge acquisition and problem solving by combining and recombining elements into larger, more refined, and more retrievable chunks. With extensive practice, a schemata can become automated and require no WM resources (e.g., riding a bike or a pathologist manipulating a slide under a microscope).

Unpacking the complexity of handoffs with cognitive load theory

Handoff communication may occur through a number of methods, including electronic, telephonic, and face-to-face.[34] Handoff protocols structure the communication process and content (e.g., patient acuity, key problems, and anticipated issues), often via templates and mnemonics.[35] Depending on the setting and the extent to which handoffs have been standardized, there may be an opportunity for the receiver to ask clarifying questions or to check for congruence between his or her understanding and the sender's. At this point, responsibility for care of the patient is transferred. Although this kind of transaction may appear relatively straightforward, even in the best of circumstances handoff protocols do not address all the issues that may arise. The transfer of a mental model is a complex task that encompasses multiple cognitive steps, each one vulnerable to information loss, information distortion, or both.

To elaborate the factors that contribute to cognitive load during a handoff, we first delineated the components of a handoff. Three important and obvious components are the sending clinician, the receiving clinician, and the patient or patient panel. In addition, workplace learning[36] and other perspectives[37] highlight the importance of the sociocultural components of a handoff such as team culture and environmental affordances. For these five components (sending clinician, receiving clinician, patient or panel, team, and environment), we generated a list of factors that are likely to affect a trainee's learning and performance during a handoff. We solicited feedback on this list from four experts in patient safety and handoffs and from four experts in medical education research. By consensus, we associated each factor with the type of cognitive load it primarily effects.

Our resulting conceptual model (Figure 1) portrays how the intrinsic load, extraneous load, and germane load of a handoff impact the WM of both the sender and receiver and ultimately the extent to which the mental model received and acted on is consistent with the reality of the patient. Table 1 highlights the variety of handoff factors associated with each type of cognitive load. In the narrative that follows, we examine in detail how each type of cognitive load and the associated factors influences handoff performance.

Handoff drivers of intrinsic cognitive load

The intrinsic load of a task represents the load associated with processing the information essential to the task. Intrinsic load arises from selecting, organizing, and integrating the relevant words and images. According to CLT, intrinsic load has four drivers. First, the number of information elements influences intrinsic load. Learning about five patients or comorbidities during sign-out imposes more load than two.[22] Second, the amount of time available for a task affects intrinsic load. For example, the need for rapid handoff and decision making concerning an acute patient demands faster processing of the information and consumes more WM resources of both the sender and receiver. Third, element interactivity, the extent to which the information elements interact with each other, impacts intrinsic load. For example, the information elements of a fever, travel history, and time elapsed since travel imposes more load when your interpretation of one element (e.g., fever) depends on how

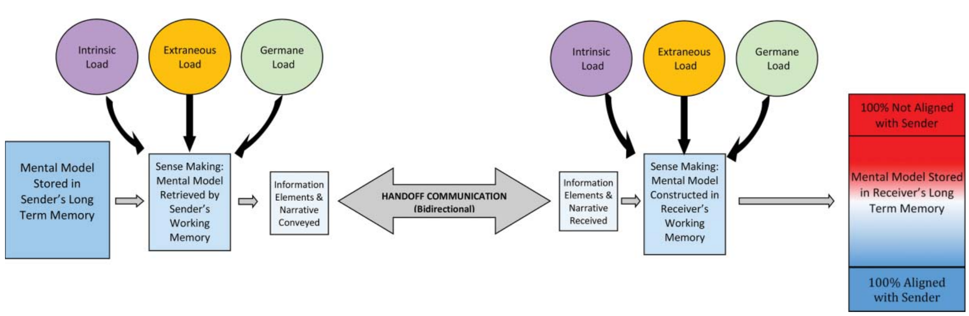

Figure 1. A patient handoff through the lens of cognitive load theory.

Table 1. Handoff factors associated with each type of cognitive load.

Type of Cognitive Load	Driver as Identified by CLT	Examples of Associated Handoff Factors
Intrinsic	Number of information elements	• Number of patients • Number of comorbidities per patient • Number of follow-up tasks
	Time	Rapid communication and decision-making demands faster processing of information
	Interactivity of the information elements	• Uncertainties or contingencies: diagnostic, therapeutic, or informational • Interactions: disease–disease, drug–drug, disease–drug • Maturity of the evidence base for the disease
	Knowledge level of the learner	• Familiarity with the handoff procedure • Maturity of learner's relevant illness scripts
Extraneous	Information search	• Sender does not identify anticipated events • Clinical information fragmented – in different places • Handoff process not clear
	Modality of information	• Information not distributed between visual and auditory channels
	Distractions	• Background noise • Interruptions • Gradients—authority, experience, specialty • Preoccupied with internal concern (e.g., how perceived by others)
	Physiology	• Fatigue • Working memory capacity
Germane	Strategies to enhance learning	• Self-explanation • Concentration • Metacognition: anticipatory planning, monitoring, adapting, generalizing • Interactive questioning

you interpret the others. These element interactivities can rapidly overwhelm WM.

By identifying element interactivity as a principal mediator of intrinsic load, CLT brings into focus features of a handoff beyond the volume of information or the time constraints. The presence of any kind of uncertainty generates contingencies, which in turn increase element interactivity and thereby makes the task more complex. Uncertainties may be diagnostic, therapeutic, or informational. Comorbidity and polypharmacy can create interactivity between disease processes and/or between therapeutics. In addition, the evidence base for the presumed disease itself may have a profound impact on the complexity of a handoff. CLT predicts that well-defined diseases for which evidence-based algorithms exist will impose less intrinsic load than a disease for which diagnosis requires expert judgment (often syndromes), treatment is trial and error, and the associated short-hands are less precise and universally understood.

A fourth determinant of intrinsic load is the degree of expertise possessed by the learner, whether sender or receiver. The more advanced learner already possesses and applies a schema that incorporates some or all of the interacting elements into a single element (e.g., congestive heart failure exacerbated by a binge of high sodium foods). As a result, the intrinsic load of a given handoff task is reduced when the learners are more advanced. CLT reminds us that knowledge matters. Experience with the process of sign-out and the local microsystem (s) as well as knowledge of the disease and the shorthand (if it exists) to succinctly communicate allow the learner to "chunk" or even automate information.

Thus, numerous handoff factors are associated with the four drivers of intrinsic load, including the number of patients, time constraints, acuity, complexity, uncertainties, interacting comorbidities and therapeutics, and maturity of the evidence base for the patient's disease. These factors effect both the sender and receiver as they seek to establish a shared mental model at sign-out.

Handoff drivers of extraneous cognitive load

Extraneous load arises from aspects of the activity that consume WM resources but are not essential to making sense of the information relevant to the task. Sometimes described as incidental processing, this type of load is often induced by the suboptimal design of a task. Handoff processes can inadvertently impose extraneous load by requiring unnecessary information search. Examples of this include providing insufficient guidance (e.g., the sender does not identify anticipated events during sign-out for the receiver) or requiring the person receiving sign-out to locate essential information (e.g., an up-to-date medication list) needed to complete the handoff. When information necessary for learning is distributed in space (e.g., requiring the sender and/or receiver to access multiple different databases for medications, progress notes) or time (e.g., the reception of information occurs at different times because of interruptions during sign-out), scarce WM resources are diverted to information search, rehearsal, and integration. In addition, extraneous load arises through the "modality effect," that is, when information that is too much for either the visual or auditory channel alone is presented via one channel rather than being distributed appropriately between two, such as when a visual diagram or written sign-out is combined with spoken words.[38] Distractions not related to the task also impose extraneous load when the learner devotes WM resources to the sensory information associated with the distraction.[39] These kind of distractions may be external (e.g., the intern's pager beeps during a handoff) or internal (e.g., the trainee is preoccupied with a personal concern) and not easily remedied by devices such as mnemonics. Finally, physiological traits and states, such as a learning disability or fatigue, can be understood as a type of extraneous load because it "consumes" or decreases WM capacity.[40] Thus, duty-hour restrictions align with the focus on diminishing extraneous load.

In sum, CLT helps identify factors that impose load unrelated to the task. CLT-related instructional interventions focus on minimizing extraneous load. An example of this strategy would be an electronic medical record feature that automatically populates all relevant information from various sources into a single handoff module or a scaffold such as a checklist for each step of the handoff that decreases search.

Of importance, intrinsic loads and extraneous loads are additive. Extraneous load interferes with learning if the intrinsic load for the task is high for that particular learner. If the task-associated intrinsic load is low, then the extraneous load may not harm performance and/or learning as long as the total load remains within the learner's WM capacity.[41]

Handoff drivers of germane cognitive load

Germane load represents the effort associated with learning that is separate and in addition to the effort associated with processing the information elements in WM. Germane load is regulated by the individual. In any given task, a trainee chooses how much effort to give to learning (e.g., combining the new information elements with already existing schemata in LTM). Strategies associated with germane load include self-monitoring to identify when inadequate understanding exists, asking clarifying questions, summarizing what has been heard, holding several different representations in WM, self-explanation, and activating prior knowledge about the patient or the disease. Even if a trainee wants to allocate effort to learning, there will be insufficient WM resources available for germane load if the intrinsic and/or extraneous load are too high and approach or exceed the learner's WM limits.

Figure 2 shows the additive effects of intrinsic load, extraneous load, and germane load relative to the total WM capacity of the learner. The combined effects of the extraneous and intrinsic load of a handoff for the less experienced early learner (Figure 2A) exceeds his WM capacity and results in no WM resources for germane load and inadequate WM resources for intrinsic load. Performance will suffer and learning will be impaired. The intermediate learner in Figure 2B has better developed schemata that results in a lower intrinsic load associated with the same handoff. In this case, the trainee's available WM is sufficient for the intrinsic and extraneous load—performance will be better, though no WM resources are available for germane load, which will limit learning. Note that simplifying the handoff for the same learner in 2A would have the same effect. Figure 2C shows the effect of reducing extraneous load through measures such as structured verbal and written templates protected from interruptions. The reduced extraneous load frees up WM for germane load, which supports learning for the intermediate.

Implications of CLT for handoff instructional design

Although CLT helps us appreciate the complexity of handoffs, it can also help guide and advance future handoff research and instructional design. Although the focus to date has been mostly on classrooms and nonmedical settings, CLT researchers have identified a number of

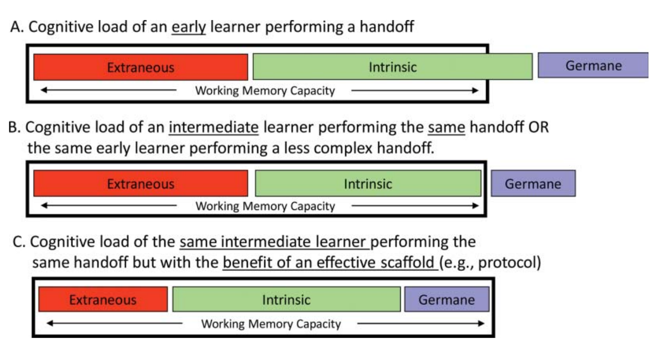

Figure 2. Interaction of cognitive load and working memory capacity during a handoff.

instructional techniques aimed at regulating cognitive load.[42–45] These techniques typically utilize three basic strategies in the following order: (a) *reduce* extraneous load, (b) *manage* intrinsic load, and (c) *optimize* germane load.

The instructional techniques developed in other settings can be applied to medical education and clinical learning. Techniques focused on reducing extraneous load include employing scaffolds or aids (*checklists and templates*), distributing information across the semi-independent visual and auditory channels, integrating written and graphical text, and minimizing the need to search for information. In the relatively uncontrolled environment of clinical care, the drivers of extraneous load tend to be easier to modify or control than those of intrinsic and germane load. Consequently, best practices to date tend to focus on reducing extraneous load by minimizing interruptions, standardizing the communication process using verbal mnemonics and written templates supported by technology, and making all relevant information accessible in a single physical space with a reliance on both auditory and visual modes of communication. Current recommended practices also include team-work training (e.g., TeamSTEPPS[46]), which can affect all three types of load: intrinsic load (by distributing load across individuals), extraneous load (by clarifying roles), and germane load (by encouraging clarifying questions).

Even with extraneous load minimized, task demands may still exceed the learners' WM. CLT then seeks to manage intrinsic load. Instructional interventions can alter the intrinsic load generated by a handoff via several strategies: (a) simplify the task to be learned (e.g., fewer patients, less acute or complex patients, more time), (b) decompose the task into "partial tasks" to be practiced until ready for the "whole task," and/or (c) enhance the expertise of the learners or team (e.g., by providing preparatory training/knowledge prior to the task). Task simplification can also be accomplished by assigning diseases with a clear etiology and evidence-based diagnosis and treatment to early learners because there are fewer interacting elements, the data are more amenable to a well-organized illness scripts, and communication is simpler. Overall, instructional techniques should titrate intrinsic load without decontextualizing the task and, if possible, while maintaining the *whole-task approach*. Whole-task approaches are recommended in instructional techniques based on CLT[18] and aim to address the problem of "transfer"[47] which occurs when knowledge or skills acquired in one setting do not transfer to another. However, part-task practice (e.g., only written or only oral sign-out) and low-fidelity simulation are often helpful for the early learner when the whole task of a handoff exceeds their WM capacity and the part-task is designed with clear links to the whole-task.

As the extraneous load is minimized and the intrinsic load is titrated to the developmental stage of the learner, instructional techniques must also seek to ensure that learners use the freed up WM capacity for learning by increasing germane load. Strategies may include prompting the sender or receiver to utilize metacognitive techniques such as monitoring one's understanding during the handoff process or other techniques such as compare/contrast, activating prior knowledge, or summarizing one's understanding and asking for confirmation. When a task is very complex, peer collaboration has been recommended to distribute cognitive load across individuals.[48]

Gradients

Our examination of cognitive load in handoffs identified an additional source: gradients. Gradients can exist between the sender and receiver, such as differences in authority, specialty, or experience. For example, a learner may be distracted by the perceived expectations of the senior supervisor (authority gradient). Or, an experienced trainee may reflexively present the patient in a highly schematized shorthand (experience gradient). If the receiver is less experienced or from a different specialty, the condensed information may be difficult to fully understand.[49] This experience or specialty gradient adds extraneous load for the receiver. The condensed language distracts the less experienced learner from understanding the relevant patient information. Similarly, the inclusion of excessive details by the novice sender can distract a more experienced learner or clinician. The sender who anticipates the "semantic gradient" created by differences in experience or specialty may take efforts to consciously reorganize the information into a format or language that he or she would otherwise not use. This makes the task far more complex and increases intrinsic load.

CLT research has also identified the so-called expertise-reversal effect, wherein the instructional techniques helpful to early learners (e.g., decreasing extraneous load or using templates) are not helpful to experts and can even result in worse performance.[20,50] This effect could mean that the current focus of best practices (e.g., use of mnemonics and templates) may actually worsen handoffs by experts while helping less accomplished clinician.

Discussion

The application of CLT to handoffs suggests a number of hypotheses not previously tested. When a handoff occurs between two clinicians of different experience levels or specialties, these gradients may create communication challenges that increase extraneous load and vulnerabilities to discordance and error. Similarly, the maturity of the evidence base for a given disease may have important effects on intrinsic load: Diseases with well-defined diagnostic and treatment algorithms may impose less load and lead to fewer errors compared to those diseases with immature evidence bases that force clinical care to rely more on idiosyncratic trial and error and individual expert judgment. Moreover, the expert-reversal effect demonstrated in classroom-based CLT research raises the question as to whether more experienced or expert clinicians might perform better with less templated handoff procedures. These hypotheses, if confirmed, have important implications for instructional techniques and for handoff protocols in settings in which trainees contribute to care.

Future handoff research and curriculum development should focus on the relatively under addressed dimensions of handoffs—those related to intrinsic and germane load. Current best practices do not take into account the knowledge level of the sender and receiver of handoff or the complexity of the cases and tend to have a "one size fits all" approach. The protocols remain the same regardless of the cognitive load associated with the handoff and regardless of the experience level of the clinicians. In addition, CLT focuses our attention on both the sender and receiver. When the cognitive load associated with either role surpasses the trainee's working memory, the accuracy of the shared mental model is threatened and learning degraded. By differentiating the WM of the sender and receiver, CLT raises the possibility that the drivers of cognitive load for senders and receivers may be different. If true, this would have important implications for educational and safety interventions. For the receiver, knowing how to listen[51] and how to monitor, verify, and enhance one's understanding is crucial. These skills need to be taught and are a driver of germane load. For the sender, the task of choosing, sequencing, and communicating the most relevant information in a manner best suited to the particular receiver requires conscious choices and brings added intrinsic load. The strategies of task simplification will be especially relevant here. For both the sender and receiver, the learner's knowledge and the patient's characteristics are primary mediators of intrinsic load. Finally, theories of metacognition or self-regulation overlap with CLT's understanding of germane load and may provide useful strategies to optimize germane load for both the sender and receiver. These strategies may include interventions that prompt the learner to reflect on and modify, as necessary, their learning process before, during, and after the activity.[52]

This examination of handoffs also identifies some of the limitations of CLT in particular and of relying on a single learning theory in general. Cognitive apprenticeship,[53] workplace learning,[36] and other sociocultural theories of learning add a fuller view of how social dynamics (above and beyond the interaction of the learner's WM with the task itself) can impact cognition and effect learning and performance. Similarly, motivation and emotion have received more attention in medical education research in recent years.[54,55] Theories in this field include goal theory[56] and self-determination theory,[57] and related research suggests that motivation influences why learning efforts are initiated, persist, and stop and have profound impact on learning outcomes. Activating emotions, such as enjoyment, have been associated with deep processing, enhanced learning, and performance, whereas negative emotions (i.e., anxiety) correlate with more superficial processing and consumption of WM resources and can impede learning.[58] These and other theories highlight different dimensions and drivers of learning relevant to handoffs and should also be employed in future handoffs research and curriculum development.

Meanwhile, the application of CLT to handoffs may help with the further development of CLT as a learning theory. Measures of cognitive load have largely been developed for classroom-based learning.[59] Significant adaption may be required to measure load associated with a workplace-based procedure. In addition, measures have only been validated for overall cognitive load.[60] Establishing validated measures of cognitive load types will be essential to testing the hypotheses generated by CLT. Finally, although the theory proposes intrinsic load and germane load as independent factors, others have argued that germane load may be a subset of intrinsic load.[61] Studies of handoffs may help answer this and other questions.

Conclusion

Handoffs represent a complex task that requires simultaneous integration of multiple skill sets. CLT, with its appreciation of WM as a bottleneck for learning, helps unpack this complexity. In particular, CLT highlights the three types of cognitive load that impact a learner during handoffs, namely, intrinsic, extraneous, and germane load. Given WM limitations and the still-developing schemata of trainees, the additive effects of these loads can easily exceed the WM capacity of the trainee, resulting in impaired learning and performance. The CLT framework helps to identify the drivers of cognitive load during a handoff and targets for future research and curriculum development aimed at improving educational and patient outcomes.

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