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Educational Article

Cognitive load theory: Practical implications and an important challenge

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الملخص

اعتمد مجال التعليم الطبي مجموعة واسعة من النظريات من عدة مجالات أخرى. ومن الأمثلة الحديثة إلى حد ما هو نظرية التحمل الإدراكي، التي نشأت من علم النفس التربوي. العديد من الدراسات التجريبية المستوحاة من نظرية التحمل الإدراكي واستعراض الآثار العملية لنظرية التحمل الإدراكي أسهمت في إعداد القواعد الإرشادية لتصميم التعليم الطبي. في الوقت ذاته، وضعت عدة مجموعات بحثية أدوات لقياس التحمل الإدراكي في سياق التعليم الطبي. وعلى الرغم من هذه التطورات، يبقى الحصول على أدلة لأنواع مختلفة من التحمل الإدراكي تحديا هاما. ومن أجل ذلك، تهدف هذه المقالة إلى أمرين: لتزويد معلمي الطب بثلاث قواعد إرشادية رئيسة لتصميم التعليمات والتقييم ولشرح بعض القضايا الأساسية في التحدي الباقي حول أنواع مختلفة من التحمل الإدراكي. تدور القواعد الإرشادية حول التقليل من النشاط الإدراكي الذي لا يسهم في التعلم، ووضع أهداف محددة للتعلم في عين الاعتبار، وتقدير العلاقة متعددة الأوجه بين التعلم والتقييم. وتتضمن القضايا الرئيسة حول التحمل الإدراكي السياق الذي يحدث في التعلم، والاستمرار في استخدام عنصر واحد لتقديرات الجهد العقلي، وتوقيت التحمل الإدراكي ونتائج التعلم.

الكلمات المفتاحية: نظرية التحمل الإدراكي؛ التعلم؛ التعليم؛ التصميم؛ القياس

Abstract

The field of medical education has adopted a wide variety of theories from other fields. A fairly recent example is cognitive load theory, which originated in educational psychology. Several empirical studies inspired by cognitive load theory and reviews of practical implications of cognitive load theory have contributed to guidelines for the design of medical education. Simultaneously, several research groups have developed instruments for the measurement of cognitive load in a medical education context. These developments notwithstanding, obtaining evidence for different types of cognitive load remains an important challenge. Therefore, the aim of this article is twofold: to provide medical educators with three key guidelines for the design of instruction and assessment and to discuss several fundamental issues in the remaining challenges presented by different types of cognitive load. The guidelines revolve around minimizing cognitive activity that does not contribute to learning, working with specific learning goals in mind, and appreciating the multifaceted relation between learning and assessment. Key issues around the types of cognitive load include the context in which learning occurs, the continued use of single-item mental effort ratings, and the timing of cognitive load and learning outcome measurements.

Keywords: Cognitive load theory; Design; Education; Learning; Measurement

Introduction

The field of medical education has adopted a wide variety of theories from other fields. A recent example is cognitive load theory (CLT),[1–11] which originated in educational psychology.[1,2,6–9] CLT defines learning as the development

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and automation of cognitive schemas stored in long-term memory about content to be learnt (e.g., anatomy of the human body[12] or a particular type of systematic problem-solving procedure[13,14]). A vast body of empirical work has demonstrated the narrow limits of human working memory,[15–18] and CLT states that the design of education has to respect these limits.[4,5,9,11] Several empirical studies inspired by CLT[12,20–22,24,26–28] and reviews of practical implications of CLT[4,5,10,11,19,23,25,29,30] have contributed to guidelines for the design of medical education. Simultaneously, several research groups have developed instruments for the measurement of cognitive load in a medical education context.[22,24,26–28] These developments notwithstanding, obtaining evidence for different types of cognitive load remains an important challenge. Therefore, the aim of this article is twofold: to provide medical educators with three key guidelines for the design of instruction and assessment and to discuss several fundamental issues in the remaining challenge concerning different types of cognitive load.

Three core guidelines for the design of instruction and assessment

Following the aforementioned definition of learning in CLT as the development and automation of cognitive schemas regarding content to be learnt, three types of cognitive load have been distinguished in the literature: *intrinsic cognitive load* (ICL), *extraneous cognitive load* (ECL) and *germane cognitive load* (GCL).[4,5,9,11] When confronted with information about content to be learnt, the incompleteness and lack of development – or lack of automation – of a learner's cognitive schemas about that content imposes ICL. The more content elements that need to be processed by working memory at a given time and/or the more interaction between elements (i.e., element interactivity[5]), the more ICL for a learner. Next, ECL is cognitive load due to cognitive processes that as such do not contribute to learning.[31,32] Finally, GCL has been viewed as cognitive load due to the deliberate engagement in cognitive processes that are beneficial to learning, including asking the right questions, appropriate self-explanation of content, accurate metacognitive monitoring of learning and performance, and following up on that monitoring with adequate learning activity.[9–11]

In recent years, several researchers have suggested a modified dual model that includes only ICL and ECL and gives a broader interpretation to ICL, depending on the goals of learning and instruction.[1–5,7,8,14] It is important to note that this dual model does not deny the *existence* of GCL; rather, it is cognitive load due to working memory resources allocated to dealing with ICL, or the part of ICL that benefits learning.[1,4,5] If none of the ICL is dealt with successfully, GCL is 0; if all ICL is dealt with successfully, all ICL is GCL. In other words, while in the traditional three-factor ICL/ECL/GCL cognitive load model[9–11] GCL is a distinct third type of cognitive load, in the modified two-factor ICL/ECL cognitive load model, GCL is a proportion (i.e., somewhere on a scale from 0 to 100%) of ICL. Effectively, the two models support exactly the same guidelines for the design of education and training. Since a variety of articles and book chapters have provided rather detailed reviews and overviews of recommendations for education and training,[3–5,8–11,19,23,25,30,33] using examples from recently published research, this article focuses on three core guidelines, two of which have been considered mainly more recently.

Guideline (1): minimize cognitive activity that does not contribute to learning

The first guideline revolves around minimizing ECL, meaning that instruction should be designed in such a way that only a minimum of working memory resources is needed for cognitive processes that do not contribute to learning as such.[4,5,8–11] Well-known examples of such cognitive processes among learners who are new to a certain topic are having to verbally process information that ought to be presented visually[5] and having to divide one's attention between information sources, in different spaces or times, that could be integrated into a single source.[3,4,10] These effects eventually disappear as learners become more proficient, and providing support where it is not needed may contribute to ECL.[5,8,10] For instance, when early stage learners have to learn a complex procedure, ECL due to ineffective problem-solving search can be reduced by having them study a worked example of a successful completion of a procedure first.[34] However, this beneficial effect of support among novice learners disappears and eventually reverses when applied to more advanced learners.[35,36]

When we ask learners to do an objective structured clinical examination (OSCE) with possible diagnoses in mind and to explicitly engage in forward (i.e., from symptom to diagnosis) and backward (i.e., from diagnosis to symptom) clinical reasoning,[37–39] we can expect a higher ICL than when we ask learners to focus primarily on the manoeuvres of the OSCE procedure.[4,22,23] Likewise, when we ask undergraduate students to practice with a simulated patient in an authentic simulated workplace environment (i.e., simulated clinical immersion), they will probably experience a higher ICL than when we let them practice with that simulated patient outside such an environment, since in the latter case there are no environmental stimuli to pay attention to.[26] Moreover, in most medical procedures, it is not sufficient to merely learn the steps of a procedure. Rather, these steps often have to be undertaken in a particular sequence to ensure a correct solution. The order matters, and that interactivity adds to ICL. In such an environment, having to address patient cases where there are many possible diagnoses and/or several comorbidities[23] may take the ICL for less experienced learners to the limits of their working memory. However, more advanced learners will probably experience a lower ICL in such a situation because they can activate more developed and perhaps already more automated cognitive schemas than their less experienced peers.

Careful reflection on this ICL factor is of paramount importance, because in the aforementioned case (i.e., OSCE and simulated clinical immersion) and other settings in medicine and healthcare, several sources not yet mentioned can contribute to ECL. First, having to address patient cases that are very complex for learners at a given stage without adequate instructional support from a supervisor or the