Computers & Education 100 (2016) 18–31

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

One for all?! Simultaneous examination of load-inducing factors for advancing media-related instructional research

Maria Wirzberger*, Maik Beege, Sascha Schneider, Steve Nebel, Günter Daniel Rey

E-Learning and New Media, Institute for Media Research, Faculty of Humanities, Technische Universität Chemnitz, Germany

ARTICLE INFO

Article history:
Received 19 February 2016
Received in revised form 15 April 2016
Accepted 20 April 2016
Available online 22 April 2016

Keywords:
Cognitive load theory
Working memory updating
Task complexity
Split-attention effect
Schemata

ABSTRACT

In multimedia learning settings, limitations in learners' mental resource capacities need to be considered to avoid impairing effects on learning performance. Based on the prominent and often quoted Cognitive Load Theory, this study investigates the potential of a single experimental approach to provide simultaneous and separate measures for the postulated load-inducing factors. Applying a basal letter-learning task related to the process of working memory updating, intrinsic cognitive load (by varying task complexity), extraneous cognitive load (via inducing split-attention demands) and germane cognitive load (by varying the presence of schemata) were manipulated within a 3 × 2 × 2-factorial full repeated-measures design. The performance of a student sample ($N = 96$) was inspected regarding reaction times and errors in updating and recall steps. Approaching the results with linear mixed models, the effect of complexity gained substantial strength, whereas the other factors received at least partial significant support. Additionally, interactions between two or all load-inducing factors occurred. Despite various open questions, the study comprises a promising step for the empirical investigation of existing construction yards in cognitive load research.

1. Introduction

Learning demands a variety of cognitive processes related to information capture, storage, and retrieval that request learners' mental resources. It involves in particular those associated with memory structures, entailing the challenge to keep track of changing contents in working memory, and their correct and stable representation in long-term memory. Particularly within multimedia learning settings, learners' limited mental resource capacity has to be taken into account to avoid impairing overload. Despite their enhanced potential in capturing motivation and engagement, such settings are prone to overly claim mental resources due to the multimodal, interactive and often distributed presentation of subjects. To be able to handle this opportunities in a balanced and constructive manner, the necessity of a closer investigation of factors and effects related to mental resource demand arises. A prominent and influential theory providing advices for the conducive design of media-transmitted instructional content is the Cognitive Load Theory (CLT). It was introduced in the late 1980s by John Sweller (1988) and emerged a well-known and extensively used approach. Nevertheless, several construction yards exist

* Corresponding author. E-Learning and New Media, Institute for Media Research, Faculty of Humanities, Technische Universität Chemnitz, Straße der Nationen 12, 09111 Chemnitz, Germany.

E-mail address: maria.wirzberger@phil.tu-chemnitz.de (M. Wirzberger).

http://dx.doi.org/10.1016/j.compedu.2016.04.010
0360-1315/

within this framework, above all issues of a valid and reliable empirical assessment of the theoretically postulated building blocks and assumptions regarding their coaction. The current research accepts the emerging challenges and contributes to their clarification, to be able to derive more detailed predictions on underlying learner cognition within a next step.

1.1. Cognitive Load Theory

Amongst its basic assumptions, the CLT postulates a practically unlimited storage capacity of long-term memory, the mental representation and organization of knowledge via schemata, and a limitation of working memory in terms of duration and capacity. Additionally, a separation of the overall cognitive load (CL) construct into different facets related to distinct aspects within a learning setting has been assumed during the last decades (Sweller, Ayres, & Kalyuga, 2011). While intrinsic cognitive load (ICL) should result from the complexity of the used learning material (referred to as element interactivity) and takes into account a learner's previous knowledge, extraneous cognitive load (ECL) arises from the instruction itself, for instance by containing interesting but irrelevant content or demanding learners to spread their attention across different sources of information. Relevant processes of schema acquisition and automation, which represent crucial aspects while learning certain contents, are assigned to germane cognitive load (GCL). Such CL types should operate additively on the available amount of cognitive resources, implying an increase in relevant processing just in the case irrelevant processing decreases. However, recent research queries the assumption of additivity (Brünken, Plass, & Moreno, 2010; Park, 2010) as well as the separability of load facets (Kalyuga, 2011; de Jong, 2010), not least due to the lack of satisfying means of measurement related to the described CL facets (Brünken, Seufert, & Paas, 2010). Yet another step forward, Sweller (2010) aimed at reformulating the three-factorial framework by attributing germane resources to handle content relevant to achieving a defined learning outcome (ICL) and extraneous resources to deal with irrelevant situational characteristics (ECL). Such dual framework would take into account the fact of certain load to be beneficial for learning, but on the other hand presumes each learner's motivation to spend all available resources to the process of learning (Kalyuga, 2011).

So far, a sophisticated approach to empirically test the assumption of three additively operating load factors was applied by Park (2010) within a series of learning experiments that varied either ECL, GCL or both. ICL was kept at a constant level because it was considered to be rather stable and hardly influenceable by instructional design. Attempting to explain her results, Park (2010) states that the emerging pattern of non-significant main effects and significant interactions strongly challenges the additive contribution of the postulated load-inducing factors. Nevertheless, the chosen approach faces certain limitations. First of all, none of the experiments comprised a variation of ICL. However, a comprehensive examination of separate and additive influences should address and manipulate all facets within the same framework. In addition, dependent variables comprised subjectively rated amounts of cognitive load, and scales on learning success with varying amounts of retention, transfer, and problem comprehension for each experiment. Objective measures related to defined behavioral outcomes might be an alternative to facilitate more universal predictions.

1.2. Task complexity and ICL

Advancing the matter of task complexity, associated with the facet of ICL, Sweller and Chandler (1994) postulate that beyond the amount of information the resource demand induced by a learning task arises from related information that has to be processed simultaneously. In doing so, they outline the crucial role of interactivity between elements of a learning task, whereat elements could be symbols, concepts, procedures or other types of task inherent units (Chen, Kalyuga, & Sweller, 2016). These are measurable a priori for instance by counting the number of separable but interdependent subtasks. Subtasks comprise defined cognitive acts that rely on learners' cognitive resources, and are demanded to various extents for differences in existing knowledge on the presented content. A felicitous implementation of a priori estimates of task complexity was introduced by Beckmann (2010). He used an abstract reasoning task with geometric symbols, and increased the level of complexity by varying the number of dimensions presented items differed on, ranging from two (shape and color) to four (shape and color of inner as well as outer components). Such controlled approach allows to give concise predictions about cognitive acts that have to be performed while solving the task, to quantify the extent of complexity in a reliable manner. Besides a significantly worse performance with increasing complexity ($\eta_p^2 = .37$) the obtained results reveal a better performance without the requirement to store results of individual subtasks ($\eta_p^2 = .47$). The arising predictability of performance outcomes supported the chosen approach. Moreover, Beckmann (2010) emphasized that apart from task-related characteristics those related to the respective situational context contribute to overall task complexity as well.

1.3. Split-attention effect and ECL

The situational aspect of instructional design generally relates to the facet of ECL, resulting in design principles to avoid distracting overload. An often studied phenomenon in this context is the split-attention effect (Chandler & Sweller, 1991, 1992; Owens & Sweller 2008), occurring in learning with various sources of information. Given that each source of information matters for understanding the learning material, learning outcomes improve when different sources of information are presented spatially integrated rather than in a separated format. An explanation assumes that in the latter case information must be maintained in working memory, while searching for elements within distributed but interconnected sources (Sweller et al., 2011). Such additional demands potentially reduce the capacity available for relevant learner involvement, and