In D. Reitter & F. E. Ritter (Eds.), Proceedings of the 14th International Conference on Cognitive Modeling (ICCM 2016). University Park, PA: Penn State.

Examining load-inducing factors in instructional design: An ACT-R approach

Maria Wirzberger (maria.wirzberger@phil.tu-chemnitz.de)
E-Learning and New Media, Technische Universität Chemnitz,
Straße der Nationen 12, 09111 Chemnitz, Germany

Günter Daniel Rey (guenter-daniel.rey@phil.tu-chemnitz.de)
E-Learning and New Media, Technische Universität Chemnitz,
Straße der Nationen 12, 09111 Chemnitz, Germany

Keywords: Cognitive Load, Instructional Design, ACT-R

Introduction

In multimedia-based learning settings, limitations in mental resource capacity have to be taken into account to avoid impairing effects on learning performance. Despite the enhanced potential in capturing motivation and engagement, the multimodal, interactive and often distributed presentation of information within such settings is heavily prone to overload learners' mental facilities. To be able to handle the arising challenges, factors and effects related to the associated resource demands should be investigated in a more detailed way.

Theoretical background

A prominent and influential theory that provides versatile advice for the conducive design of media-transmitted instructional content from a cognitive perspective is the Cognitive Load Theory (Sweller, 1988; Sweller, Ayres, & Kalyuga, 2011). It is concerned with the question in what way learning scenarios demand learners' cognitive resources, since without knowing anything about underlying human cognition, instructional design is blind (Sweller et al., 2011). Amongst its basic assumptions, the theory 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. Mental resource demands related to learning situations arise from three sources: While task complexity based on learners' previous knowledge constitutes *intrinsic load*, effects of inappropriate instructional presentation add to *extraneous load*. Both aspects affect performance on a structural and short-term level. By contrast, schema acquisition and automation, characterizing *germane load*, have to be considered on processual and long-term accounts. According to the theory, learning performance is impaired if the total amount of processing requirements exceeds the limited capacity of human working memory.

Project focus

This project focusses on the question, how load induced due to schema acquisition changes over time while working on a learning task. Besides of distinct cognitive mechanisms in different stages over the learning process, the influence of structural load facets in this context will be investigated.

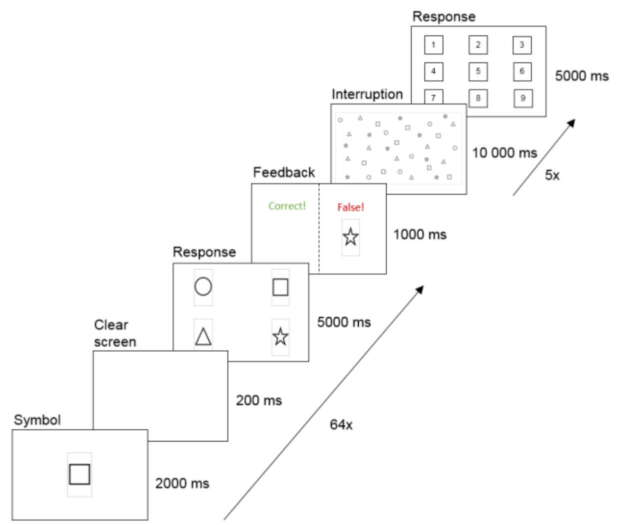

Fig. 1. Schematic trial structure. Presentation of second symbol analog and both separated by clear screen.

Task setting

In the first instance, a basic learning task is used to approach the focus of interest. Compared to comprehensive learning settings, such facilitates a more concise and controllable inspection of underlying cognitive mechanisms and processes. The chosen task (see **Fig. 1**) requires participants to figure out and memorize combinations of arbitrary geometric symbols. They are presented one or two symbols one after another and have to indicate which symbol completes the combination by selecting the correct symbol from an offered choice on the screen. For instance, a circle and a square being displayed would result in choosing a star. Such combinations have to be remembered and constitute the knowledge schema obtained over the task. The number of symbols determining the following symbol represents the intrinsic load component that is varied between subjects. An interrupting secondary task induced at defined stages during the assignment characterizes the extraneous load component that is included as within-subjects variable. Within the secondary task, participants have to search for and count instances of two selected types of geometric symbols from a picture, for example all circles and stars, and indicate their numbers afterwards. Both structural load components are considered as independent variables in this setting. Learning performance is recorded continuously via correctness and duration of responses. The resulting efficiency score reflects the amount of mental resources invested to acquire the task-related schema (germane load component) and serves as dependent variable.

Experimental results

Preliminary results from an already conducted human experimental setting with 116 student participants (93 female, M_{age} = 23.25 years, range: 18-44 years) confirm influences of both structural load features on the observed learning performance. Apart from differing patterns of performance for easy and difficult versions of the task, they indicate a specific loss pattern in performance due to the interruptions especially in the easy condition. Based on that findings, various open questions on relevant cognitive mechanisms underlying the aspired temporal model of load progression arise.

Load measurement

In general, when attempting to investigate such issue, common approaches of load measurement by subjective questionnaires or physiological indicators face limitations in terms of diagnosticity and sensitivity. Experimentally manipulated performance measurement indeed provides a controlled way of assessment, but merely operates on indirect means as well and therefore lacks accessibility. On that point, the cognitive architecture ACT-R (Anderson & Lebiere, 1998; Anderson, 2007) offers the opportunity to clarify cognitive determinants that potentially underlie the observed performance. Implementing such a model structure raises the need to clearly think about each step relating to a given task, to ensure compatibility with founded psychological theories on human information processing.

Model development

The developed cognitive model will take into account existing work on the acquisition of complex cognitive skills (Anderson, 1982; Van Merriënboer, 1997; Taatgen & Lee, 2003). In correspondence with Bartlett (1932) and Gagné and Dick (1983), the formation of schemata will be addressed in both declarative and procedural manners, emphasizing the relevance of subsymbolic mechanisms like *activation*, *production compilation* or *reward*. Additionally, the model will base upon research on interruption and resumption during task processing (Trafton, Altmann, Brock, & Minz, 2003; Wirzberger & Russwinkel, 2015), since the disruptiveness of an interruption at a time is influenced by the amount and accessibility of available cognitive resources. On technical accounts, a milestone will consist in establishing a direct connection between the ACT-R model and the already existing Python-based experimental task via a JSON network interface (Hope, Schoelles, & Gray, 2014). Such methodology provides the option to link the developed model to more complex and lifelike multimedia-based learning settings prospectively. In doing so, predictions and observations from the basic scenario can be validated in richer knowledge domains, as already planned within the next step.

Conclusion

Overall, this project constitutes a fine step forward in understanding cognitive processes while acquiring knowledge from media-transmitted instructional content. In doing so, it provides relevant insights into a so far rather vague defined theoretical framework, and additionally contributes to interconnect approaches from different fields of research.

Acknowledgments

The authors gratefully acknowledge funding from the German Research Foundation (DFG), GRK 1780/1.

References

Anderson, J. R. (1982). Acquisition of cognitive skill. *Psychological Review, 89,* 369–406.

Anderson, J. R., & Lebiere, C. J. (1998). *The atomic components of thought*. New York: Psychology Press.

Anderson, J. R. (2007). *How can the human mind occur in the physical universe?* New York: Oxford University Press.

Bartlett, F. C. (1932). *Remembering: An experimental and social study*. Cambridge, MA, USA: Cambridge University Press.

Gagné, R. M., & Dick, W. (1983). Instructional Psychology. *Annual Review of Psychology*, *34*, 261–295.

Hope, R. M., Schoelles, M. J., & Gray, W. D. (2014). Simplifying the interaction between cognitive models and task environments with the JSON Network Interface. *Behavior Research Methods, 46*, 1007-1012.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*, 257-285.

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory.* New York: Springer Science + Business Media.

Taatgen, N. A., & Lee, F. J. (2003). Production compilation: A simple mechanism to model complex skill acquisition. *Human Factors, 45*, 61–76.

Trafton, J. G., Altmann, E. M., Brock, D. P., & Mintz, F. E. (2003). Preparing to resume an interrupted task: Effects of prospective goal encoding and retrospective rehearsal. *International Journal of Human-Computer Studies, 58*, 583–603.

Van Merriënboer, J. J. (1997). *Training complex cognitive skills: A four-component instructional design model for technical training*. Englewood Cliffs, NJ: Educational Technology Publications, Inc.

Wirzberger, M., & Russwinkel, N. (2015). Modeling interruption and resumption in a smartphone task: An ACT-R approach. *i-com, 14*, 147-154.