Working Memory Involvement in Causal, Conceptual and Procedural Multimedia Learning Tasks

Erlijn van Genuchten, Katharina Scheiter, Anne Schüler
Knowledge Media Research Center
Konrad-Adenauer-Str. 40, 72072, Tübingen
e.genuchten@iwm-kmrc.de

Abstract. The present study investigates the relative importance of different working memory components for multimedia learning, namely the visuospatial sketchpad, the phonological loop, and the central executive. Considering the assumption that the contributions of these components depend on the importance of text and pictures for understanding the learning material, different task types are used (i.e., conceptual, causal and procedural tasks). It is assumed that text and pictures contribute differently to understanding in these task types. In a 2x3 experiment, participants are assigned to one of two groups (text-only or text-picture group; between-subjects), studying two materials of each task type (within-subjects). Several tasks are used to measure the capacity of the different working memory components serving as continuous factors in the study; as dependent variable, learning outcomes are assessed. The results are not addressed in this proposal, because the data gathering is still in progress. They will be presented at the conference.

Keywords: Multimedia; working memory; causal task; conceptual task; procedural task.

Introduction

Multimedia is defined as presenting both words (such as spoken or printed text) and pictures (such as illustrations or videos), and learning with multimedia occurs when people build mental representations from words and pictures (Mayer, 2005). The most widely accepted theoretical framework concerning learning with multimedia is offered by the Cognitive Theory of Multimedia Learning (Mayer, 2005). This theory emphasizes the role of working memory (WM) in the construction of knowledge representations in long-term memory; however, there are only a few studies investigating these working memory assumptions at an empirical level.

According to Baddeley's WM model, a distinction is made within WM between the central executive (CE), the visuospatial sketchpad (VSSP), and the phonological loop (PL; Baddeley, 1986). The CE is a control system which has the capacity to focus, divide, and switch attention, and to link WM with long-term memory. The VSSP and the PL are capable of holding and rehearsing visuospatial and verbal information, respectively. The relative importance of these different WM components in multimedia learning can be investigated using correlation analyses between a learner's capacities of the different WM components and learning outcomes (Andrade, 2001).

Considering the assumption that the contributions of these components depend on the importance of text and pictures for understanding the learning material, different task types are used in this study. A distinction is made between conceptual, causal and procedural learning tasks in order to investigate whether there are processing differences in WM across task types. Conceptual tasks focus on the integration of knowledge concerning concepts and their relationships (Hiebert & Carpenter, 1992), causal tasks focus on knowledge concerning cause-and-effect chains (Mayer & Chandler, 2001), and procedural tasks focus on the temporal order and spatial relationships between actions (Brunyé et al., 2006).

Although this distinction has not been made in previous studies, it is expected that the extent to which textual and pictorial information is used differs between the three task types (Baddeley, 1986). Specifically, it is hypothesised that learners benefit more from pictorial information in procedural tasks, because of the spatially demanding nature of these tasks, than in causal tasks, in which both pictorial and verbal information are equally important for understanding the system (Brunyé et al., 2006). In turn, pictorial information is hypothesised to be more important in causal tasks than in

conceptual tasks, in which information concerning relationships between pieces of information is often more difficult to depict than to describe (Brunyé et al.). Therefore, the contribution of the PL is hypothesised to increase with verbal information becoming more important (i.e., from procedural to causal to conceptual tasks), whereas the contribution of the VSSP is hypothesised to increase with pictorial information becoming more important (i.e., from conceptual to causal to procedural tasks). The CE should be most strongly involved in learning causal tasks compared to the other two tasks, because the integration of verbal and pictorial information is most relevant here.

Similarly, it is hypothesised that the difference in learning outcomes between the just-text and text-picture group is larger when the picture is more important (i.e., larger multimedia effect; see Table 1).

Table 1: Expectations Concerning WM Involvement, Importance of Text and Pictures and Size of the Multimedia Effect for the Three Different Task Types.

Task type	Conceptual	Causal	Procedural
Contribution of picture / involvement of VSSP	+	++	+++
Contribution of text / involvement of PL	+++	++	+
Need for integrating text and pictures / involvement of CE	+	++	+
Size of the multimedia effect	+	++	+++

Research Question

The overall question in this research concerns the relative importance of the different WM components during learning in conceptual, causal, and procedural tasks. Therefore, the main aim is to test WM involvement. The secondary aim is to test whether a multimedia effect is found for the developed experimental material, and if so, whether the size of the effect reflects the expectations concerning the importance of the picture. The results may allow multimedia learning material to be improved.

Method

Participants and Design

WM involvement and the appropriateness of the learning material were tested using a 2x3 design. Ninety-seven participants (72 female and 25 male; M = 23.70 years, SD = 3.23 years) were assigned to one of three groups and received just text or text and picture (between-subjects variable; in the text-picture condition, the position of the pictures was counterbalanced, implying that they were presented either to the left or the right of the text) and learned materials of each task type (within-subjects variable). Moreover, the WM capacity measures served as continuous factors in the study. The main dependent variable was learning outcomes.

Material, Measures and Procedure

Before starting the series of tests, participants are asked to give their informed consent, to fill in a demographic questionnaire, and to perform a reading speed test. Then, participants perform two blocks each consisting of 1) three learning tasks (one of each type), 2) questions concerning these learning material, 3) post-test questions to assess learning outcomes, and 4) two WM capacity tests. Each point is described in more detail.

Nine learning tasks have been developed of which three are conceptual, three causal, and three procedural. All learning tasks concern fictitious information, as prior knowledge affects learning

outcomes, and contain 1/2 A4-page text accompanied by one composite picture. Each participant learns six out of these nine learning tasks, two from each type.

Questions concerning the learning material (e.g., how useful was the picture) are used for each task to obtain direct measures concerning the appropriateness of the material.

After learning, the post-tests are conducted in the same order in which the material was learned. Several retention tests are used to test participants' obtained knowledge: 1) verbal free recall (written), 2) pictorial free recall (drawn), 3) verbal and pictorial recall yes/no verification tasks, 4) verbal transfer yes/no verification tasks, and 5) text-picture integration yes/no verification tasks.

WM capacities are measured using the Digit Span (repeating number sequences; PL; Wechsler, 1958), Corsi Block (repeating visual tapping sequences; VSSP; Milner, 1971), Listening Span (judging whether sentences are true, while remembering the last word of each sentence; CE_{PL}; Daneman & Carpenter, 1980) and Spatial Span task (judging whether letters are mirrored, while remembering the rotation of each letter; CE_{VSSP}; Shah & Miyake, 1996). Two tasks are needed for the CE, because a task for the CE always involves one of the two subsystems. By taking two tasks (one involving the PL, one involving the VSSP), the variance unique to the CE can be determined.

The learning phase and post-test phase are learner-paced. The total duration of one session is approximately 2 1/2 hours.

Results and Discussion

As the data gathering has been finished recently, the results will be presented at the conference.

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