# The role of attribution, modality, and supplantation in multimedia learning

**Joerg Zumbach, Birgit Reisenhofer, Stefan Czermak, Peter Emberger, Claudio Landerer and Gerhard Schrangl**

University of Salzburg

**Abstract** In this research, the influence of attributions, code, and modality of learning material is investigated. Within an experiment, we compared four versions of learning material about the eutrophication of a lake and its underlying processes. In one condition, the material was presented text only. Ina second condition, the text was illustrated by images representing core stages during the process of eutrophication. A third condition was a computer animation containing the same information as the text-based conditions while the changes of a lakes' state were visualised dynamically. Explanations were provided as text fields within the animation. A forth condition was also animation but all verbal information were presented by audio. Results showed no influence of media specific attribution regarding easiness/difficulty of text or animations. In addition, no evidence for occurrence of the modality effect was found. Both animation conditions led to increased learning outcomes. This effect is explained under aspects of supplantation.

## 1. Multimedia learning and a cognitive perspective

Research on multimedia learning is a spreading field within the area of cognitive and educational psychology. During the last decade, this research has mainly been influenced by cognitive science. Here, information processing theory from a memory perspective is a major theoretical approach for explaining benefits of mixed visual/textual or visual/auditive information. Based on the theory of working memory as suggested by Baddeley and colleagues (Baddeley, 1998; Baddeley & Logie, 1999), several subsequent theories propose approaches how to use these limited resources by using specific properties of human working memory.

A major theoretical framework here is provided by Cognitive Load Theory (e.g., Sweller, 1999; Sweller, van Merriënboer & Paas, 1998) suggesting that several different kinds of cognitive resources during information processing are required. First, Intrinsic Cognitive Load (ICL) that is mainly influenced by interactivity of elements that have to be processed simultaneously. Instructional design has to mainly to focus on learners' prior knowledge when presenting new information to learners in order to keep ICL within a limit that does not exceed learners working memory prerequisites. Second, Extraneous Cognitive Load (ECL) that is mainly affected by inadequate design of learning material, e.g., resulting in a split-attention effect or lost-in-information problems. Third, Germane Cognitive Load (GCL) that occupies working memory resources by activating prior knowledge an schemata in order to integrate new information.

Based on Cognitive Load Theory, several approaches to reduce ECL have evolved. Mayer and colleagues, for example, (cf. Mayer, 2005; Moreneo & Mayer, 1999) suggest using multi-modal information processing instead of a uni-modal information presentation. The Modality Effect (e.g., Mayer, 2005) states that by using auditive information in combination with images help to reduce cognitive load by adequately using working memory resources and to avoid split-attention. Empirical evidence for the modality effect is convincing (e.g., Clarebout & Elen, 2007) though it cannot be replicated in any case (Tabbers, Martens & van Merriënboer, 2004).

Another advantage of multimedia learning is assumed to be in dual-coding of combined image/verbal information that is complementary. A separate subsymbolic but also interactive processing of multi-code information is theoretically and empirically advantageous over mono-code information presentation (e.g., Schnotz, 2005).

Finally, multimedia might help to overcome problems of static media. Dynamic visualisations might help learners to build mental models by supporting inference drawing as describes by supplantation theory (Salomon, 1979). Thus, dynamic visualisation might lead to superior learning outcomes compared with static visualisations.

Empirical evidence for these selected phenomena is convincing, though almost only cognitive issues in media learning are addresses. Especially in media mediated learning, there is a body of evidence that beneath cognitive variables, analyses of motivational and attribution parameters can play a major role in understanding multimedia learning.

## 2. Learning with media and an attribution perspective

Attributions play a central role in our view on the world and understanding about its underlying mechanisms. Attribution theory (cf. Kelley, 1973) is essential in order to explain phenomena beyond cognition or interaction of cognition, emotion, and motivation.

Within the area of media-based learning, attribution processes have also to be shown to play a major role in processing information. A major contribution here is provided by the work of Gavriel Salomon and colleagues and their research on attribution in reading and watching television. Salomon (1984; Cohen & Salomon, 1979; Salomon & Leigh, 1984) examined how children's prior expectations about the ease of learning with text or televisions interacts with the amount of invested mental effort during learning with print or television and objective learning outcomes. Results suggest that television is assumed to be easier in learning than text. In fact, learning with print led to better learning outcomes than watching a television film containing the same information (see also Beentjes, 1989). Children also invested more mental effort in processing the print material than the television film. This difference in attribution seems to be a result of an enculturation process as demonstrated by Bordeaux and Lange (1991).

When media like printed texts and televisions are exposed to specific attributions, an attribution effect related to animation-based learning could also be expected. Here, more research is needed in order to examine possible attribution-media interaction effects.

## 3. Learning with text, pictures and multimodal information: the influence of attributions

In this research, we examine the influence of attributions toward media in different conditions and relate them to recent cognitive theories in processing the same information represented in different kinds of codes and modality. We expect attribution towards the kind of representation to play a central role in investment of mental effort and, thus, in activation of Germane Cognitive Load. Therefore, we developed four learning scenarios dealing all abut the same content (about the influence of nitrate entry into a lake over several years and its influence on the lake's properties as an ecosystem). We expected text-based learning material to be estimated as more difficult than learning from computer-based animations. On the other hand, more invested mental effort has to be expected here. Related to learning outcomes we assume text based learning with text and pictures to be superior to unimodal animation-based learning. In expectance of occurrence of a modality effect, we expect a picture/voice-based animation to lead to the best learning performance. All these three representations should be advantageous over a text-only condition. But in general, we expect these effects to be mainly determined by media specific attributions.

## 4. Method

### *4.1 Participants and variables*

Overall, 86 participants took part in this study. Mean age was 19.85 (SD = 5.58). 17 were male, 69 female. Half of participants were students at the University of Salzburg, the other half were students at a high school in Salzburg.

In order to measure the individual learning success a knowledge pre- and post-test was conducted. It included an 18-item multiple-choice test and two open end tasks in order to measure learner's knowledge and understanding for the subject "eutrophication of lakes".

For assessing media-specific attribution we used a questionnaire adapted from Salomon (1984). We measured the perception of realism attributed to each media and the casual attributions for failure/success to different media.

Cognitive-load was assessed by using the NASA-TLX- questionnaire (Hart & Staveland, 1988) and motivation by using the QCM (Rheinberg, Vollmeyer & Burns, 2001). With exception of the attribution scale (pre test only) and the NASA-TLX (post test only) all measures were applied in pre and post test.

### *4.2 Material and Proedure*

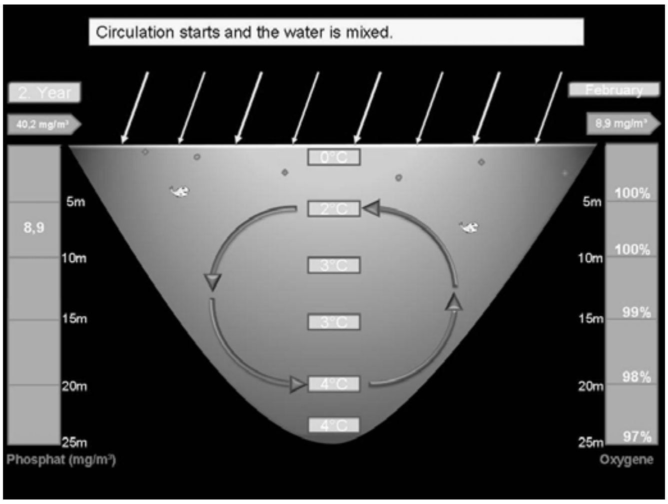
The learning material was about the process of eutrophication of lakes. The seasonal circle for five years with different parameters and their development over the time were presented. Four different version of the same content have been developed: a text only version, a text version with images from an animation, an animation with spoken text, and an animation with written text fields. All versions had the same content, though it was presented in different codes or modalities (see Fig. 1).

At the beginning, participants were informed about the procedure of the experiment. Then the pre test was applied. After the pre test, participants were randomly assigned to one of the four conditions. The treatment time was constant with 20 minutes. Afterwards, the post-test was applied. Overall, participation took about 50 minutes. No reward was given for participation.

### *4.3 Hypotheses*

It was assumed that the text conditions lead to higher learning outcomes than the animation condition with written text based on Salomon's findings. A comparable result was expected within the narrated animation condition due to expected occurrence of a modality effect. The animation with audio should lead here to higher learning outcomes than the animation condition with text. In addition, we expected differences in attributions. Learning with the print material should be estimated as much more difficult than learning with computer-based animations. Thus, a corresponding effect within cognitive load should result.

**Fig. 1.** Sample screen from the learning material (animation with written text).




## 5. Results

An ANCOVA comparing learning outcomes with pre test performance in the knowledge test as covariate and post test performance in the knowledge test as dependant revealed a significant influence of the covariate ($F (1, 81) = 8.27$, $p < 0.01$; eta squared = 0.09) and a one-sided significant effect of the treatment conditions ($F (3, 81) = 2.27$, $p < 0.05$; eta squared = 0.08). A LSD test revealed significant differences between "text & pictures" and both animation conditions. All other conditions did not differ significantly though a separate ANCOVA comparing both text conditions with both animation conditions revealed a significant main effect with the animations leading to increased learning performance (see Fig. 1). There was no evidence for occurrence of the modality effect.

An analysis regarding the media specific attribution of easiness or difficulty revealed no significant influence on knowledge test performance. There were also no significant differences between all experimental groups regarding motivational aspects as measured with the QCM. Also groups did not differ in perceived cognitive load assessed with the NASA-TLX questionnaire (see Fig. 2).

The lowest mental effort and perceived cognitive load is here in the condition text with images. Overall, cognitive load as reported by participants is emphasized a mediocre (minimum 1 and maximum 5).

**Fig. 1.** Means in Knowledge post test.

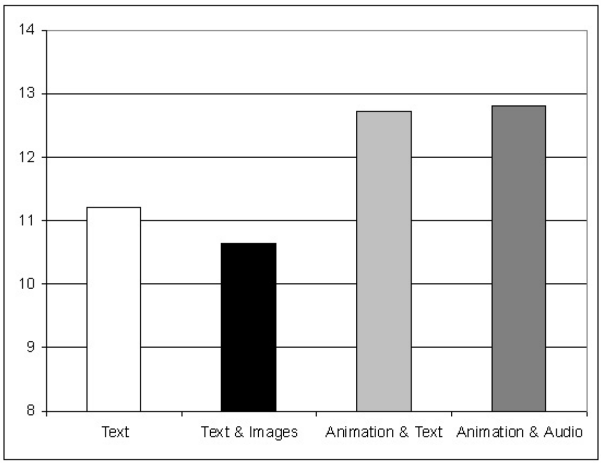
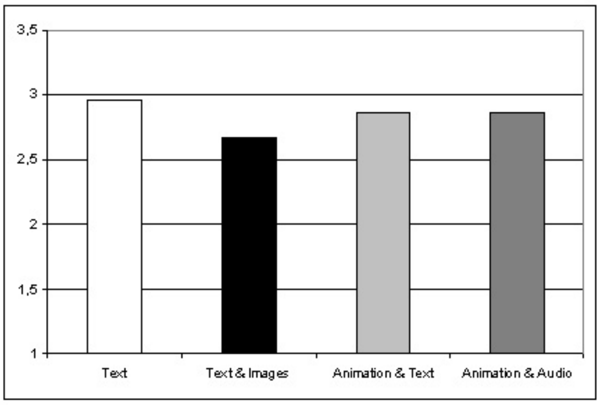



**Fig. 2.** Results in Cognitive Load.



## 6. Discussion

Attributions play a central role in our everyday construction of the world. As basic research provided by Salomon and colleagues (Salomon, 1984, Salomon & Leigh, 1984) has shown, also cognitive processes in interaction with learning material are affected by attribution processes. In this study, the role of attributions within text- and animation-based learning was examined. Though we expected an interaction of attribution on learning with specific media, we could not find this effect in this sample. As there is evidence from research that learning with text is estimated as "difficult" we expected that learning with animations is assumed to be "easy". Consequently, higher mental effort should be invested by learners into learning with text and lower mental effort in learning with animations. As there was no unambiguous pattern of media specific attributions within this sample, this effect could not be shown. Nevertheless, results in cognitive load self-report undermine the results of learning outcomes: the higher the invested mental effort, the better are the learning outcomes.

Another effect that should have been replicated was the modality effect. A basic explanation for its non-occurrence could be that it is restricted to more simple and timely reduced settings. Here, the animation lasted about 15 minutes within a complex domain. Thus, it is probable that other memory effects occur that cannot by explained by the working memory model provided by Baddeley (1998).

A rather interesting results of this study is, that both animation conditions led to superior learning outcomes compared to the text-conditions. A basic explanation for this phenomenon is also provided by the work of Salomon (1979). By using a rather dynamic that a static visualization of the eutrophication of a lake, the medium itself might have supported cognitive processed of drawing inferences. Thus, it has supplanted the building of a mental model in a more appropriate manner than the static text-based condition.

Overall, it seems to be a worthy strategy to foster not only on cognitive process within in the area of multimedia learning but rather to include motivational and emotional parameters. In addition, it seems to be necessary to examine consistent findings from the area of a cognitive theory of multimedia under ecological valid circumstances. As some authors also failed to reproduce the modality effect (e.g., Tabbers et al., 2004) it might be possible that in long-term use of image-audio-combination more instances than working memory are involved and, thus, underlying basic principles of cognitive information processing are limited in their validity.

## References

Baddeley, A. D. (1998). Human memory: Theory and practice. Boston: Allyn and Bacon.

Baddeley, A. D., & Logie, R. H. (1999). Working memory: The multiple-component model. In A. Miyake & P. Shah (Eds.). Models of working memory: Mechanisms of active maintenance and executive control (pp. 28-61). New York: Cambridge University Press.

Beentjes, J.W.J. (1989). Learning from Television and Books: A Dutch Replication Study Based on Salomon's Model. Educational Technology Research and Development, 37(2), 47-58.

Bordeaux, B. R. & Lange, G. (1991). Children's reported investment of mental effort when viewing television. Communication Research, 18(5), 617-635.

Clarebout, C. & Elen, J. (2007). In Search of Pedagogical Agents' Modality and Dialogue Effects in Open Learning Environments. e-Journal of Instructional Science and Technology, 10 (1). Online-Journal: http://www.usq.edu.au/e-JIST/

Cohen, A.A. & Salomon, G. (1979). Children‘s literate television viewing: Surprises and possible explanations. Journal of Communication, 29, 156-163.

Hart, S. G., & Staveland, L. E. (1988). Development of a multi-dimensional workload rating scale: Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), Human mental workload (pp. 139-183). Amsterdam, The Netherlands: Elsevier.

Kelley, H. H. (1973). The processes of causal attribution. American Psychologist, 28, 107-128.

Mayer, R. E. (2005). Cognitive Theory of Multimedia Learning. In R. E. Mayer (ed.), The Cambridge Handbook of Multimedia Learning (pp. 31-48). Cambridge: University Press.

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. Journal of Educational Psychology, 91(2), 358–368.

Rheinberg, F., Vollmeyer, R., & Burns, B. (2001). QCM a questionnaire to assess current motivation in learning situations. Diagnostica, 47, 57–66.

Salomon, G. (1984). Television is "easy" and print is "tough": The differential investment of mental effort in learning as a function of perceptions and attribution. Journal of Educational Psychology, 76(4), 647-658.

Salomon, G. (1979). Interaction of media, cognition and learning. San Francisco, CA: Jossey-Bass.

Salomon, G., & Leigh, T. (1984). Predispositions about learning from print and television. Journal of Communication, 32, 119-135.

Schnotz, W. (2005). An integrated Model of text and picture comprehension. In R. E. Mayer (ed.), The Cambridge Handbook of Multimedia Learning (pp. 49-69). Cambridge: University Press.

Sweller, J. (1999). Instructional design in technical areas. Camberwell: ACER Press.

Sweller, J., van Merriënboer, J. J. G., & Paas, F. W. C. (1998). Cognitive architecture and instructional design. Educational Psychology Review, 10, 251-296.

Tabbers, H. K., Martens, R. L., & van Merriënboer, J. J. (2004). Multimedia instructions and cognitive load theory: Effects of modality and cueing. British Journal of Educational Psychology, 74, 71-81.