

Investigating Means to Reduce Cognitive Load from Animations: Applying Differentiated Measures of Knowledge Representation

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Abstract

This paper covers an experiment designed to investigate the relationship between the didactical setting and learning effects with animations. We investigated whether the cognitive load imposed by animations could be reduced when the students could control the flow of the animation. We did not find an effect due to the fact that the students did not actively use this feature to take more control of the presentation. Further, by applying differentiated knowledge measures, we investigated if the characteristics of the acquired knowledge were related to the characteristics of the multimedia presentation. We found that media do not influence knowledge acquisition homogeneously. The multimedia effects found in this study are in line with known principles of didactical multimedia design. This study sheds light on some theoretical aspects involved in the complex interaction between learning content, presentation, learning, and resulting knowledge. (Keywords: animation, cognitive load, knowledge categories, learning content, learning performance.)

INTRODUCTION

The experiment reported in this paper was motivated by open questions regarding learning effects of animations: Why or when (i.e., in which didactical settings) do animations work and what is the reason for them not to work? This study is a follow-up of our former studies designed to test the following driving assumption (Guttormsen Schär & Zuberbühler, 2005; Guttormsen Schär & Kaiser, 2006; Guttormsen Schär, 2006): *Animations support learning better when students can reduce the cognitive load caused by the continuous information flow by having the full control of the information flow themselves.* Hence, first we shall take a closer look at cognitive load.

Cognitive Load (CL)

CL is related to human information processing capacity. The working memory can actively process only a limited number of elements (Baddeley, 1994). This limitation is a bottleneck for information processing in general and for learning in particular. Cognitive overload results as soon as the information processing capability exceeds this limit. Various cognitive strategies aim at extending the processing capacity. Multiple information elements can be coded into larger singular elements (i.e., schemata), which are categorized according to the manner in which they will be used. Once a schema has been acquired, it can undergo a process of automation. Schema automation allows those schemas to be processed unconsciously, with consequent working memory implications. The long-term memory can hold large numbers of automated schemata, and as

such they influence performance once material has been properly learned (Pollock, Chandler, & Sweller, 2002; Sweller, 1999).

Three types of CL can be identified: external, intrinsic and germane (Kirschner, 2002; van Merriënboer et al., 2002). External CL refers to the learning environment and the way the information is presented. Intrinsic CL refers to characteristics of the learning task and the effort it imposes on the learner to construct adequate schemata. Germane CL is related to processes that contribute to the construction and automation of schemas. Our study concentrates on external CL (Paas et al., 2003; Pollock, Chandler, & Sweller, 2002).

One origin of external CL is information redundancy. One view builds on the assumption that redundant information corresponds with equally more learning, as long as the information presented is consistent and relevant (review in Large, 1996). This view is called the information delivery view, and is problematic (Mayer, 2001; Mayer & Moreno, 2002). Split attention, which also is an effect of information redundancy, induces learners to share their attention between two sources of information (e.g., Sweller, 1999). Another source of external CL is information channel overload, which is explained theoretically in the Dual Coding Theory (DCT) (Paivio, 1986; Mayer, 2001). According to DCT split attention on one processing channel is detrimental for learning. Consequently, multimedia presenting dually coded information to one processing channel (e.g. 'picture + text' to the visual channel or spoken text and written text to the verbal channel) would imply a channel overload.

External CL is a more predominant issue with dynamic media than with static media. A general explanation for external CL with animations is that students cannot process the information in the same speed as it is being presented. Rieber's research represents early contributions to specific suggestions for how to reduce CL from animations. He found that animated presentations better supported learning when the information was presented in smaller information chunks with a pause between each chunk (Rieber, 1991a, 1991b). Our experiment investigated the assumption that individual control over the animated information flow has the same didactical effect as information chunking as found by Rieber (1991b). The rationale is that when students control the information flow, they can chunk the information in a meaningful way, according to their own processing pace. Further, self-management does not intrude in the learning process, as compared to active guidance or instructions. Extensive guidance can increase the germane CL with negative effects for the learning outcome, particularly for complex learning tasks (van Merriënboer, Kester, & Paas, 2006).

Static—Dynamic Assumption

This study also aimed at testing an assumption addressing the relationship between learning content and multimedia presentation: *Dynamic visualisations most optimally represent dynamic learning content (e.g., processes), while static visualisations most optimally represent static information content (e.g., facts)*. This assumption is not thoroughly theoretically grounded but rather derived from studies indicating a possible relationship between characteristics of the learning

content, presentation form, and resulting knowledge (e.g., Large, 1996; Park & Hopkins, 1993; Rieber, 1989; Rieber et al., 1990; Rieber, 1990a; Rieber, 1990b; Rieber & Kini, 1991). Also newer studies confirm that the distinction between static and dynamic content is a relevant issue (Salden, Paas, & van Merriënboer, 2006). The rationale behind this assumption is as follows: The conceptual link between animated presentations and learning content has been lacking in many studies. It is possible that many studies failing in finding the expected benefit of animations, failed because the animated presentation was not representing the learning material appropriately. This may have directed the attention away from the key elements, or the animations were not necessary to learn (Rieber, 1990b; Kinzer et al., 1989; Pane et al. 1996). A formal analysis of learning content has received little attention in the multimedia literature. There is an inherent problem with this, because many studies suggest that there is a close relationship between characteristics of the learning content and the effect of animated presentations. The analysis of learning content has been given more attention in the computer supported instructional design domain (Guttormsen Schär, 2006). The work of David Merrill and his taxonomy of learning content described as different categories is well accepted and often applied to e-learning (Merrill, 1983, 2001). Merrill's work builds on the work of Gagné, who was among the first to define instructional events, related mental processes and correlating didactical means (Gagné, 1985).

Learning content analysis should be a part of good multimedia design. It is the act of describing the nature of the learning content before deciding which medium and didactical context can represent the information optimally (e.g., ISO 14915-3, 2002; Alty, 1993, Rieber, 1990a). Applied to animations, we infer that positive effects of animations depend on whether they reflect dynamic qualities of the learning content. Animations can support the building of a mental representation when they serve as a meaningful visual analogy. This is particularly the case in three situations (Large 1996; Park & Hopkins, 1993), i.e. when visualising:

1. motion or trajectory
2. temporal aspects, e.g., a concept or rule over time, or a relation between time and space
3. concealed information (partly or complete), e.g. a dynamic process that is difficult for learners to imagine on their own, for the explicit representation of highly abstract and dynamic concepts and processes in science, or explicitly representations of invisible flow of information (e.g., current in electronic systems).

Rieber investigated the effect of animated presentations on incidental and intentional learning, in a way applying to our static-dynamic assumption (Rieber, 1990a, 1990b). Incidental learning referred to the kind of information that implicitly is embedded in dynamic presentations (i.e., implicit dynamic information about the relationship between the dynamic learning content); intentional learning referred to knowledge that the students were instructed to try to learn. Rieber found that dynamic knowledge content was better learned with dynamic presentations. This study aimed at further investigating those findings.

Testing Relationships Between Media, Learning Content and Knowledge

Our former studies showed that the effect of (multi-) media presentations on learning depended on the kind of knowledge tested (Guttormsen Schär & Kaiser, 2006; Guttormsen Schär & Zuberbühler, 2005). Also in this study, we aimed at testing learning performance with elaborated knowledge measures. We defined three knowledge categories: static/dynamic (process or facts knowledge), modality (verbal or visual knowledge), and quality (passive or active knowledge). These three categories are described below:

A distinction between *static/dynamic* knowledge is related to characteristics of the learning content. A basically dynamic learning topic (e.g., a process) contains both dynamic and static aspects. Hence, to test the effect of media on learning fully, the learning outcome must be tested with measures reflecting both static and dynamic knowledge characteristics. A distinction between static and dynamic information has been suggested from various sides (Guttormsen Schär & Zuberbühler, 2005; Paechter, 1996; Rieber, 1991a, 1991b; ISO 14915-3, 2002). A classical definition categorizes *static learning content* as facts or concepts (Merrill, 1983). In this experiment we particularly tested knowledge of facts, which refer to objects, events or symbols, for example: the value of π (pi) is 3.1415926. Facts may describe quantitative features of an object/a thing or an individual, or refer to steps or phases of a process. Facts may also be the name of a person, date, name or specification of objects. Static learning content remains stable in a relative time span, for example descriptions (of a painting), concepts (e.g., the definition of 'standard-deviation' in statistics is stable and does not change over time) (CISCO, 1999; Guttormsen Schär, Messerli, & Schluep, 2004; Merrill, 1983). *Dynamic learning content* refers to how something interacts. Dynamic learning content is well exemplified by processes: A process is a description of a flow of events, may it be of scientific, organizational or mechanical characteristics. It is a (complex) flow of interdependent causalities (Cisco, 1999; Merrill 1983). A process is not necessarily linear, and it is different from a procedure, which describes how a certain task should be executed.

The distinction between *verbal and visual knowledge* is derived from the dual-coding theory, which postulates that the processing of visual and verbal information proceeds in two independent and parallel channels (Guttormsen Schär, 2006; Mayer, 2001; Paivio, 1986). The dual coding theory also postulates that verbal and visual information are stored according to verbal and visual characteristics (Engelkamp, 1991). Therefore, it is theoretically sound to assume that the processing and later retrieval of either verbal or visual knowledge may be influenced by the media presentation.

The distinction between *active and passive knowledge* is heuristic and refers to a difference between active and passive ways of knowing (e.g., Tang & Gero, 2001). This distinction is commonly applied to language knowledge. Active language knowledge is used when producing speech (i.e., talking). It is generally expected that passive language knowledge is broader and based on recognition rather than active production. Active knowledge has similarities with explicit knowledge, and passive with implicit, intuitive knowledge (Berry & Dienes, 1993; Hayes & Broadbent, 1988). This knowledge category refers to a differ-

ence in quality of the two forms. The inclusion of passive and active knowledge measures in this study is explorative, and not related to hypothesis testing.

METHOD

We compared three different multimedia settings: 'animation + voice', 'picture + voice', and 'picture + text'. Due to consistent empirical findings in former research, showing the negative effect of mono-media and triple media combinations, those media settings were not included in this study. The 'picture + text' setting was implemented as control, it is expectedly inferior to the 'picture + voice' setting because of high CL on the visual channel. All the multimedia settings were implemented with individual flow control (stop & play). The expected relationships between the settings and knowledge forms are formulated in the following operational hypotheses:

- H1: The 'animation + voice' setting results in better learning performance than the 'picture + voice' and 'picture + text' settings.
- H2: The learning effect of the 'animation + voice' setting correlates positively with flow control activities.
- H3: The 'animation + voice' setting results in better *process knowledge* than the 'picture + voice' and 'picture + text' settings.
- H4: The 'picture + voice' setting results in better *facts knowledge* (i.e. static) than 'animation + voice' and 'picture + text' settings.
- H5: The 'animation + voice' and 'picture + voice' settings result in better *visual knowledge* than the 'picture + text' setting.

Tasks

The human immunology process represented the dynamic learning content, which was implemented on a level enabling also novice students to understand it. This process was shown and described from the point when a virus enters the body, through the multiplication of a virus and the defence reactions from the immune system by the T-cells, B-cells and the associated signal substances and proteins.

The *knowledge tasks* were implemented as different interactive computerised tests addressing the knowledge categories (i.e., facts and process knowledge verbal/visual, passive/active). The various test tasks are described below.

Design and Variables

A 3x8 mixed design was applied with the factors *media* as a between-group factor and *knowledge tasks* as a within-group factor. The media-factors were 'animation + voice' (AV), 'picture + voice' (PV) and 'picture + text' (PT). The within-group factor *knowledge tasks* had eight test items covering the three different knowledge categories: static/dynamic, knowledge modality, and knowledge quality. Four test questions were designed to each of the static and dynamic knowledge categories, resulting in eight different test tasks as shown in Table 1. The knowledge categories were operationally defined as follows:

- Static knowledge was defined as knowledge of facts aspects of the human immunology process.

Table 1: Distribution of the Knowledge Categories and Tests

Knowledge categories		# Knowledge test	
Facts knowledge	Visual	Passive	Q1: Visual MC: Select the correct picture among six pictures where only one represents a correct answer. Scores: correct or wrong
		Active	Q2: Structures of a blood cell responsible for an immune reaction should be selected out of a sample of various relevant and irrelevant structures. The selected elements were dragged and dropped in to a picture of a cell. Scores: 0—6 points
	Verbal	Passive	Q3: Verbal MC: Select one correct verbal utterance from six fact items. Scores: correct or wrong
		Active	Q4: Six verbal expressions about cell structure functions should be correctly combined with six cell structures. Scores: 0—6 points
Process knowledge	Visual	Passive	Q5: Visual MC: Select correct pictures from a selection of several process related images. Scores: 0—6 points
		Active	Q6: Sort pieces of a puzzle in the correct sequence. The pieces of the puzzle were pictures representing key events of the process. Scores: correct or wrong
	Verbal	Passive	Q7: Verbal MC: Select one correct verbal utterance on process issues from six items. Scores: correct or wrong
		Active	Q8: Open question: Write the answer to a process issue. Scores: 0—6 points

- Dynamic knowledge was defined as knowledge of the sequences of the human immunology process.
- Visual knowledge was defined as knowledge about visual cues related to either process or facts issues.
- Verbal knowledge was defined as the ability to verbally express either process or facts issues correctly.
- Passive knowledge was defined as the ability to *recognise and identify* specific information among other test items related to either facts or process issues.
- Active knowledge was defined as the ability to actively *reconstruct* knowledge related to either facts or process issues.

Pre-experimental knowledge was tested with four multiple-choice questions addressing the same topic as the learning task. Each question had 6 alternatives from which only one was correct. After the knowledge tests, the participants were asked to indicate their preference for the presented media combination on a five-point scale. The controls for third variables were age, gender, education, computer experience, colour vision and pre-experimental task knowledge. Table 2 (page 70) shows an overview of the experimental variables.

Table 2: Overview of the Experimental Variables

Independents		Dependents
<i>Media (between group):</i>	<i>Test tasks (within group):</i>	Fact-, Process-, Visual-,
Animation + Voice (AV)	8 tasks related to the	Verbal-, Active, Passive-
Picture + Voice (PV)	human immunology	knowledge,
Picture + Text (PT)	process	Media Preference

Control variables

Age, Gender, Colour-vision (subjective reports), Education (also including study direction for the students), Computer experience (five point scale), Pre-experimental task knowledge (multiple choice test)

Participants

Thirty-six adult, paid males (n=20) and females (n=16) between 20 and 35 years in age participated in the experiment. The participants had various educational backgrounds, but the majority were students. Students from life sciences with knowledge that could interfere with the experimental learning topic were excluded from the sample.

Procedure

The participants were first introduced to the experiment and generally told that we were investigating multimedia learning. The learning and test settings were fully computerised, i.e., all information to the participants was shown on the screen. Before they started to learn, demographic data and pre-experimental knowledge were recorded. When the participants were ready they proceeded to the learning session. The introduction to the learning task was displayed as the first screen of the learning part, and the participants decided when they wanted to start to learn. The learning time was set to 15 minutes. During the learning time the participants could navigate back and forward in the information. After time-out the knowledge tests started, it was not possible to return to the learning session. The knowledge tests had no time limit, and the test tasks appeared in random order. It was also not possible to go back and correct a former knowledge task. Finally, the participants answered a preference question related to the media combination they had used. The experiment lasted between 25 and 45 minutes.

Production

The tasks were implemented in an experimental setting programmed with Macromedia Flash. The animation was produced from CAD generated 3D colour drawings and was visually appealing. It exclusively showed elements relevant for the learning task.

Three different variations of the experimental program were implemented, according to the three media settings. The animation was first produced and implemented with flow control including start/stop-buttons, progress feedback and the possibility to repeat sections. The information about the immunology process was thoroughly edited into a manuscript, recorded as voice, and synchronised with the flow of the 'Animation + Voice' version. Nine pictures

were selected and exported from the Flash animation for the picture versions. The pictures represented key-points of the learning content. These pictures were integrated in a new Flash film and combined with either text or voice. The recorded voice was matched to the pictures in the 'Picture + Voice' version. In the 'Picture + Text' version the text represented exactly the same information as in the voice versions. The text to each picture was positioned to the right of the pictures. The flow control for the picture versions included next/previous instead of start/stop buttons.

The films and the knowledge tests were programmed for random order presentation and implemented as separate Flash movies to enable a dynamic flow of the experimental program. All movies were at last combined in a main Flash movie, which loaded the child movies dynamically. All click-able elements of the three settings were implemented with scripts, which logged the actions. Also the answers to the knowledge tests were automatically registered and logged.

RESULTS

Most of the following statistical tests were performed with normalised values of the variables. This was necessary to get comparable values for parametric and non-parametric data.

Effects of media

The mean values from the knowledge test and the main effects are shown in Table 3 (page 72). As the table shows, both the multimedia settings AV and PV resulted in better learning performance than PT. There were no significant differences between the groups for media preference.

Effects of knowledge categories

The means and main effects of the knowledge categories are shown in Table 4 (page 72).

Interaction effects

The analysis of variance revealed some interaction effects between media and knowledge categories. The interaction effects are shown in Table 5 (page 72).

Navigation Activity

There was no correlation between the navigation activities in the AV setting and the knowledge tests (Spearman's Rank Korrelation, $r=0.464$). This was calculated by a correlation analysis between use of the navigation elements (stop, start, spooling) and re-coded mean results of the knowledge tests. The mean number of navigation activities for the AV group was 8.54, 34.11 for PV and 34.92 for PT.

Effects of third variables

There were no effects of gender, age, computer-experience, and colour vision for the dependent variables. We found a relation between education level- and process- and active knowledge (linear regression, $p=0.042$ and $p=0.016$, respectively), and pre-experimental knowledge and process-, passive-, active- and visual knowledge ($p=0.011$, 0.021 , 0.014 and 0.043 respectively).

DISCUSSION

The animated presentation did not result in a better learning performance than when the visual information was presented statically. This is evident from both the main effect of media and the interaction effects. Hence, Hypothesis

Table 3: Mean Scores and Main Effects of Media

Media	Mean	St. dev.	Main effects	Chi ² /Z	p
Picture + Text (PT)	1.50	1.39	AV > PT	-2.85 *	0.004
Picture + Voice (PV)	2.18	1.64	PV > PT	-2.90*	0.004
Animation + Voice (AV)	2.15	1.61			

Mann-Whitney

Table 4: Means Scores and Main Effects of Knowledge Categories

Knowledge	Mean	St. Deviation	Main effects	t	p
Process	8.41	2.74	Process > Facts	2.94	0.006
Structure	7.28	2.59			
Passive	5.84	2.67	Active > Passive	7.12	0.000
Active	9.85	3.17			
Visual	9.06	3.13	Visual > Verbal	3.90	0.000
Verbal	6.63	2.96			

Table 5: Interaction Effects Between Knowledge and Media

Knowledge	Media	Mean	St.-d.	Order	Chi ²	p
Process	PT	7.07	2.67	No effect	-	-
	PV	9.27	1.80			
	AV	8.76	3.23			
Fact	PT	4.93	2.85	AV > PT	8.590	0.003
	PV	8.21	1.59	PV > PT	8.923	0.003
	AV	8.42	1.77			
Passive	PT	4.91	2.72	No effect	-	-
	PV	5.67	1.55			
	AV	6.80	3.26			
Active	PT	7.09	3.03	AV > PT	6.063	0.014
	PV	11.81	1.82	PV > PT	11.88	0.001
	AV	10.38	2.75			
Visual	PT	6.79	3.16	AV > PT	5.258	0.022
	PV	9.94	1.86	PV > PT	4.781	0.029
	AV	10.18	3.19			
Verbal	PT	5.21	3.41	No effect	-	-
	PV	7.54	1.76			
	AV	7.00	3.18			

1 was not supported. The results of this experiment replicated the media effects from our last study (Guttormsen Schär & Zuberbühler, 2005). What this experiment showed is a modality effect, that is, a combination of spoken verbal and visual information is better than the combination of visual text and pictures. This is in line with the dual coding theory (information channel overload) and the modality principle as described by Mayer (Mayer, 2001; Paivio, 1986).

The experiment was designed to test the effect of animated presentations when the students were given full control of the information flow. We investigated whether individual control over the information flow would reduce the CL resulting from the animation. The flow control, as implemented in our experiment, was a variation of Rieber's design, where an animation effect was found by implementing forced pauses in the animation flow (Rieber, 1991b). We did not find a positive correlation between the use of the flow control and the learning performance in the AV setting, which principally leads to the rejection of Hypothesis 2. The participants, however, rarely used the opportunity to control the information flow in the AV setting (the average use was only eight control actions). Rather, the participants tended to repeat the full animation sequence. This makes it questionable if the correlation analysis is valid for evaluating Hypothesis 2 at all. A direct comparison with the use of the navigation in the PV and PT settings is not possible because those groups *had to* navigate to access the next information part. In any case, only nine interactions would have been necessary in the PV and PT settings (one click to move forward to each of the nine pictures), but both groups navigated an average 34 times! Consequently, the frequent navigations in the PV and the PT settings could be responsible for the missing animation effect, as it suggests that the PV group learned more actively than the AV group. This also shows that it may be suboptimal to give the control of the information chunking in the AV setting to the learners. As long as the students do not make use of this possibility, the information should be divided into distinct sequences according to the natural structure of the information content as suggested by Rieber (1991b).

The PV and PT groups actively engaged in building up a mental model of the information and they were verifying this model by navigating back and forward in the pictures. This is in line with Salomon (1984), who suggested that optimal learning is related to the invested mental effort to learn. Support for the idea that invested mental effort supports learning is also found in several studies related to implicit and explicit learning in a computerised setting. We found that computer user-interfaces implying high mental effort (e.g., command-based interaction) in a learning situation resulted in better learning performance than when learning with interfaces implying lower mental effort (e.g., direct manipulation) (Guttormsen Schär, 1996, Guttormsen Schär, et al. 1997). We, therefore, suggest also focusing further animation research on the issue of invested mental effort, as it seems like animated presentations induce students to a passive learning mode.

Obviously, it was possible to learn with less effort in the AV setting. This finding can be related to Rieber's studies, where he found that animations support learning in less time (1991a, 1991b). Consequently, animations seem to sup-

port knowledge acquisition in another way than static pictures. The dynamic characteristics of the animation correspond to implicit dynamic information (i.e., about the critical relationships); this dimension of information is missing in static presentations. The participants in the PV group needed to develop a representation of the dynamic aspects of the learning actively.

Hypotheses 3 and 4 address two possible relationships between media and resulting knowledge. Both Hypotheses refer to the assumption postulating a relation between media and knowledge representation. Hypothesis 3 was rejected, because there was no effect of media for process knowledge at all. Hypothesis 4 was also rejected because both the settings AV and PV resulted in better facts knowledge than the PT setting. Hence, as our results generally support a modality effect, and no animation effect, the settings for evaluating the static-dynamic assumption was not given in this experiment. A relation between media presentation and knowledge representation is, however, still plausible. We suggest continuing the exploration of our assumption in further studies.

Hypothesis 5 was supported. Media combinations *without* double load on one modality (i.e., visual & auditory combinations) resulted in better visual knowledge than when the visual channel was occupied with the processing of two visual information sources (i.e., text and picture). Hence, our results support the expected negative effect of information channel overload. This result also replicates our former studies, which showed that double load on the visual channel is detrimental for learning (Guttormsen Schär & Kaiser, 2006; Guttormsen Schär & Zuberbühler, 2005).

The interaction effects show that the effect of media was not homogeneous for all the knowledge categories. The measures for fact-, active- and visual-knowledge reflect the media effect as described above. There was, however, no effect of media for the other knowledge measures (i.e., process-, passive- and verbal knowledge). This missing media effect for process knowledge may reflect that the process content was salient enough to be learned in any of the media settings. The main effect of process knowledge supports this assumption.

The main effects of the knowledge modality (verbal / visual) and quality (active / passive) are difficult to interpret at this stage. The better visual knowledge may be related to a picture superior effect, that is, the visual knowledge was dually coded (verbal and visual) and therefore more deeply understood and easier retrievable. The “Picture superiority effect” is a phenomenon derived from the dual coding theory (Paivio, 1986, Nelson, Reed & Walling, 1976). It can be speculated that the active test tasks supported the students to better retrieve their knowledge than with the passive test tasks. Further interpretations at this stage would however be tentative.

We did not find effects of third variables that influenced the experimental outcome of this study. The randomisation resulted in a homogenous distribution of the participants to the groups. The found effects are congruent with expectations: The effects of higher pre-experimental knowledge showed that people with a relevant knowledge base generally have advantages when learning. We also found a somewhat weaker positive effect of education level, which also is in accordance with expectation.

CONCLUSIONS

This study pursued two main research questions: First, how to reduce external CL when learning with animations, and second, whether animated presentations are generally more suitable when learning dynamic learning content. The results continue to suggest that animations induce high extraneous CL, which hinders a possible didactical benefit compared to static pictures. It continues to be a challenge to measure the interaction between external and germane CL (Paas et al., 2003). We suggested that external CL would be reduced when students control the information flow themselves. This study has not fully been able to test that assumption. The main reason is that the students do not seem to make use of the opportunity to reduce the CL in that way. *We therefore suggest presenting animations with distinct logical chunks, separated by a small pause, to help students in building a mental representation of the information.*

Our findings suggest two other conclusions: First, animations seem to have a pacifying effect on students. Static visual presentations encourage the students more to engage in active learning than the dynamic presentations. Second, animations convey implicit information about dynamic information content. Obviously students are able to perceive and retrieve this information without actively engagement with the animation. It is plausible that the missing animation effect, in this and in many other studies, may be caused by an interaction between these two effects. Passive learning and implicit dynamic information give learners the impression that they have understood and learned, although this knowledge could be better consolidated. This may block the students in carrying out learning activities that would lead to deeper understanding. *We, therefore, suggest focusing further animation research also on the process of how people build mental representations from dynamic visual presentations.*

This study has not been able to show a relationship between static and dynamic media as supporting knowledge representations of static and dynamic learning content respectively. If such relations exist—they can first only be tested when an animation effect can be consistently established, and second this relationship seems rather to be under control by complex interactions of several factors.

In general, our results support that multimedia learning should be investigated with differentiated knowledge measures. The relation between media, learning content characteristics and knowledge representation should be further investigated. Obviously there is a relation between media presentation and the resulting knowledge. *Learning content characteristics should be given more weight in this kind of research. A differentiated knowledge concept also reflecting characteristics of the learning content, particularly in a research context, ensures that too general conclusions are drawn about the effects of media on learning performance.*

Another relevant factor to include in further research is learners' spatial ability. This is a factor that has been found to interact with characteristics of the learning content as well as with the individual information processing of information presented with various media, as well as general learning ability (e.g. Mayer, 2005).

Contributors

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REFERENCES

- Alty, J. L. (1993). Multimedia: We have the technology but do we have the methodology? In H. Maurer (Ed.), *Proceedings of EUROMEDIA '93* (pp. 3–10). Orlando, FL: AACE.
- Baddeley, A. D. (1994). The magical number seven: Still magic after all these years? *Psychological Review*, 101, 353–356.
- Berry, D. C., & Dienes, Z. (1993). *Implicit learning: Theoretical and empirical issues*. Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.
- CISCO (1999), *RIO strategy v3.0 June 25, 1999*, Cisco Systems, Inc. Retrieved January 14, 2003, from http://www.cisco.com/warp/public/779/ibs/solutions/learning/whitepapers/el_cisco_rio.pdf
- Engelkamp, J. (1991). *Das menschliche Gedächtnis* (2. Auflage ed.). Göttingen: Verlag für Psychologie.
- Gagnè, R. M. (1985). *The conditions of learning and theory of instruction* (4th ed.). New York: Holt, Rinehart & Winston.
- Guttormsen Schär, S. (1996). The influence of the user interface on solving well- and ill-defined problems. *International Journal of Human Computer Studies*, 44, 1–18.
- Guttormsen Schär, S. (2006). *Multimedia didactics. Studies on the learning effects of dynamic visual media, based on analyses of cognitive models and learning content characteristics*. Aachen: Shaker Verlag.

Guttormsen Schär, S., & Kaiser, J. (2006). Revising (multi-) media learning principles by applying a differentiated knowledge concept. *International Journal of Human Computer Studies*, 64, 1061–1070.

Guttormsen Schär, S., Messerli, S., & Schlupe, S. (2004). Information categories for learning-object metadata. An empirical study on the practical validity of theoretically founded information categories. In L. Cantoni & C. McLoughlin (Eds.), *Proceedings of Ed-Media 2004* (pp. 2221–2226). Lugano, Switzerland: AACE

Guttormsen Schär, S., Schierz, C., Stoll, F., & Krueger, H. (1997). The effect of the interface on the learning style in a simulation based learning situation. *International Journal of Human Computer-Interaction*, 9(3), 235–253.

Guttormsen Schär, S., & Zuberbühler, H. J. (2005). Evaluation of dynamic media and cognitive load. Investigating learning effects by various knowledge categories. *Elektrotechnik und Informationstechnik e&I*, 12, 498–505.

Hayes, N. A., & Broadbent, D. E. (1988). Two modes of learning for interactive tasks. *Cognition*, 28, 249–276.

ISO 14915-3 en. (2002). *Software ergonomics for multimedia user interfaces. Part 3: Media selection and combination* (International Organization for Standardizations, ISO 14915–3:2002).

Kinzer, C. K., Sherwood, R. D., & Loofbourrow, M. C. (1989). Simulation software versus expository text: A comparison of retention across two instructional tools. *Reading Research and Instruction*, 28, 41–49.

Kirschner, P.A. (2002). Cognitive load theory: Implications of cognitive load theory on the design of learning. *Learning and Instruction*, 12, 1–10.

Large, A. (1996). Computer animation in an instructional environment. *LISR*, 18, 3–23.

Mayer, R. E. (2001). *Multimedia learning*. Cambridge: Cambridge University Press.

Mayer, R. E. (2005). *The Cambridge handbook of multimedia learning*. Cambridge: Cambridge University Press.

Mayer, R. E. & Moreno, R. (2002). Animations as an aid to multimedia learning. *Educational Psychology Review*, 14(1), 887–99.

Merrill, M. D. (1983). Component display theory. In C. M. Reigeluth (Ed.), *Instructional-design theories and models: An overview of their current status* (pp. 279–333). Hillsdale, NJ: Lawrence Erlbaum Associates.

Merrill, M. D. (2001). Components of instruction. Toward a theoretical tool for instructional design. *Instructional Science*, 29(4), 291–310.

Nelson, D. L., Reed, U. S., & Walling, J. R. (1976). Pictorial superiority effect. *Journal of Experimental Psychology: Human Learning and Memory*, 2, 523–528.

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. M. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist*, 38(1): 63–71.

Pane, J. F., Corbett, A. T., & John, B. E. (1996). Assessing dynamics in computer-based constructions. In R. Bilger, S. Guest, & M. J. Tauber (Eds.), *Proceedings of The International Conference in Computer Human Interaction CHI'96*, (pp. 198–204). New York, NY: ACM Press.

- Paivio, A. (1986). Dual coding theory. In A. Paivio (Ed.), *Mental representations. A dual coding approach* (pp. 53–83). Oxford: Oxford University Press.
- Paechter, M. (1996). *Auditive und visuelle Texte in Lernsoftware*. Münster: Waxmann.
- Park, O. C., & Hopkins, R. (1993). Instructional conditions for using dynamic visual displays: A review. *Instructional Science*, 21, 427–449.
- Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction* 12, 61–86
- Rieber, L. P. (1989). The effects of computer animated elaboration strategies and practice on factual and application learning in an elementary science lesson. *Journal of Educational Computing Research*, 5(4), 431–444.
- Rieber, L. P. (1990a). Animation in computer-based instruction. *Educational Technology Research & Development*, 38(1), 77–86.
- Rieber, L. P. (1990b). Using computer animated graphics in science instruction with children. *Journal of Educational Psychology*, 82, 135–140.
- Rieber, L. P. (1991a). Animation, incidental learning, and continuing motivation. *Journal of Educational Psychology*, 83(3), 318–328.
- Rieber, L. P. (1991b). Effects of visual grouping strategies of computer-animated presentations on selective attention in science. *Educational Technology Research and Development*, 39(4), 5–15.
- Rieber, L. P., Boyce, M. J., & Assad, C. (1990). The effects of computer animation on adult learning and retrieval tasks. *Journal of Computer Based Instruction*, 17(2), 46–52.
- Rieber, L. P., & Kini, A. S. (1991). Theoretical foundations of instructional Applications of Computer-Generated Animated Visuals. *Journal of Computer Based Instruction*, 18(3), 83–88.
- Salden, R. J. C. M., Paas, F., & van Merriënboer, J. J. G. (2006). A comparison of approaches to learning task selection in the training of complex cognitive skills. *Computers in Human Behavior* 22(3), 321–333.
- Salomon, G. (1984). Television is “easy” and print is “tough”: The differential investment of mental effort in learning as function of perceptions and attributions. *Journal of Educational Psychology*, 76, 647–658.
- Sweller, J. (1999). *Instructional design in technical areas*. Camperwell, Victoria: Acer Press.
- Tang, H. H. & Gero, J. S. (2001). Roles of knowledge while designing and their implications for CAAD. In J. S. Gero, S. Chase & M. Rosenman (Eds.), *Proceedings of CAADRIA'01*, (pp. 81–89). Sydney: Key Centre of Design Computing and Cognition, University of Sydney.
- Van Merriënboer, J. J. G., Schuurmann, J. G.de., de Croock, M. B. M., & Paas, F. G. W. C. (2002). Redirecting learners’ attention during training: Effects on cognitive load, transfer test performance and training efficiency. *Learning and Instruction* 12(1): 11–37.
- Van Merriënboer, J. J. G., Kester, L., & Paas, F. (2006). Teaching complex rather than simple tasks: Balancing intrinsic and germane load to enhance transfer of learning. *Applied Cognitive Psychology*, 20(3), 343–352.