2 Theoretical Background

2.1 Beginnings of Multimedia Research

The study of the impact of auditory and visual learned information on memory became popular in research shortly before the possibilities of digital media in education won recognition. Reviews by Penney (1975, 1989) revealed a superiority of auditory over visual learning in the recall of verbal items. However, this superiority disappears with more complex information such as text. In fact, it was found that visual learners remember more of the learned material than auditory learners and pay more attention to details (Nelson, Balass, & Perfetti, 2005; Rickheit, Strohner, Miisseler, & Nattkemper, 1987). Furthermore, a large body of evidence gave attention to the learning effect of images additional to text. It was established that images can improve the learning outcome if they are helpful or necessary to understand the text (Carney & Levin, 2002; Levin, Anglin, & Carney, 1987). Both research fields raised the question of the most suitable information modality to learn with images. The modality effect offers a possible answer and is briefly defined in the following.

2.2 Modality Effect

The modality effect is an evidence-based guideline to optimize designing multimedia instructions. It states that learning in a multimedia environment with images and corresponding information can be improved when the information is presented auditory rather than visual (Mayer, 2001, 2005; Sweller, 2005). This effect mostly occurs in system-paced environments in which learners have no control over the learning pace (Ginns, 2005).

2.3 Reversed Modality Effect

The modality effect can also be reversed. This means that a visual presentation of the information in learning with images can be superior under certain circumstances. There is some evidence suggesting that a reversal occurs, on the one hand, in self-controllable learning environments (Tabbers, Martens, & van

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Merriënboer, 2001, 2004) and, on the other hand, if the learned material is recalled from long-term memory (Schweppe & Rummer, 2012; Segers et al., 2008; Witteman & Segers, 2010).

2.4 Multimedia Processing

Important fundamentals for theories concerning the modality effect yielded Paivio's dual coding approach (1986) as well as Baddeley's working memory model (1992). The dual coding approach postulates that the processing of visual and verbal information in the human mind runs in two separate channels. The channel in which the material is processed depends on the presentation mode of the information. A text, for example, is always processed in the verbal channel, whether or not it is presented auditory or visual. Furthermore, Paivio (1986) assumed that the amount of the possible processible information by each channel at once is strongly limited. In addition, the working memory model (Baddeley, 1992) also postulates that two separate channels in the working memory are in charge of processing visual and auditory information. In contrast to the dual coding approach (Paivio, 1986), the nature of the sensory perception is responsible for the selection of the channel in which the information is processed. In other words, it depends if people record the information through ears or eyes. Therefore, visual texts are processed in the visual and auditory texts in the auditory channel. According to Paivio (1986), a capacity-limited processing of auditory and visual information is assumed. Both approaches made important contributions for theories on multimedia learning which are described in the following.

2.5 Theories of Multimedia Learning

Cognitive load theory. Sweller's cognitive load theory (2005) is a general framework containing several guidelines to improve learning by reducing cognitive load. One of these guidelines describes the risk of a cognitive overload in learning with images and visual texts. Considering Baddeley's working memory model (1992), Sweller (2005) assumed that cognitive overload can be prevented if a text is presented auditory rather than visual due to the division of the processing of the image and the auditory information in two separate channels. He called this auditory superiority the modality effect.

Cognitive theory of multimedia learning. Mayer's cognitive theory of multimedia learning (Mayer, 2001, 2005) also incorporates concepts for designing optimized learning environments. One of these concepts is the

modality principle[1] which also recommend an auditory presentation of information to corresponding images instead of visual texts. In contrast to Sweller's cognitive load theory (2005), Mayer not only used Baddeley's working memory model (1992), but also took up the theory of Paivio (1986). Thus, information comes either through eyes or ears (Baddeley, 1992) but can change the channel in the working memory (Paivio, 1986). In other words, a visual text, for example, is recorded through the visual channel but is processed in the verbal part of the working memory. Figure 1 displays the information path from perception to long-term memory.

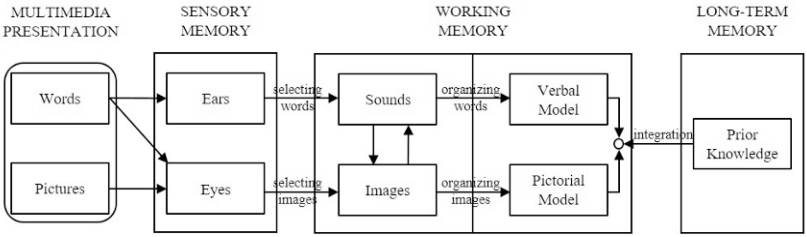

Figure 1: Cognitive theory of multimedia learning (adapted from Mayer, 2005).

The split attention effect. The split attention effect is often mentioned as a possible cause of the modality effect. It describes a divided attention within multimedia learning which occurs when two interrelated sources of information are presented separately (Kalyuga, Chandler, & Sweller, 1998; Sweller et al., 1998). Learning an image with corresponding visual text is a good example for this effect. In order to integrate text and image information mentally, a learner has to switch constantly between both visual information sources. This may lead to a cognitive overload which is often accompanied by a loss of information (Chandler & Sweller, 1991, 1992; Low & Sweller, 2005; Schnotz & Kürschner, 2007; Sweller et al., 1990, 1998; Sweller & Chandler, 1994).

2.6 Previous Studies on Multimedia Learning

Short-term modality effect. In a highly regarded study, in accordance with the cognitive theory of multimedia learning (Mayer, 2001, 2005), differences in the recall of visual and auditory learned material were tested with a 16-step learning material on the lightning process (Moreno & Mayer, 1999). The learning pace

1 Note that both terms, the modality effect and the modality principle, are used interchangeably in this paper.

was predefined by the system and therefore uncontrollable by the learners. The length of time, in which each of the 16 individual scenes were displayed, was adapted on the required time the corresponding auditory narration took. In regard to the differentiated learning outcomes, two question types were asked: First, retention tasks which test the simple memorization of the learned material, for example factual knowledge, and second, transfer tasks which test the ability to transfer the learned knowledge into new contents. According to the cognitive theory of multimedia learning (Mayer, 2001, 2005), a modality effect was found in both retention and transfer questions. The learning material and the implementation method of this study, especially the usage of system-paced learning environments, became widely established in this field of research (e.g., Ginns, 2005; Schmidt-Weigand, Kohnert, & Glowalla, 2010; Schweppe & Rummer, 2012; Witteman & Segers, 2010).

It can be assumed that the time pressure in system-paced environments may increase the negative influence of the split attention effect. Auditory system-paced learners only have to inspect the images while the corresponding information is presented through their ears. In contrast, visual learners have to split their visual attention between texts and images in the same predefined time. Therefore, the auditory superiority might be a result of the less stressful and time-consuming learning experience while integrating both information sources mentally. The studies by Tabbers et al. (2001, 2004) may give confirmation for this assumption since they showed a reversed modality effect in retention (Tabbers et al., 2001, 2004) and in transfer tasks (Tabbers et al., 2004) when participants learned in a self-paced environment. With unlimited learning time, the negative influence of the split attention effect seems to disappear.

In addition, Schmidt-Weigand et al. (2010) provided with their eye-tracking study deeper insights into the split attention effect by investigating the viewing behavior in slow, medium and fast system-paced as well as in a self-paced environment. On the one hand, they found that the less learning time visual system-paced learners get, the more they use text-directed processing strategies (Hegarty & Just, 1993; Rayner, Rotello, Stewart, Keir, & Duffy, 2001): They consider the text first, more frequently and longer than the image in order to get as much detailed information as possible in the limited time. Furthermore, they split their visual attention quickly and continuously between images and texts. Schmidt-Weigand et al. (2010) concluded that this viewing behavior results in a lack of time to integrate image and text mentally and leads to an inferiority of visual learning. On the other hand, they almost found no switchover in visual self-paced conditions. According to Tabbers et al. (2001, 2004), these results indicate that the negative influence of the split attention effect can be reduced with more

or unlimited learning time. However, no modality effect or its reversal was found in their study, whether in transfer nor in retention tasks.

Long-term modality effect. To the authors' knowledge, only three studies currently examined the modality effect over time (Schweppe & Rummer, 2012; Segers et al., 2008; Witteman & Segers, 2010). One of these studies investigated the long-term learning success of students after learning in a system-paced environment (Schweppe & Rummer, 2012). The other both tested in self-paced environments with children (Segers et al., 2008; Witteman & Segers, 2010). Long-term results revealed reversed modality effects one day after learning in transfer tasks (Witteman & Segers, 2010) and one week later in transfer (Schweppe & Rummer, 2012; Segers et al., 2008) as well as in retention tasks (Schweppe & Rummer, 2012). These results suggest that the modality effect can be reversed after learning in self- and even in system-paced environments when the learned material is recalled from long-term memory.

2.7 Limitations of Previous Research

Research on the modality effect is still conflicting. Two main reasons for this circumstance should be mentioned.

First, while the short-term modality effect in system-paced environments is well investigated (for an overview, see Ginns, 2005), studies which examined self-paced learning and long-term recall are rare and have various limitation which make it difficult to draw comparisons. The most regarded studies on self-paced learning, for example, used considerably longer learning material as well as longer text-segments per scene (Tabbers et al., 2001, 2004) than the widely used material on lightning process (Moreno & Mayer, 1999). Both may give an advantage to visual learners due to a generally reduced cognitive load with more learning time (Leahy & Sweller, 2011) and because visual learners can switch back much easier to complicate text parts than auditory learners (Green, 1981). Furthermore, the few studies on the long-term modality effect partially tested children (Segers et al., 2008; Witteman & Segers, 2010), whereby variables such as reading ability and understanding of the content need to be considered. Moreover, two of these studies were executed in school or university settings (Schweppe & Rummer, 2012; Segers et al., 2008) which made it difficult to control the influence of confounding variables. Furthermore, the influence of the memory effect was almost ignored in recent studies since the same test questions were asked immediately and one week after learning. Therefore, the measurement of effective learning is difficult, which is characterized by such a deep anchoring in the memory that one can recall different contents of the material short- and long-term.

A second reason for the conflicting situation in this field of research may be the disregard of further important impacts on the modality effect. Subjective experiences during the study, especially the possible perceived stress in a system-paced environment, could have important influences on the modality effect. Moreover, the motivation was previously ignored, although it was found that intrinsically motivated learners perform better than less motivated learners (Deci, Ryan, & Williams, 1996; Vansteenkiste, Lens, & Deci, 2006).

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