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Cognitive Processes in Children's Multimedia Text Learning

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SUMMARY

The cognitive processes underlying children's multimedia text learning were studied using a self-paced task and authentic school texts with mostly representational pictures in an elementary school setting. Both the quantity and quality of learning were assessed immediately following intervention and 1 week later. In a within-subjects design, all of the children were taught four lessons of a different format: (1) written presentation only; (2) written presentation accompanied by pictures; (3) oral presentation only and (4) oral presentation accompanied by pictures. With respect to the quantity of learning, a short-term modality effect was found with oral presentation producing better results than written presentation when accompanied by pictures. A multimedia effect was found for only the oral conditions. With respect to the quality of the children's learning, an initial short-term modality effect was found but reversed 1 week following intervention with no evidence of a multimedia effect. Copyright © 2008 John Wiley & Sons, Ltd.

The use of computers as an instructional medium enables the presentation of multimedia lessons that may include text, speech, pictures, animation and so forth. Whether the multimedia presentation of information produces greater learning gains than the presentation of information using a single medium, however, remains very much open to question. The present study focuses on a small part of the wide range of multimedia possibilities: the oral versus written presentation of information with or without the inclusion of illustrations. These are not options *per se* associated with the computer and therefore a lot of the relevant research has been conducted prior to the computer era. In one line of research, the effects of oral versus written presentation on the recall of information have been compared. The issue of particular interest in these studies, however, was the existence, operation and architecture of short-term memory (see Penney, 1989). More recently, the applied value of this research has been considered with respect to the issue of meaningful learning (Mayer, 2001). In a second line of research, the added value of pictures for learning from text has been considered (see Carney & Levin, 2002). Both lines of research will be considered in greater detail in the sections below and then the purpose of the present study will be outlined.

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Oral or written presentation: the modality effect

The research on the effects of different modalities of presentation on memory has a long history. In reviews by Penney in both 1975 and 1989, an advantage of oral conditions over written conditions was generally found when 'recall as a function of auditory and visual presentation of verbal items' was assessed (Penney, 1975, p. 68). Subjects tend to remember more words from a list when the list is presented in an oral format. According to Penney, however, the long-term aspects of memory are largely ignored in these studies. Dean, Yekovich, and Gray (1988) and later Duis, Dean, and Derks (1994) all found reversed or less robust effects for long-term memory storage. According to Nelson, Balass, and Perfetti (2005), reading activates both orthography and phonology while listening does not and reading therefore leaves a long-term memory trace that includes both orthographic and phonological information while listening does not.

Such reversed memory effects have similarly been found for the reading of a text versus listening to a text. According to Rickheit, Strohner, Müsseler, and Nattkemper (1987), reading results in an ability to recall more facts than listening because listeners tend to extract only the main lines of information from a text while readers pay attention to many details as well. These results should be considered in the light of the experience a reader has with a type of text, for in other research, Rickheit et al. (1987) found only an advantageous effect of reading over listening when the subjects were adults who used written communication as their main mode of communication; when the subjects were adults who relied more on oral communication in their work than written communication, better recall was found for listening as opposed to reading.

All of this raises the question of just how the learning of less experienced readers and listeners, such as children in elementary school, proceeds when exposed to discourse and text. In a new line of research concerned with the development of guidelines for multimedia learning and the application of principles from cognitive psychology, Mayer and co-workers have proposed a cognitive theory of multimedia learning (Mayer, 2001). Based on the dual-coding theory of Paivio (1986) and the short-term memory model of Baddeley (1986), several so-called multimedia principles aimed at the reduction of cognitive load to maximize learning have been formulated. Based on observed modality effects, for example, Mayer argues that a higher *quantity* of learning (i.e. recall of facts) and *quality* of learning (i.e. capacity to use what is learned in new situations) are attained when the material to be learned is presented in an oral-with-pictures as opposed to the written-with-pictures format (Mayer, 2001). This is partly in keeping with what Penney (1989) found although Penney's review did not address the inclusion of pictures.

In addition, no attention is paid to the reversed or less robust effects commonly found for long-term memory. The written-with-pictures format is assumed to cause overload because both the written text and the pictures enter the cognitive system via the visual channel and the text must then be transferred to the auditory channel. In the case of oral-with-pictures, information enters the cognitive system via both the visual and auditory channels (i.e. the eyes and the ears), and this is considered optimal. And in a meta-analysis of studies up until 2004, Ginns (2005) indeed showed the overall robustness of this modality effect, as defined by Mayer.

Ginns (2005) further reported that very few studies of elementary school children have been conducted but that a clear modality effect is apparent. In a study not included in Ginns' meta-analysis, modality-dependent differences were not detected in the learning of 12-year-olds in a realistic school setting (Mann, Newhouse, Pagram, Campbell, & Schulz, 2002). However, the children in this study had to write their answers down in a workbook,

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which thus included reading and writing in the oral condition and therefore may have confounded and/or masked any modality effects.

The modality effects observed in the aforementioned studies were only established—to the best of our knowledge—using measurements directly following intervention while one's main interest should presumably be in the long-lasting effects of specific learning situations and formats. Furthermore, the pacing of the presentation of the information to be learned was not considered in the relevant studies. If the instructional system is learner as opposed to system paced, for example, certain modality effects may disappear or even reverse themselves. Such disappearance or reversal, however, has only been detected in a study of adults exposed to a technical design text (see Tabbers, 2002) and a learner-paced study with no pictures supplementing the text (Rickheit et al., 1987). According to Mayer and Chandler (2001) who found more positive effects of reading than listening on the answering of transfer questions in a user-paced condition, the extra time available to study the material may actually be the factor of importance and not user control. Reading a text at one's own pace may also entail more active information gathering and therefore elicit deeper learning (Nelson et al., 2005). Further research on the issue of long-term learning effects in self-paced multimedia learning environments is therefore clearly needed.

The added value of pictures: the multimedia effect

The modality effect identified by Mayer involved the use of pictures to supplement the oral versus written presentation of text. In a meta-analysis by Levin, Anglin, and Carney (1987), the long line of research concerned with the added learning value of different types of pictures accompanying written text was examined and illustrations—with the exception of those used for decorative purposes—have been consistently found to lead to relatively greater text learning. In a more recent review by Carney and Levin (2002), the authors noticed that the most recent work of Mayer and co-workers involved so-called *interpretational pictures* or, in other words, pictures that help clarify difficult text (e.g. how the brakes on a car work?, or how the human respiratory system works?) (Mayer & Anderson, 1992; Mayer, Fennell, Farmer, & Campbell, 2004). The additive learning effect of pictures accompanying oral or written texts was then referred to as a *multimedia effect* by Mayer (2001) while the negative effect of decorative pictures was considered part of a so-called coherence effect (Mayer, 2001), in which irrelevant information causes negative learning effects.

In children's school textbooks, so-called *representational pictures* are most common and have been found to result in heightened learning effects but to a lesser extent than interpretational pictures (Carney & Levin, 2002). Representational pictures repeat part of the content of the accompanying text (e.g. involve a photograph or drawing of a character or an event taking place in a story). Carney and Levin reported on the mostly studies of children recalling or understanding narratives either with or without *interpretational* pictures. In a study not considered by Carney and Levin, Hannus and Hyönä (1999) found illustrated texts from authentic school textbooks to produce higher scores than non-illustrated texts on detailed retention questions (i.e. a multimedia effect) but, in contrast, only a differential effect of illustration versus non-illustration for the handling of comprehension questions by high-ability fourth graders but not low-ability fourth graders. Koran and Koran (reported in Hannus & Hyönä) nevertheless found students with low reasoning abilities to benefit *more* from the presence of pictures accompanying written texts than students with high reasoning abilities. Hannus and Hyönä explained the differences in the results in terms of the fact that more than one picture was visible per page

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in their own study, which requires a greater ability to process the information and therefore benefits only those students with an already higher ability.

The present study

The purpose of the present study was to shed greater light on both the modality and multimedia effects among a population of elementary school children assessed in a realistic school setting using authentic materials. The research reviewed above is influential in the sense that the design of study materials is currently being based on the results of such research. Especially a theory such as the cognitive theory of multimedia learning, which integrates oral versus written presentation and the added value of pictures needs further validation. Very few studies, for example, have been conducted in a school setting and the long-term effects of the relevant multimedia approaches are largely unknown. Additional research is therefore needed to guide the development of multimedia lessons that promote deeper learning on the part of elementary school children.

The cognitive theory of multimedia learning cannot be directly transferred to the school situation for a number of reasons. To start with, the subjects in the studies by Mayer and co-workers were mostly adolescents and adults with a rather high degree of reading ability. The extent to which their reading ability may have influenced the results is thus unclear. Furthermore, the multimedia lessons on which this research is based invariably explain a rather technical or complex phenomenon such as, how a car brake works? or how the human respiratory system works?, which is in marked contrast to the more general issues mostly found in school textbooks. The study by Hannus and Hyönä is one of the very few studies to address the cognitive theory of multimedia learning in school textbooks. Yet another obstacle to the generalization of this theory of multimedia learning to the school situation is that most of the relevant studies involve system-paced interventions that are not very common in school situations where the learner typically goes through the material to be learned at his or her own pace. Whether the modality effect holds for learner-paced interventions, for example, is still mostly unclear (see Ginns, 2005). Finally, the results on which the cognitive theory of multimedia learning is based have yet to be evaluated on a long-term basis: what do children remember 1 week later?

As already mentioned, a less robust or even reversed modality effect has been observed in the long run in some studies (Dean et al., 1988; Duis et al., 1994). In these studies, however, retention was measured after presentation of a word list (without pictures), the research was conducted in a setting other than a school setting, and the intention was not to consider deeper learning. The aim of the present study was therefore to disentangle the issues raised above by presenting children with four different types of learner-paced multimedia lessons in a within-subjects post-test retention design: (1) oral text only (O), (2) oral text accompanied by pictures (OP), (3) written text (W) and (4) written text accompanied by pictures (WP).

Possible differences between children were also taken into consideration in the present study. The advantage of oral over written presentations was expected to be higher for particularly children with lower verbal abilities because the cognitive load of reading a text is greater than the cognitive load of listening to a text for these children (also see Jong, 1998). Nevertheless, Aaron (1991) has reported a correlation between listening comprehension and reading comprehension, which could mask any advantage of an oral condition. In a similar vein, when Mayer and Sims (1994) compared students with high versus low spatial abilities, they found mainly high spatial ability students to benefit from

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the pictures accompanying a text. In the present study, both children's verbal and spatial intelligence were therefore assessed.

In the present study, the intervention was learner-paced. For this reason, it was expected that the written conditions, in particular, would produce greater learning effects immediately following intervention. That is, the children in the written conditions were expected to have—and typically take—more time to study the target material than in the oral conditions (cf. Mayer & Chandler, 2001).

Finally, the use of pictures was expected to exert a positive effect on the learning and recall of the children in both the written and oral conditions. Nevertheless, it was expected that a greater loss of knowledge would occur in the long run in the oral conditions as opposed to written conditions in keeping with the long-term reversed modality effect found by Dean et al. (1988) and in keeping with the results of adult discourse studies showing reading to generally produce better results than listening (Rickheit et al., 1987).

METHOD

Participants

The participants were 128 children from five fifth-grade classes in an elementary school in a middle-class suburb of a city in the south of the Netherlands. Second-language learners and children either diagnosed with language/learning problems or suspected of such were excluded from the analyses. The average age of the remaining 113 children was 10;8 (years;months, SD = 5.3 months). The sample consisted of 62 boys and 51 girls.

Measurements of cognitive abilities

Prior to the intervention, the following cognitive abilities were assessed using a number of subtests from the ISI-Reeks III (van Boxtel, Snijders, & Welten, 1980), an instrument that has been shown to be both clearly reliable and valid.

Verbal intelligence

Verbal intelligence was measured using three subtests. Specifically, the child had to: (1) underline in a series of five words a synonym of the word presented in bold face, (2) underline in a series of five words an opposite of the word presented in bold face and (3) underline in a series of five words those two words that relate to three words presented in bold face.

Spatial intelligence

Spatial intelligence was measured using three other subtests. The subtests were: (1) sliced figures: which requires the respondent to select two figures that jointly form the presented figure; (2) rotated figures: the respondent has to select two figures that are a rotation of the presented figure and (3) understanding figures: the student has to underline in a series of five figures those two figures that relate to three presented figures.

Intervention

The intervention consisted of four multimedia lessons presented in Microsoft Powerpoint^{TM} (cf. Ginns, 2005). The children could move back and forth through the pages at

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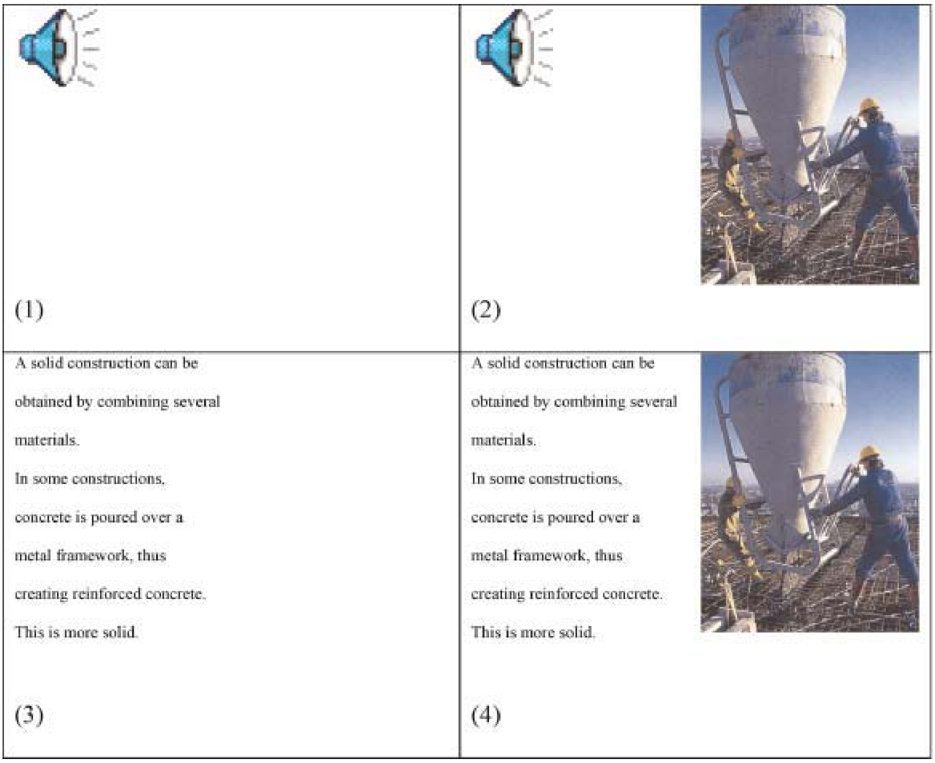

Figure 1. Example from a page in each of the four conditions: (1) oral text only (O), (2) oral text accompanied by pictures (OP), (3) written text only (W) and (4) written text accompanied by pictures (WP)

their own pace. The lessons consisted of as yet untaught texts on construction and energy from the physics book used in the school (Smits, Rutgers, Weeber, & Zanthing-Muis, 2002). The four multimedia lessons consisted of a title page and seven text pages. The accompanying pictures came from the book or, when unavailable, from the Internet. The lessons were presented in four different formats: (1) oral text only (O), (2) oral text accompanied by pictures (OP), (3) written text only (W) and (4) written text accompanied by pictures (WP) (Fig. 1). The lessons involved 190–240 words.

On an average, the children took 108.5 seconds to study a lesson. A univariate ANOVA showed more time ($p < .001$) to be consumed in the oral conditions (O condition = 119.9 seconds; OP condition = 120.4 seconds;) than in the written conditions (W condition = 96.1 seconds; WP condition = 97.9 seconds).

Questionnaires

For each of the four lessons two versions of a questionnaire were constructed to measure text comprehension and learning on a short- and long-term basis. The questionnaires involved seven multiple-choice questions and three open-ended questions. The multiple-choice questions were directly related to the text and therefore assessed the children's quantity of learning (e.g. *What is 'reinforced concrete'? (a) Concrete combined with a wooden triangular construction, (b) Concrete combined with a metal framework.)*

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The open-ended questions required the application of knowledge from the text to a new situation and therefore assessed the children's deeper learning (i.e. quality of learning). An example of such a question is: *'If you were building a hut in the woods without any metal objects, how could you make it a solid construction?'*

The children's interest and self-reported prior knowledge were also measured by asking them to rate 10 questions concerning the lesson topic along a Likert scale of one to four (e.g. *If a TV show is on building bridges, do you find it interesting?* (1) *No*, (2) *Hardly*, (3) *A bit*, (4) *Yes*; or, *Do you consider yourself good in technique?* (1) *No*, (2) *Hardly*, (3) *A bit*, (4) *Yes*.

Procedure

The ISI intelligence tests were administered by a certified school psychologist at the beginning of the school year (i.e. in September). The interest and prior knowledge questionnaires were administered by the third author, who is also a certified teacher, 1–2 weeks prior to the intervention.

The intervention was conducted in the fall across a period of 4 weeks. All of the children were presented the lessons in the same order, with one lesson every week, but the multimedia format of the lesson and the version of the questionnaire administered to measure short- or long-term performance were varied in a randomized block design (e.g. Child 1 received the text only version of the first lesson, version A of the questionnaire immediately following the lesson and version B of the questionnaire 1 week later; Child 2 received the text only version of the first lesson, version B of the questionnaire immediately following the lesson and version A of the questionnaire 1 week later; Child 3 received the text plus pictures version of the first lesson, version A of the questionnaire immediately following the lesson and version B of the questionnaire 1 week later; etc., etc., etc.). The children were taken out of their classrooms in groups of four and administered the intervention on computers located in the school hall. The third author was always present during the intervention and measured the time taken to go through the lessons by the children.

Immediately following a lesson, the children were seated separately at tables and asked to complete one version of the questionnaire to measure short-term learning effects. The alternate version of the questionnaire was administered in the class by the teacher 1 week later to measure long-term learning effects.

During the intervention period, the book from which the texts were taken was not available to the children.

Analyses

General Linear Model Repeated Measures analyses were undertaken using Time (short-term, long-term), Text Format (written, oral) and Picture Format (pictures, no pictures) as within-subjects factors. The aim of these analyses was to test for differential effects of text and picture format across time on both quantity and quality of learning. *Post hoc* analyses using paired samples t-tests with an adjustment of the alpha level from .05 to .005 were also conducted. Alpha levels between .005 and .05 were reported as trends.

The cognitive abilities of the children (verbal intelligence and spatial intelligence) and their interest/prior knowledge were entered separately in follow-up analyses as

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between-subject factors. For these analyses, the sample was divided into two groups involving children scoring above or below the group mean for the variable in question.

Some children were not at school on all testing occasions. When possible, these children were tested at a later point. This was nevertheless not always possible, which explains the slight differences in the numbers of subjects throughout the analyses.

RESULTS

Multiple-choice questions: quantity of learning

The univariate ANOVAs revealed a main effect of Time ($F(1, 106) = 6.399$, $p = .013$, partial $\eta^2 = .057$), an interaction between Time and Picture Format ($F(1, 106) = 7.238$, $p = .008$, partial $\eta^2 = .064$), and an interaction between Time, Text Format and Picture Format ($F(1, 106) = 10.061$, $p = .002$, partial $\eta^2 = .087$). When the latter interaction was explored in greater detail, the OP condition (oral text accompanied by pictures) was found to produce the best results immediately following a lesson: OP > WP ($p = .004$), OP > O ($p < .001$), OP > W ($p = .027$) and W > O ($p = .039$). One week later, no differences between the different conditions were found. The OP scores also showed a significant decrease across time ($p < .001$). The short- and long-term means and standard deviations for the different conditions are presented in Table 1.

Cognitive abilities and prior knowledge effects

When *verbal intelligence* was added to the ANOVAs as a between-subjects factor, the same effects were found as in the preceding analyses along with a main effect of verbal intelligence ($F(1, 104) = 7.032$, $p = .009$, partial $\eta^2 = .063$), and two additional interactions involving verbal intelligence: Time × Verbal Intelligence ($F(1, 104) = 4.407$, $p = .038$, partial $\eta^2 = .041$) and Time × Text Format × Verbal Intelligence ($F(1, 104) = 8.525$, $p = .004$, partial $\eta^2 = .076$). When the three-way interaction involving children with high versus low verbal intelligence was further explored, no significant differences for the text formats or time were found for those children with low verbal intelligence. However, the children with high verbal intelligence showed a tendency to score better in the oral conditions than in the written conditions immediately following the intervention ($p = .015$) but not 1 week later. That is, the observed trend disappeared over time and the oral conditions showed significant decreases over time ($p < .001$).

The inclusion of *spatial intelligence* as a between-subjects factor produced no additional effects. However, when *interest and prior knowledge* were included in the analyses, an

Table 1. Means and standard deviations (SD) for the four multimedia conditions (W, WP, O and OP) immediately following intervention (short term; ST) and 1 week later (long term, LT) (maximum score of 7 on multiple choice questionnaires)

Condition	ST mean	SD	LT mean	SD
W	5.21	1.195	5.01	1.437
WP	5.11	1.313	4.90	1.273
O	4.88	1.426	5.16	1.275
OP	5.51	1.262	4.89	1.562

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additional Interest/Prior Knowledge × Text Format interaction was detected (F(1, 96) = 5.996, p = .016, partial η^2 = .059). For those children with low interest/prior knowledge, no significant differences between the text formats were found. For those children with high interest/prior knowledge, a nonsignificant trend (p = .014) towards relatively higher scores in the oral conditions than in the written conditions appeared to be the case.

Open-ended questions: quality of learning

When the open-ended questions were analyzed, only the interaction between Time and Text Format was found to be significant (F(1, 106) = 55.418, p < .001, partial η^2 = .343. More detailed analyses showed the oral conditions to produce better performance than the written conditions immediately following intervention (p < .001) but a reversal of this pattern 1 week later (p < .001). Both the oral and written conditions showed significant differences across time (p < .001). The short- and long-term means and standard deviations for the different conditions are presented in Table 2.

Role of cognitive abilities and prior knowledge

Neither *spatial* nor *verbal intelligence* produced additional interaction effects when entered into the analyses of the open-ended questions as between-subjects factors. Verbal intelligence again did show a main effect (F(1, 104) = 8.748, p = .004, partial η^2 = .078).

When *interest/prior knowledge* were entered into the analyses as a between-subjects factor, however, the following interactions were found for the open-ended questions in addition to the original effects: Text Format × Interest/prior knowledge (F(1, 96) = 5.509, p = .021, partial η^2 = .054); Time × Picture Format × Interest/prior knowledge (F(1, 96) = 5.324, p = .023, partial η^2 = .053); and Text Format × Picture Format × Interest/prior knowledge (F(1, 96) = 9.741, p = .002, partial η^2 = .092). Although the four-way Time × Text Format × Picture Format × Interest/prior knowledge interaction was not significant (F(1, 96) = 3.336, p = .071, partial η^2 = .034), the presence of two significant three-way interactions nevertheless prompted us to compare the four conditions in the short and long run for those children with low versus high levels of interest/prior knowledge.

No differences between the four conditions immediately following intervention were revealed for those children with low interest/prior knowledge. One week later, however, the children's performance in the W condition (written text without pictures) was better than in both oral conditions (O (p < .001) and OP (p < .001)) and a trend towards significantly better than in the WP condition (p = .027). For the children with little or no prior interest or

Table 2. Means and standard deviations (SD) for the four multimedia conditions (W, WP, O and OP) immediately following intervention (short term; ST) and 1 week later (long term, LT) (maximum score of 3 on the open-ended questionnaires)

Condition	ST mean	SD	LT mean	SD
W	1.145	.801	1.449	.895
WP	1.051	.835	1.449	.777
O	1.336	.821	1.210	.776
OP	1.481	.714	1.112	.787

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knowledge, moreover, performance in the W condition increased over time ($p < .001$). Finally, a trend towards better long-term performance in the WP condition than in the O condition was also observed ($p = .038$).

For those children with high interest/prior knowledge, their performance in the narrative conditions immediately following intervention was better than their performance in the textual conditions immediately following intervention (O > W, $p = .003$; O > WP, $p = .001$; OP > W, $p = .005$; OP > WP, $p = .001$). One week later, the WP condition produced the best scores (WP > OP, $p < .001$; WP > W, $p = .003$; trend for W > O, $p = .039$) and a significant increase over time was thus observed for the WP condition as well ($p < .001$).

CONCLUSIONS AND DISCUSSION

In the present study, the cognitive processes associated with the multimedia learning of elementary school children were assessed in a school setting using authentic school pictures and texts in a self-paced task. Both the quantity and quality of the children's learning were evaluated immediately following intervention and 1 week later. In a within-subjects design, all of the children received the same four lessons in the same order but in a different format that was presented in a mixed design (1) written text only; (2) written text accompanied by pictures; (3) oral text only or (4) oral text accompanied by pictures.

The modality effect (which refers to the advantage of oral vs. written text both accompanied by pictures) was replicated for the quantity of short-term learning. Oral presentation with pictures produced better short-term performance than written presentation accompanied by pictures. One week later, however, the detected difference was gone. The multimedia effect (which refers to the added value of pictures) was only found for the oral condition and not for the written condition (with the short-term difference between OP and W only showing a trend).

With regard to the quality of the children's learning, the modality effect was again apparent immediately following intervention and independent of the inclusion or noninclusion of pictures but completely reversed itself 1 week later. Evidence for a multimedia effect was not found.

In the present study, the intervention was learner-paced and we therefore expected the written conditions to produce better learning results immediately following the intervention than the oral conditions. The children were expected to take more time to study the information to be learned in the written conditions than in the oral conditions. Contrary to our expectation, however, the children in the oral conditions were found to take more study time, and the modality effect detected in many other studies (Ginns, 2005) was replicated immediately following intervention. The effect of self-pacing within the context of the present study was apparently not strong enough to suppress the modality effect as found to occur in the studies by Tabbers (2002) and Mayer and Chandler (2001). Contrary to these studies, the respondents in the present study were children who simply did not take the extra time that adults appear to in textual conditions.

The use of pictures was expected to facilitate the children's learning and recall in both the oral and written conditions. This effect was not consistently found, however, which could be due to the fact that some of the pictures in our intervention were more decorative than representational. Decorative pictures have been found to suppress learning while

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representational pictures have been found to enhance learning (Carney & Levin, 2002). In the present study, the coherence effect (which refers to negative learning effects when irrelevant information is added) may have suppressed multimedia effects. To determine the relevance of the pictures, we therefore had 12 Educational Psychology master's students to judge the relevance of the pictures. The average score of 5.5 along a scale of 1–10 suggests that the pictures in the textbooks were judged to be at least moderately relevant. Another explanation for the failure to find a general facilitating effect of pictures can be derived from Mayer and Sims (1994) who mentioned that students who possess prior knowledge may not need visual aids because they can construct their own mental models. The children in our study clearly had some prior knowledge related to the texts in our intervention. Only 6 out of the 104 children who completed the questionnaires produced a score below 20 points for the 10 questions using a four-point Likert scale, and the lowest score was 14.

With respect to the children's learning and recall 1 week later, we expected a greater loss of knowledge in the oral conditions than in the written conditions. This was found to be partly the case for the multiple-choice questions. That is, the initial modality effect disappeared 1 week later and the oral presentation with pictures condition showed a significant drop over time while the sheer oral condition did not.

With respect to the quality of the children's learning, the oral conditions showed a general decrease after 1 week. The written conditions, in contrast, showed an unexpected increase after 1 week. After exposure to the written conditions, the children appear to consolidate what they have learned and allocate the information in a place in long-term memory. In neurocognitive research, McClelland, McNaughton, and O'Reilly (1995) explain this so-called consolidation effect as follows: a memory may be initially stored in the hippocampal system and later reinstated in the neocortex where new knowledge is connected to existing knowledge, which leads to deeper understanding. This theory may explain the occurrence of the present results for the quality of learning and not the quantity of learning. The fact that the consolidation effect was found for only the written conditions can be explained by the more active gathering of information and deeper learning prompted by the reading of information and more passive consumption of information and superficial understanding often allowed by listening (Nelson et al., 2005).

To a small extent, we found evidence for individual differences in children's multimedia learning. The short-term advantage of oral presentation over written text was expected to be greater for children with low verbal abilities than for children with high verbal abilities, but this effect was not found, probably because reading comprehension and listening comprehension are related (Aaron, 1991). No differential effects of the inclusion or noninclusion of pictures were found for the children with high or low spatial or verbal abilities although sometimes decorative pictures included in the present intervention may explain the lack of an effect. Interest and prior knowledge also appeared to be somewhat related to individual differences for the children in our study. Those children with high interest and prior knowledge levels showed a direct effect of exposure to an oral versus written presentation and a positive retention effect for exposure to text with supplemental pictures.

The present study revealed modality effects for elementary school children working in a fairly realistic setting with authentic schoolbook texts. However, the modality effects were only visible immediately following intervention. The short-term advantage of the oral presentation of information over the visual presentation of information can be explained by the lighter cognitive load associated with the processing of oral as opposed to written information. In the long run, however, oral presentation may actually lead to poorer

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information storage and learning. One week following the intervention, the different multimedia formats produced similar learning gains in quantitative terms; in qualitative terms, however, the written conditions produced better results than the oral conditions. This finding does not necessarily mean that all multimedia lessons for children should have a written format accompanied by pictures. Perhaps teachers or curriculum designers could build in follow-up tasks that would attempt to solidify the immediate gains of oral presentation so that they may not fade over time, in an effort to maintain its advantage.

At this point, some possible limitations on the present study should be mentioned for consideration in future research. First, the study was done with children of one age group and with one specific type of text and pictures. Some of the pictures used in the present intervention may have been more decorative than intended. Future research should therefore attempt to unravel just how the type of picture contributes to multimedia and modality effects. Second, whether or not the children actually read or listened to the texts and how often they did this was not assessed within the context of the present study. To measure this may be of interest in future research and also to determine the amount of time and attention paid to different types of pictures. Furthermore, the lessons used in the present study were very short and the children still needed more time to study the oral presentations than the written presentations. It is conceivable that longer texts might influence the results and even reverse the observed pattern. Future research should therefore take this possibility into consideration.

Finally, it should be taken into account that teachers and curriculum designers do not simply present a topic once and leave it, as was done in the experimental setting of the present study. A study that looked at how recursive learning might or might not maintain the advantage of oral presentation with pictures advantage would be an interesting next step.

With regard to the practical implications of the present findings, the results speak in favour of the interactive literacy initiatives currently being undertaken by schools and the use of the Internet as a knowledge source (cf. Verhoeven, Segers, Bronkhorst, & Boves, 2006; Bransford, Brown, & Cocking, 2000; Leu & Kinzer, 2000). Most of the information on the Internet involves text with either accompanying pictures or no pictures and these are the conditions that produced the best learning 1 week after the intervention within the present study. By setting standards for high-quality interactive learning environments and testing such environments in the field, additional guidelines for the construction of new software and course materials can be established and thereby the literacy development of children promoted to the greatest extent possible.

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