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A Study on the Learning Efficiency of Multimedia-Presented, Computer-Based Science Information

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ABSTRACT

This study investigated the effects of multimedia presentations on the efficiency of learning scientific information (i.e. information on basic anatomy of human brains and their functions, the definition of cognitive psychology, and the structure of human memory). Experiment 1 investigated whether the modality effect could be observed when the learning material contained auditory information and visuals altered in complexity, and whether the redundancy effect is caused by redundant information or by interference in information processing. In Experiment 2, verbal-only information was used to examine whether subjects could perform better with auditory rather than with on-screen textual information, and whether the length of the verbal information would exert an effect on learning. The results of Experiment 1 contradicted the prediction of the modality effect in that subjects learned no better or even worse with the audio-visual format of learning material than did subjects with the visual-only one. Besides, redundant information per se did not impair learning, which suggested that the redundancy effect could be rather caused by the interference in information processing. The results of Experiment 2 indicated a negative effect of auditory information on learning regardless of the length of the verbal information. No evidence supported the superiority of auditory instructional mode over the visual one.

Keywords

Multimedia presentations, Learning efficiency, Modality effect, Working memory, Cognitive load theory

Introduction

Multimedia presentations are widely used in e-learning environments. Learning material is often presented with text, audio, video, and static pictures, whereby same information is sometimes repeatedly presented by different media. According to the cognitive load theory, when the learning material has high intrinsic load or high element interactivity and when they are presented as text with any kind of visuals, it is better to present texts aurally because the efficiency of information processing in working memory will be enhanced if information is presented in different modalities (i.e. the modality effect). When visuals are combined with text presented visually, learning is impaired because learners have to split their attention between text and visuals, in order to integrate both sources of information (i.e. the split-attention effect). The modality effect and the split-attention effect seem to be repeatedly confirmed in a series of studies conducted by Sweller, Mayer and their co-workers (Mousavi, Low and Sweller, 1995; Sweller, van Merriënboer, and Paas, 1998; Kalyuga, Chandler, and Sweller, 1999; Mayer and Moreno, 1998, 2002; Moreno and Mayer, 1999; Mayer, Moreno, Boire, and Vagge, 1999).

Advocates of cognitive load theory often refer to the studies reviewed by Penney (1989) and the working memory model proposed by Baddeley (Baddeley and Hitch, 1974). However, when examining what exactly those reviewed studies and Baddeley's model indicated, it can be found that the theories claiming the positive effect of dual mode presentation on learning are highly dubious. First, the studies reviewed by Penney actually investigated the nature of short-term retention of verbal stimuli. Typical tasks for the subjects of those studies consisted of the recall of a series of digits or single words. It was found that the auditory stimuli almost always resulted in higher recall than did the visual ones, which was termed the modality effect. Some researchers plead for the superiority of auditory information over the visual one based on their belief in the modality effect. The problem is that remembering digits or a word list greatly differs from normal learning situations in which no such short-term memory but rather the comprehension of the learning material is required. There is actually no valid theoretical basis to apply the observed phenomena in those studies to multimedia learning theory. As Penney already put it in her article "In spite of the large and robust effects of presentation modality found in short-term memory tasks, there was no evidence of any permanent effects on learning, and modality effects in long-term memory tasks were conspicuously absent." (Penney, 1989: 398).

Second, when pictorial material is involved, some theorists referred to Baddeley's working memory model and Paivio's dual coding theory (Paivio, 1986, 1991) to back up their theories. Again, both theories suggested that working memory contains modality- or code-specific processors, but the theories did not indicate that working memory always has more capacity to process information presented in different modalities than if it were presented in the same modality. According to Baddeley's working memory model (Baddeley and Hitch, 1974; Baddeley 2000), working memory consists of a central executive and at least three subsidiary systems – the phonological loop, the visuo-spatial sketchpad, and the episodic buffer (see Figure 1). The central executive is an attentional controller that supervises and coordinates the subsidiary systems in working memory. It was characterized as "a limited capacity pool of general processing resources". The phonological loop has the function of processing speech or printed text, whereas the visuo-spatial sketchpad is responsible for setting up and manipulating mental images. The episodic buffer is assumed to be the place where information from the subsystems of working memory and that from long term memory is integrated. According to Baddeley, "It is assumed to be episodic in the sense that it holds integrated episodes or scenes and to be a buffer in providing a limited capacity interface between systems using different codes… This allows multiple sources of information to be considered simultaneously, creating a model of the environment that may be manipulated to solve problems and plan future behavior" (Baddeley, 2001: 858).

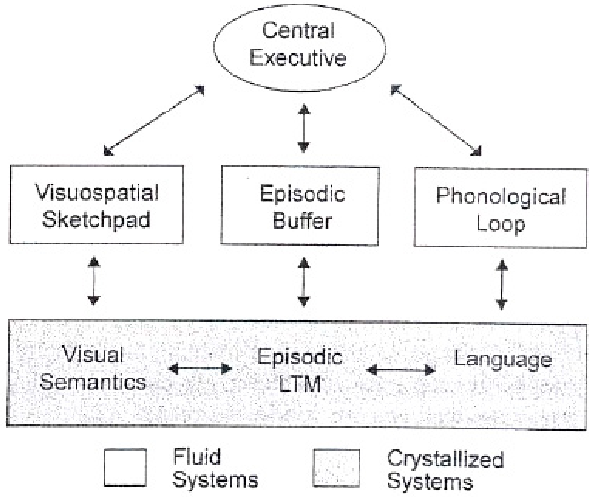

Figure 1. The working memory model by Baddeley (2000: 421)

According to the cognitive theory of multimedia learning (Moreno and Mayer, 2000), when learners simultaneously process pictorial and verbal information, they need to integrate both types of information in the working memory in order to form a mental model based on their understanding of the learning material (see Figure 2). In Baddeley's model, it is the central executive or the episodic buffer that is responsible for integrating information from different subsystems. However, the capacity of the central executive or the episodic buffer is very limited and will not be substantially increased even if the phonological loop and the visuo-spatial sketchpad are simultaneously used to process information.

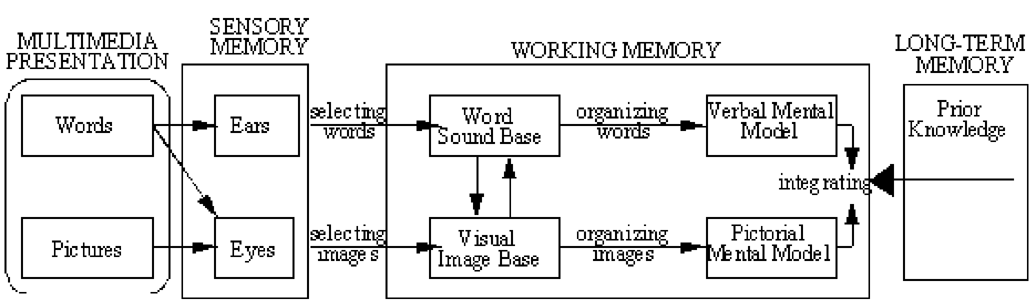

Figure 2. Cognitive theory of multimedia learning (Moreno & Mayer, 2000).

Furthermore, it is not plausible not to associate a split-attention effect with dual mode presentation because the general processing resources of the central executive or episodic buffer need to be shared or divided for processing two types of information at the same time, which certainly leads to a split of attention.

Recently, more and more studies provided results imposing limitations on the modality effect. Tindall-Ford, Chandler, and Sweller (1997) found that the modality effect was only obtained for learning materials with high element interactivity but not for those with low element interactivity. Jeung, Chandler, and Sweller (1997) found that using auditory texts did not improve learning when they were presented together with visually high-demanding diagrams. Tabbers, Martens, and van Merriënboer (2004) even found a reversed modality effect when students were asked to study multimedia-presented learning material on a computer for an hour and were tested subsequently. They concluded that the reversed effect was probably attributed to the relatively long learning time and the self-controlled learning speed. Guan (2003, 2006) found negative effects of dual mode presentations on learning efficiency in a series of multimedia learning scenarios in which subjects were allowed to learn the instructions at their own paces without restricted learning time. Moreover, Ginns (2005) conducted a meta-analysis of the modality effect based on research review and found that the pacing of presentation determines the occurrence of the modality effect. Under system-paced conditions in which the learning time and the playing of audio instructional material were controlled by the experimenters, the modality effect occurred, whereas the opposite effect occurred under self-paced conditions in which learners could control their own learning speed and were not limited in terms of learning time and the frequency of playing of audio instructional material. All the studies mentioned above suggest the need of re-examining the validity of the modality effect proposed by the cognitive load theory and the cognitive theory of multimedia learning.

In terms of the redundancy effect, Kalyuga (Kalyuga, Chandler, & Sweller, 1999, 2000; Kalyuga 2000) found that presenting texts aurally was not beneficial for learning when the same texts were already presented visually, or when the information given in the auditory texts was not useful to the more experienced learners. This phenomenon refers to the redundancy effect. Since redundant information can often be found in multimedia-based learning material, it is necessary to investigate whether learning is impaired simply because some of the information was repeated in different formats or because the presentation mode actually caused interference in information processing. It is assumed that simultaneously presenting the same text visually and aurally can easily cause interference between reading and listening to the text because the speed of reading is usually faster than that of listening. Hence, it is intriguing to examine whether the interference would be eliminated when the speed of presenting visual and auditory text is synchronized. If learning is not impaired in this case, it follows that it is not the redundancy of information that impairs learning but the interference elicited by the simultaneous processing visual and auditory text.

In line with the issues discussed above, this study aimed to investigate whether using dual mode presentation (i.e. audio-visual presentation) could really facilitate the learning of scientific information, whether presenting the same information in two different modalities really impaired learning, whether subjects could learn better with auditory text than with on-screen text, and whether the length of text played a role in this regard. In this study, two experiments were carried out to investigate these issues. Experiment 1 examined the validity of the modality effect and the redundancy effect in the context of learning science information. Experiment 2 investigated whether the modality effect existed for verbal-only information in different lengths. Self-paced learning was adopted for both experiments because it resembles the real e-learning situations more closely.

Experiment 1

The goal of this experiment was to investigate whether using dual-mode presentation really facilitates the learning of scientific information, especially whether the modality effect could always be observed when the learning material contained auditory information with visuals of different complexities, and finally, whether the redundancy effect is simply caused by the presence of redundant information or rather by the interference during information processing.

Materials

Nine different multimedia presentations were used to present the instructional material with the same content about the basic anatomy of human brain and its functions. The nine conditions are as follows: Condition 1 [on-screen text/simple diagram], Condition 2 [on-screen text/medium diagram], Condition 3 [on-screen text/complex diagram], Condition 4 [auditory text/simple diagram], Condition 5 [auditory text/medium diagram], and Condition 6 [auditory text/complex diagram]. In Condition 7 [auditory text/animation], animation was applied to complex diagram as a visual aid in order to examine whether animation could help reduce the load of visual search. Condition 8 [running on-screen text/animation] was adapted from Condition 7 by using system-paced running text instead of the auditory one. Condition 9 [running on-screen text + auditory text/animation] employed system-paced running text and auditory text together with animation. The content of the instructional material consisted of four sections, which was displayed by seven Web pages: (1) the structure of the brain, (2) specific functions of cerebral cortices, (3) the functions of the midbrain and the limbic system, and (4) the coordination and integration of central nervous system. Examples of the instructional material are given in figures 3-6.

Figure 3. An example of the instructional material for Condition 1

Figure 4. An example of the instructional material for Condition 2

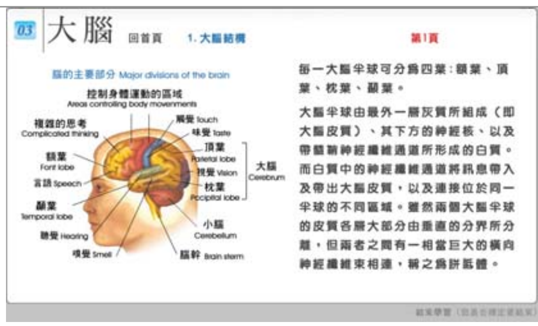

Figure 5. An example of the instructional material for Condition 3

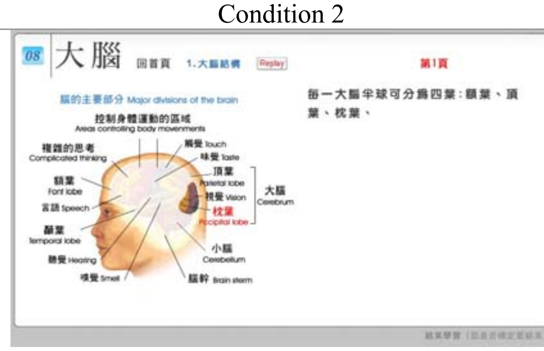

Figure 6. An example of the instructional material for Condition 8

Subjects and Procedures

The subjects were 178 students at a university in Taiwan, whose majors were Applied Linguistics, Physics, Business Administration, or Electrical Engineering. Firstly, they were asked to take a pretest which consisted of 12 multiple choice questions concerning the basic anatomy of human brain and it functions. The test questions were constructed in line with the three criteria of Bloom's taxonomy: knowledge, comprehension, and evaluation. The *knowledge* questions tested subjects' memory of the facts that were explicitly stated in the learning material (e.g. *What is the function of primary sensory cortex?*). The *comprehension* questions, on the other hand, tested whether subjects could translate knowledge into new context and predict consequences (e.g. *If a patient with brain lesion can speak fluently, but his speech is meaningless, and he cannot understand other people's speech, where could the lesion site locate in his brain?*). The *evaluation* questions tested whether subjects could compare and discriminate between ideas (e.g. *Which of the following is not true in terms of the functions of basal ganglia and limbic system?*).

Subsequently, the subjects were randomly assigned to the experimental conditions and were asked to learn the computer-based instructional material at their own pace. While they were learning, their learning time, viewing sequences as well as viewing frequencies were registered by a computer. Although the learning time was not limited, subjects were told that they should concentrate on learning and their learning time would be taken into account for the evaluation of their learning efficiency. A subject could finish learning if he or she had the confidence to take the posttest. To achieve the consistency and reliability of pretest and posttest, the same test was used for both cases, though the subjects were not aware of this before they took the posttest.

The measurement of learning efficiency

If subjects' learning times were not taken into account, the scores of posttest would be the direct measurement of their learning outcomes. However, based on the belief that efficient multimedia presentations should enable learners to process information easily and quickly, I suggest that the learning time should be considered as well. Parallel to my previous studies (Guan, 2003), learning efficiency in this study was calculated as follows:
*Learning efficiency = score of posttest/ learning time (in seconds)*100*

To avoid comparing learning efficiency in fractions, it is multiplied by 100. According to this formula, it followed that learning efficiency was high when the score of posttest was high while the learning time was short.

Hypotheses

If the modality effect occurs, subjects who received auditory information with simple or medium complexity of diagrams should outperform their counterparts, but not if the diagrams are too complex. Using animation as guidance for visual search should reduce the load on visual memory and thus, restore the modality effect (cf. the study by Jeung et al., 1997). Finally, if the redundancy effect exists, presenting the same text both visually and aurally along with animation should greatly impair learning.

Results

The data of some subjects were excluded because they either failed to finish viewing all instructional material or to complete the posttest. The mean pretest scores, mean posttest-scores, the standard deviations, and the number of subjects of Conditions 1 to 6 are given in Table 1. A Levene's test for homogeneity of variances was computed for the pretest scores to examine whether the variances of subjects' performance on pretest did not significantly differ from each other across conditions. The result showed that the difference of variances was not significant ($F(8, 136)=1.453$, $p=0.18$). For conditions 1 to 6, an ANCOVA was computed for two main factors *text mode* (visual vs. auditory) and *picture complexity* (simple, medium, complex) with *pretest score* as the covariate. The result showed that the effect of *text mode* on the posttest scores was significant ($F(1, 102)=4.434$, $p<0.05$, partial$\eta^2=0.042$), whereas the effects of picture complexity and the interaction between the two main factors were not significant. The subjects receiving learning material with on-screen text (mean=6.492, SE=0.216) performed significantly better than their counterparts who received learning material with auditory text (mean=5.822, SE=0.234). Moreover, posthoc tests (Bonferroni) showed no significant difference in posttest scores between the six experimental conditions.

Table 1: The descriptive statistics of Conditions 1 to 6

Condition	Mean pretest score	Standard deviation	Mean posttest score	Standard deviation	Number of subjects
1: on-screen text/simple static	3.29	1.68	6.19	1.29	21
2: on-screen text/medium diagram	3.74	1.76	6.79	1.93	19
3: on-screen text/complex diagram	3.89	1.76	6.53	1.47	19
4: auditory text/simple diagram	3.81	1.52	5.63	2.31	16
5: auditory text/medium diagram	3.11	1.84	5.72	1.60	18
6: auditory text/complex diagram	3.94	2.11	6.12	2.19	16

Nonetheless, when comparing the learning efficiency, significant differences were found between the experimental conditions. Table 2 shows the mean learning efficiency, the standard errors, and the number of subjects of each experimental condition.

Table 2: The mean learning efficiency of Conditions 1 to 6

Condition	Mean learning efficiency	Standard Error	Number of subjects
1: on-screen text/simple static	9.403	0.593	21
2: on-screen text/medium diagram	9.632	0.621	19
3: on-screen text/complex diagram	8.310	0.622	19
4: auditory text/simple diagram	6.524	0.677	16
5: auditory text/medium diagram	6.833	0.642	18
6: auditory text/complex diagram	6.196	0.678	16

The results of ANCOVA showed that the effect of *text mode* on learning efficiency was significant ($F(1, 102) = 24.868$, $p < 0.001$, partial$\eta^2 = 0.196$). The subjects receiving on-screen text (mean=9.125, SE=0.351) learned much more efficiently than their counterparts who received auditory text (mean=6.53, SE=0.381). The effects of picture complexity and the interaction between the two main factors did not reach statistical significance. Posthoc tests (Bonferroni) indicated significant differences between Conditions 1 and 4, Conditions 1 and 6, Conditions 2 and 4, Conditions 2 and 5, Conditions 2 and 6.

In order to find out whether using animation could reduce the load of visual search and create a certain modality effect, the performance of subjects in Conditions 6 and 7 was compared. According to ANCOVA, the use of animation did not exert an effect on the learning efficiency of those subjects. The subjects receiving the complex diagrams (n=16, mean=6.429, SE=0.504) performed slightly better than those receiving animated complex diagrams (n=10, mean=5.445, SE=0.637), but the difference was not significant.

Furthermore, for examining whether the redundancy effect was simply caused by presenting redundant information, the performance of subjects in Conditions 8 and 9 was compared. The result of ANCOVA showed that the effect of using redundant information on learning efficiency was statistically not significant but reached a certain practical significance ($F(1, 23)=2.489$, $p=0.13$, partial$\eta^2 = 0.098$, effect size: medium. According to Cohen (1973), Thompson (2006) and Vacha-Haase & Thompson (2004), the effect size is medium when partialη^2 is larger than 0.06 and smaller than 0.14). The subjects in Condition 8 (n=14, mean=6.483, SE=0.548) tended to perform worse than the subjects in Condition 9 (n=12, mean=7.793, SE=0.594), which contradicted the redundancy effect.

Finally, subjects' performance on answering the three types of questions – knowledge, comprehension, and evaluation – was analyzed. A series of ANCOVA analyses with the main factor *instruction mode* and pretest scores as the covariate were computed. The results indicated that the effect of instruction mode on the scores of *knowledge* was significant ($F(8, 133)=2.936$, $p< 0.01$, partial$\eta^2 = 0.15$). Posthoc test (LSD) showed that the subjects of Condition 4 achieved much lower scores on knowledge questions than did the subjects of other conditions. (mean=2.129, SE=0.23, mean accuracy rate: 42.58%. The mean accuracy rate was calculated by dividing the mean score on knowledge by the total score on knowledge. Subsequent mean accuracy rates followed the same pattern). No significant difference was found among subjects of other conditions and the overall mean score of *knowledge* was 3.05 with the mean accuracy rate of 61%. Moreover, the effect of instruction mode on the scores of *comprehension* was significant ($F(8, 133)=2.63$, $p<0.01$, partial$\eta^2 = 0.139$), whereas that on the scores of *evaluation* was not. The overall mean score of *comprehension* was 2.39 with the mean accuracy rate of 59.64%, and that of *evaluation* was 0.92 with the mean accuracy rate of 30.7%. Posthoc test (LSD) showed that the subjects of Condition 9 achieved significantly higher scores on comprehension questions (mean=3.325, SE=0.277, mean accuracy rate: 83.13%) than did the subjects of other conditions.

Discussion

In this experiment, subjects were allowed to learn the information without a time limit. Since the learning time was not equal across the subjects, I suggest that it is more meaningful to compare the learning efficiency rather than comparing the posttest scores. For one, the effects of different instruction modes on learning could not be revealed because subjects could spend longer time to compensate for the weakness of certain instruction modes. For another, a truly beneficial instruction mode should enable learners to learn efficiently, i.e. achieve the learning goal with as little learning time as possible. As the results demonstrated, when the learning time was not considered, the posttest scores alone were not able to distinguish subjects' learning performance across the conditions. It is therefore legitimate and more meaningful to compare the learning efficiency instead of only comparing the posttest scores. In the following, I shall focus on discussing the results in regard to learning efficiency.

The results of Experiment 1 contradicted the modality effect in that the subjects who received auditory instructions combined with simple or medium complexity of diagrams performed significantly worse than the subjects who received the same diagrams combined with on-screen text instructions. When the diagrams were complex, no significant difference was found in the performance between subjects receiving on-screen or auditory text. With regard to the effect of animation, the result indicated that the use of flash movie did not successfully assist visual search and did not reduce the load of visual memory because the subjects of Condition 7 performed no better than those of Condition 6.

Furthermore, it is interesting that the subjects of Condition 9 tended to achieve higher learning efficiency than did the subjects of Condition 8. This result indicated that the redundancy effect was not simply caused by presenting redundant information to the learners. It is assumed that the speed of running on-screen text was synchronized with that of the auditory text, and as a consequence, it was not difficult to follow the instructional information. By contrast, if the on-screen text was not running, or if the speed of both (visual and auditory) texts was not synchronized, strong interference would impair the processing of information. Nevertheless, how subjects actually processed the information of animation, running on-screen text and auditory text simultaneously, and how they benefited from these presentations, remain unclear. The possibility that the synchronized presentation of running on-screen text and the auditory text might enhance memory cannot be ruled out. Further investigations are certainly required to clarify this issue.

Finally, subjects' performance on the three types of questions indicated that subjects' performance on knowledge questions was the best, which was only slightly better than that on comprehension questions but substantially better than that on evaluation questions. It should be noted that subjects' performance on *comprehension* items was very close to that on *knowledge*, which clearly demonstrated that the subjects did not just memorize the content of the learning material but also achieved deeper understanding of the content, i.e. a higher level of learning. The most interesting result was that the subjects of Condition 9 outperformed all other subjects in comprehension questions. It seems that using system-paced running on-screen text with synchronized auditory text and animation helped subjects achieve deeper understanding of the learning material. The subjects of Condition 4 did not perform well on knowledge questions. This could be due to the fact that information provided in simple diagrams was either sparse or more scattered. Thus, it might be difficult for the subjects to integrate the pictorial information with the auditory information during learning.

Experiment 2

The objective of Experiment 2 was to investigate whether subjects could perform better with auditory rather than with visual information when verbal-only material was provided, and whether the length of verbal information would exert an effect on learning.

Materials

The learning material contained two topics: one was about the definition of cognitive psychology, which consisted of 182 Chinese characters, whereas the other one was concerned with the structure of human memory, which comprised 607 Chinese characters. Each topic was presented by a single web page. Two presentation modes were employed: auditory versus visual. Examples of the long and the short instructional material presented by on-screen text are shown in Figures 7 and 8.

Subjects and procedures

The subjects were 165 students who also participated in Experiment 1. They were randomly assigned to one of the experimental conditions. Due to the amount of headphones available in the computer lab, more subjects were recruited for the on-screen condition (n=93) than for the auditory one (n=72). The subjects were asked to learn the information of both topics that were presented by one of the presentation modes. They were allowed to learn at their own pace with the learning time registered by computer. They took pretests and posttests for assessing their levels of knowledge before and after learning the information. For the condition with longer information both pre- and posttest consisted of eight multiple choice questions, whereas for the condition with shorter information both tests contained three multiple choice questions. The questions of those tests were based on two criteria of Bloom's taxonomy: knowledge and evaluation. Examples of *knowledge* questions for long and short instructional condition are as follows: *"What is the primary form of encoding in short-term memory?"*, and *"What is cognition?"*, whereas the examples of *evaluation* questions for each condition are: *"Which of the following has nothing to do with amnesia?"*, and *"Which of the following is not studied in the field of cognitive psychology?"*.

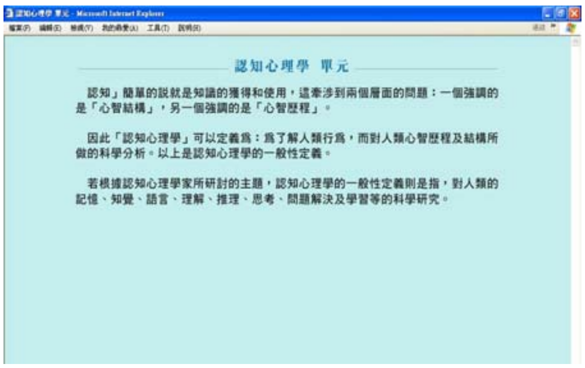

Figure 7. The instructional material on the definition of cognitive psychology.

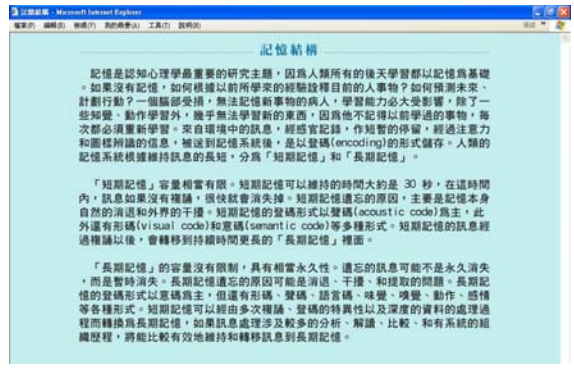

Figure 8. The instructional material on the structure of human memory.

Results

For the long instructional conditions, the data of some subjects were excluded because the subjects failed to finish their posttest. Table 3 showed the mean pretest and posttest scores, the standard deviations, and the number of subjects of on-screen text and auditory text conditions.

Table 3: The descriptive statistics of the long instructional conditions

Condition	Mean pretest score	Standard deviation	Mean posttest score	Standard deviation	Number of subjects
on-screen text	4.45	1.37	6.65	1.10	92
auditory text	4.20	1.45	6.02	1.21	65

To make sure that the unequal number of subjects did not bias the results, a Levene's test for homogeneity of variances was computed for the pretest scores. The result indicated that the variances of subjects' performance on pretest of both conditions were roughly the same ($F(1, 155)=0.107$; $p=0.744$). An ANCOVA was then computed for the main factor presentation mode (on-screen vs. auditory) with the pretest score as the covariate. The result showed that the effect of presentation mode on the posttest scores was significant ($F(1, 154)=10.435$, $p<0.005$, partial$\eta^2 =0.063$). The subjects who learned with on-screen text outperformed their counterparts.

Moreover, when comparing subjects' learning efficiency between the two conditions, the result indicated that the effect of presentation mode on the learning efficiency was significant ($F(1, 154) = 47.80$, $p < 0.001$, partial$\eta^2 =0.237$). The subjects who learned with on-screen text performed significantly better than the subjects who learned with auditory text. The mean learning efficiency, standard error and number of subjects of the two conditions are given in Table 4.

Table 4: The mean learning efficiency of the long instructional conditions

Condition	Mean learning efficiency	Standard Error	Number of subjects
on-screen text	5.97	0.266	92
auditory text	3.10	0.317	65

The analysis of subjects' performance on the two types of questions showed that the effect of presentation mode on *knowledge* was significant ($F(1, 153)=15.477$, $p<0.001$, partial$\eta^2=0.092$) while that on *evaluation* was not. The subjects learned with visual text (mean=5.311, SE=0.092, mean accuracy rate: 88.52%) outperformed their counterparts (mean=4.749, SE=0.109, mean accuracy rate: 79.15%) in terms of answering *knowledge* questions.

For the short instructional conditions, the data of 10 subjects of on-screen text condition were further excluded because they also failed to finish the posttest. Table 5 shows the mean pretest score, the mean posttest score, the standard deviations, and the number of subjects of the on-screen and auditory text conditions.

Table 5: The descriptive statistics of the short instructional conditions

Condition	Mean pretest score	Standard deviation	Mean posttest score	Standard deviation	Number of subjects
on-screen text	1.18	0.61	1.76	0.56	82
auditory text	1.05	0.65	1.86	0.46	65

According to the Levene's test for homogeneity of variances, the variance of subjects' performance on pretest of both conditions did not differ significantly ($F(1, 145)=0.67$; $p=0.414$). An ANCOVA was computed for the main factor presentation mode (on-screen vs. auditory) with the pretest score as the covariate. The result showed that the effect of presentation mode on the posttest scores was not significant. However, when comparing the learning efficiency, the result of ANCOVA indicated that the effect of presentation mode on the learning efficiency was significant ($F(1, 144)=20.85$, $p<0.001$, partial$\eta^2=0.126$). The subjects who learned with on-screen text significantly outperformed the subjects who learned with auditory text. Table 6 shows the mean learning efficiency, standard errors and number of subjects of each condition.

Table 6: The mean learning efficiency of the short instructional conditions

Condition	Mean learning efficiency	Standard Error	Number of subjects
on-screen text	4.22	0.283	82
auditory text	2.27	0.318	65

Subjects' performance on answering the two types of questions indicated that *presentation mode* did not have any effect on their performance on *knowledge* or *evaluation*. The overall mean score of *knowledge* was 0.77 with a mean accuracy rate of 38.25%, and the mean score of *evaluation* was 1 with a mean accuracy rate of 50%.

Discussion

The results of Experiment 2 clearly showed that the auditory presentation mode of text did not produce any superiority in learning over the on-screen presentation mode, regardless of the length of text. Instead, negative effects were constantly found with the auditory text. In line with these results, the alleged superiority of auditory text was not confirmed in this study.

Subjects' performance on the two question-types indicated that for the long instruction conditions, subjects learning with visual text could more correctly recall the facts about the learning material in comparison to the subjects learning with auditory text. This is clear evidence against the modality effect proposed by the cognitive load theory. For the short instructional conditions, however, no significant difference was found between subjects' performance on answering the two types of questions, which indicated that even short auditory text could not exert any positive effect on recalling or judging the facts given in the text.

General Discussion and Conclusion

In this study, the modality effect and the redundancy effect were examined. The results of both experiments showed no evidence supporting the benefit of using dual mode presentation for instructional material. Instead, counter-evidence was repeatedly found when comparing subjects' posttest scores and learning efficiency: dual mode presentation yielded either negative or no effect on subjects' posttest scores and learning efficiency. These findings seem to be consistent with those of the studies allowing self-paced learning with unlimited learning time. As Tabbers et al. (2004) found a reversed modality effect in their study, they concluded that the reversed effect was probably due to the relatively long learning time and the self-controlled learning speed. In line with this, the results of the current study along with those of my previous research and the studies reviewed earlier indicate that the modality effect is probably only observable under highly controlled experimental conditions in which learners are asked to learn a short piece of information with a limited fixed learning time. When the learning material is longer, and when students can learn the instructional material at their own pace, a negative effect can readily be found with dual mode presentation. Another important finding of this study was that the modality effect observed in the short-term verbal memory studies cannot be legitimately applied to multimedia-based learning scenarios in which subjects are required to comprehend and learn meaningful subject matter.

In terms of the redundancy effect, it was found that the presence of redundant information alone did not impair learning. Since the speed of self-running on-screen text was synchronized with that of the auditory text, it seems that the processing of visual and auditory text did not interfere with each other but was harmonized or even reinforced. Further studies need to be done to examine more exactly how learners process redundant and non-redundant information at the same time. The overall results of this study suggest that educational practitioners need to think seriously about the effects of multimedia presentations on learning efficiency. Especially, the use of dual-mode presentation as an instructional format should be considered cautiously, or it may only impair learning.

While the present study reveals interesting results, some limitations may exist in this study. For one, the subjects were all Taiwanese first-year university students with different majors that are not related to neuroscience, cognitive science or cognitive psychology. Whether the same result patterns could be replicated with students whose majors are related to the subject matter to be learned is unclear. For another, all subjects in this study speak Mandarin, a logographic language, which is different from alphabetic languages. It is important for future studies to further investigate whether the interaction between the simultaneous processing of auditory and visual verbal information would be different depending on the nature of the language.

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