Effect of Pointer Presentation on Multimedia E-Learning Materials

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Abstract: The content development method is one of the most important research topics in e-learning, and this paper assumes the dual-channel model of information processing and presents the results of experiments testing the hypothesis that the information presented by visual content (text, still images) synchronized with audio content (narration) will be comprehended better when a pointer is used to guide the learner's fixation point. Results of memorization tests and content-understanding tests given after e-learning with various content-presentation formats (narration, text with/without narration, still images, still images plus text with/without narration, video, and video plus text) show that the learner's acquisition of deep knowledge but not superficial knowledge is facilitated when a pointer is used in the presentation of multimedia content.

1. Introduction

Developing effective content is the very important research topic in e-learning, and educational psychologists have long thought that new information should be presented in a way that minimizes the cognitive load on the learner's working memory. Sweller and Chandler (1994) and Sweller (1999) differentiate between the intrinsic cognitive load due to the difficulty of the material and the extraneous cognitive load due to the method of presentation. The intrinsic cognitive load is large when the difficulty of the material is not suitable for the level of the learner, and the extraneous cognitive load is large when the material is not presented well (poorly written explanations, small lettering, unclear illustrations, etc.). In this paper we are concerned wit the effectiveness of presentation rather than with the inherent difficulty of the teaching materials and will use the term "cognitive load" to mean the extraneous cognitive load.

Mayer (2001), the leading authority on multimedia instructional materials, defines multimedia instruction as "a method for simultaneously presenting visual content (text, pictures, video) and sound content (narration)" and emphasizes that multimedia material can reduce the extraneous cognitive load on a studying learner.

A theoretical foundation for multimedia is provided by the dual-channel model proposed by Paivio (1986), which posits that human beings process audio and visual information in two independent channels, each with its own working-memory capacity. Not only is a learner's working-memory capacity therefore best exploited by using these two channels at the same time, synchronized information in the two channels is transmitted more effectively that either the audio or visual information alone. Mayer (1989) and Mayer and Gallini (1990) obtained better recall-test results when combining still images with annotated text, and Clark and Paivio (1991) showed that scores in recall tests were significantly higher when still images and narration had been simultaneously than they were when only still images had been presented. Mayer and Anderson (1992) also found that learning results were better when narration and video contents were presented together that when only one was presented. Finally, Mayer and Moreno (1998) showed that recall scores wee higher after the presentation of narration synchronized with video than they were after the presentation of text synchronized with video. The above research demonstrates that multimedia materials that present visual content temporally synchronized with sound content optimize the allocation of cognitive resources and promote comprehension.

Synchronization between audio and visual contents is therefore thought to be an important characteristic of effective multimedia material. Comparing the case in which the learner listened to narration synchronized with video with the case in which the learner listened to narration before and after the video, Mayer and Anderson (1991) found that the former produced significantly better scores in recall tests. These results underscore the importance of synchronized presentation of visual and sound content. In addition, Mayer et al. (1995) compared the presentation of a still image and its corresponding text in close proximity to each other with that of a still image and text separated from each other and found that the former produced better recall-test results. Similarly, Moreno and Mayer (1999) showed that presenting video close to its corresponding text produced better recall-test results than presenting video separated from its corresponding text. Accordingly, it is important that visual content in the form of still images and related text are presented adjacent to each other on the same page or screen. In other words, the spatially synchronized presentation of visual content is important.

In actual multimedia materials, however, the learner may not be able to temporally and spatially synchronize the media and may not be able to determine exactly what within the visual content the sound content is talking about. In such a cases, not only will the auditory and visual channels fail to interact occur but the learner will also have to use a considerable amount of cognitive resources to determine where the audio and visual should be synchronized. A considerable amount of content comprehension is consequently lost. A common solution to this problem is to present a pointer synchronized with the audio and visual contents so as to control the learner's point of fixation and thereby synchronize these contents temporally and spatially. Shimizu et al. (1981), for example, have shown that the degree to which the fixation point of students can be controlled differs significantly depending on whether or not some form of pointer is used when making presentations in an ordinary classroom. And Mochida et al. (1996) have shown that significantly higher test scores are obtained after a pointer was used.

In this paper, we analyze and model in more detail the features and advantages of pointer presentation in multimedia materials based on the dual-channel model. We show that pointer presentation promotes comprehension not only by activating the interaction between audio and visual content but also by reducing the cognitive load for temporally and spatially synchronizing multimedia and by allocating working-memory resources more efficiently. The previously reported experiments were all conducted in group-presentation environments, and Sato and Akihori (2005) have pointed out that focusing attention in a group-presentation environment enhances the social presence and affective learning of learners and that such an environment differs from the independent-learning environment common in e-learning. It is therefore necessary to test whether the empirical results introduced above can be applied to an e-learning environment.

We also describe a controlled experiment that we performed with and without pointers in e-learning environments with content presented (to 130 learners) in various ways: narration only, text with and without narration, still images only, still images plus text with and without narration, video only, and video plus text. We measured the learner's point of fixation by using an eye-mark recorder, gave memory-retention and content-comprehension tests, and evaluated questionnaire responses.

2. Multimedia Materials and the Dual Channel Model

Mayer (2001) defines multimedia materials as "materials that simultaneously presents visual content (text, pictures, and video) and sound content (narration)" and presents comprehension and retention test results showing that multimedia materials improve comprehension and retention. The effectiveness of multimedia materials can be a dual-channel model in which audio and visual information are processed in channels whose capacities are independent of each others' (Fig. 1) (Clark and Paivio 1991, Paivio 1986). Accordingly, the working-memory capacity available to a learner is exploited most effectively by using the two channels simultaneously.

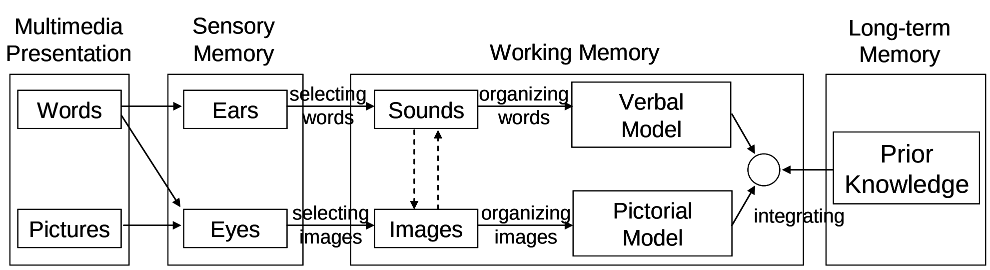

Figure 1: Dual-channel model

For example, information presented in the form of narration (spoken words) and pictures would be processed as follows. A learner hearing words and constructing a verbal mental model via the auditory channel also generates from those words pictorial code that is used in the visual channel to help construct a pictorial mental model. At the same time, the learner is seeing pictures and constructing a pictorial mental model via the visual channel while also generating from those pictures verbal code that is used in the auditory channel to help construct the verbal mental model. The interaction between the verbal and visual channels improves comprehension by making the allocation of cognitive capacity more efficient.

3. Cognitive Resource Efficiency Improvement with Pointer

Efficient interaction between the information being processed in the auditory and visual channels will occur only when the two kinds of information are synchronized. If the learner does not understand what part of a picture the narration concerns, comprehension will be impaired not only because mutual interaction not occur but also because part of the learner's cognitive capacity will be used to search for correspondences between the two kinds of information.

This paper proposes that controlling the learner's fixation point by using a pointer synchronized with audio and visual contents will improve comprehension and retention because it will reduce the cognitive load and enable working-memory capacity to be allocated more efficiently.

4. Experiment

4.1 Experimental Overview

We checked for synchronization between audio and visual information by using an eye-mark recorder (NAC EMR-8, Tobli X50 eye tracker) to measure a learner's fixation point during e-learning sessions in which content was presented on the display of a personal computer. After the sessions we tested the learning and gave the learners (130 college and graduate students) questionnaires so we could evaluate their opinions of the multimedia content.

During the lesson, the subject was asked to perform no operations or tasks other than view the e-learning content displayed on the monitor.

4.2 Experimental Content

The content of the teaching material used in experiment 1 was "Principles of lightning formation" that of the material used in experiment 2 was "Footbrakes in automobiles," and that of the material used in experiment 3 was "Mechanisms of AMEDAS (Automated Meteorological Data Acquisition System)."

In each of these experiments the same content was presented in different formats (see Figure 2). The features of these content formats are summarized below.

1. Text: Presents the content of the sentences that would be heard as narration. As shown in (1) of Fig. 2, no summarizing, demarcating, color coding, etc. are performed here. This format can have three patterns: text and synchronized narration, text and synchronized narration with a pointer, and text to be read silently without narration. In the case of silent reading, the screen is displayed and switched to the next page with the same timing as that of narration playback.
2. Still images: These consist of pictures, conceptual diagrams, photos, etc. As shown in (2) of Fig. 2, they may include annotation. This format can have two patterns: synchronized narration with or without a pointer.
3. Still images plus text: As shown in (3) in Fig. 2, text corresponding to the narration is displayed next to the images. This format can have three patterns: synchronized narration with or without a pointer, and silent reading with no narration. In this content format the pointer is displayed over images.
4. Video: As shown in (4) in Fig. 2, mechanical and phenomenological operations are described by animation or video material synchronized with narration. There are two patterns here: pointer or no pointer. In this format the pointer location is synchronized with immediate subject of the narration.
5. Video plus text: As shown in (5) in Fig. 2, text corresponding to the narration is displayed as subtitles corresponding to the immediate content of the video.
6. Narration only: Only audio information in the form of a narration is presented here with no visual content other

than a warning message as shown in (6) of Fig. 2.

All content was prepared in Flash format. The content playback time was 3 minutes, 19 seconds for experiment 1; 1 minute, 54 seconds for experiment 2; and 2 minutes, 22 seconds for experiment 3. The pointer format used in this experiment was the same as the red, arrow-type of mouse cursor.

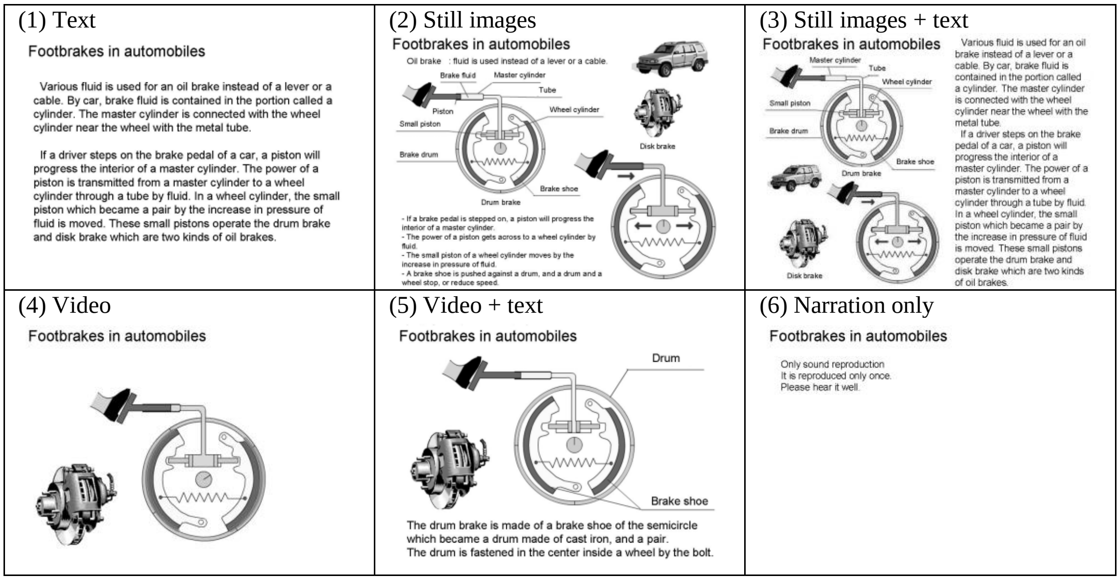

Figure 2: Content screens

4.3 Experimental Procedure

One of the patterns listed in Table 1 was assigned to a subject, who the put on an eye-mark recorder and proceeded to view the lesson in question. In this design, each subject studied content with a pointer once and 30 subjects were assigned to each content presentation pattern of each experiment. Study time was limited to the content playback time (i.e., subjects could not repeat lessons).

The subjects were given two types recall tests after the experiments

- Memory test: Subjects were quizzed on terminology and other items appearing in lessons. 1 point per question.

Example of problem: Lightning occurs from a difference in (   )

- Comprehension test: Subjects were asked to describe operational details and principles. It was thus a test of deep-level understanding. The answers were in essay form and 10 points were given for a perfect answer. Model answers are generated from the narration (or, the corresponding text) of contents, and it is divided into the clause of n piece significant.

Example of problem: Explain the mechanisms behind the generation of lighting and thunder.

Table 1: Content Patterns (P Indicates Pointer-Presentation Content)

Pattern	Experiment 1	Experiment 2	Experiment 3
1	Text (no audio)	Still images	P + video + text
2	Still images + text (no narration)	Text	P + video
3	Narration only	P + video	P + still images + text
4	Text	Video + text	P + still images
5	Still images	Text (no audio)	P + text
6	Still images + text	P + video + text	Text
7	Video	P + text	Still images
8	Video + text	P + still images	Still images + text
9	P + text	Still images + text (no narration)	Video
10	P + still images	Narration only	Video + text
11	P + still images + text	Video	Narration only
12	P + video	Still images + text	Still images + text (no narration)
13	P + video + text	P + still images + text	Text (no audio)

It should be pointed out here that a subject could not pass the comprehension test by just memorizing terminology and not understanding the lesson content. This comprehension test was designed to evaluate the model-integrating process in Fig. 1 given the promotion of pointer presentation in this paper. For each experiment there were 19 memory-test questions and 4 comprehension–test questions. Subjects were given 20 minutes to complete each test. Questionnaires on content were given to each subject immediately after the experiment, and a memory retention test was conducted three days later.

5. Results

5.1. Effectiveness of Multimedia Learning Material Based on the Dual-Channel Model

Figure 3 shows bar graphs indicating the average percentages of correct responses in tests of all contents given to subjects after the experiment. T-testing the significance of the differences between the test results for narration-only content and text-with-no-narration content, we found the results of the memory tests to differ significantly at the 5% level (df=58, d=8.36, t=2.04, $p<0.05$) and those of the comprehension test to differ significantly at the 10% level (df=58, d=7.34, t=1.45, $p<0.10$). Simizu (1993) also shows the comparable result in the presentation situation.

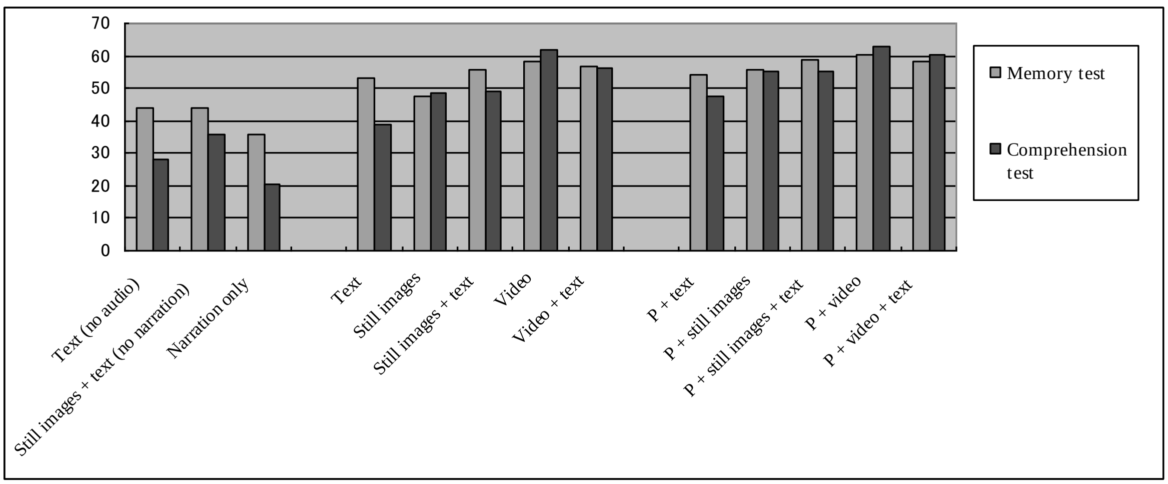

Figure 3: Recall-test scores (P indicates pointer-presentation on content)

Next, we combined still images with these contents, and we performed a t-test against the difference of the mean value of the test result of still images + text without narration content and still images with narration content. Then, it was shown that the correct answer rate of the still images contents with narration was higher in the significance level 5% (df=58, d=12.57, t=2.42, $p<0.05$) for the comprehension test. In the previous analysis result, the test result only of visual contents was better than that only of sound contents. However, it was shown to reverse the test result only by adding still images contents to them. Because the dual-channel model posits independent working-memory capacities in the auditory and visual channels, these results can be interpreted as indicating that information presented in visual + visual formats concentrates in the visual channel when and exceeds the working-memory capacity of that channel. That is, we were able to present the result of improving the validity of the dual channel model that had not been shown in the early research.

5.2. Synchronization of Visual Contents and Narration with Pointer

Figure 4 shows examples of time-sequence data for pointer movement over certain content, fixation-point locus with pointer, and fixation-point locus without pointer. The vertical axis represents fixation-point coordinates (unit: pixel), the horizontal axis represents time (sec), and the black and gray plots respectively indicate the X and Y coordinates of the subject's fixation point. Here, pointer movement is determined by the content creator and as such can be treated as a standard reflecting the intentions of the creator. For example, it can be seen in Fig. 4 that subject's fixation point conforms more closely to the standard when a pointer is used than it does when a pointer is not used.

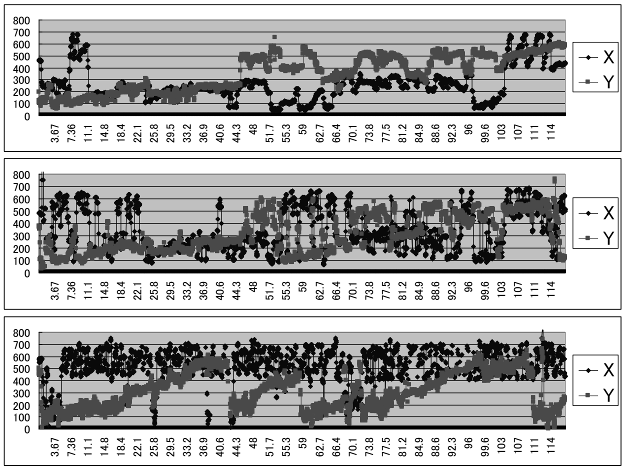

Figure 4: Examples of fixation-point coordinate data
(Top: pointer movement; middle: fixation-point locus with pointer; bottom: fixation-point locus without pointer)

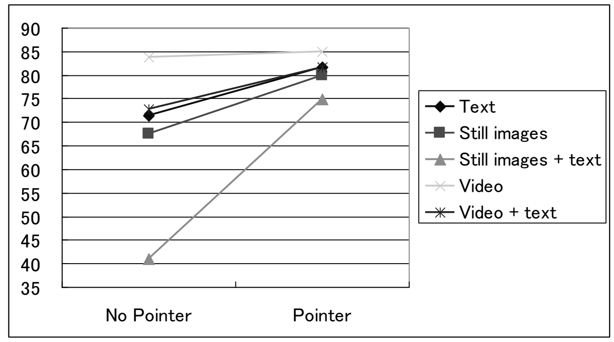

Figure 5: Ratio of stationary fixation-point time by content format.

Table 2: F-test of square-error ratio between pointer and fixation point

	No Pointer	Pointer
Average	72792.553	38860.022
Variance	894614107.6	375472770.7
Number of observations	73	68
Degree of freedom	72	67
Variance ratio	2.383	
P(F<=f) one-sided	0.0002	
F boundary value, one-sided	1.491	

Table 3: Result of Multiple Comparison for Contents Presented without a Pointer

	Test statistics HSD	Mean difference d	Significance
1−3	13.97	30.33	p<0.05
1−4	−5.77	−12.53	p<0.05
2−3	11.94	26.47	p<0.05
2−4	−7.40	−16.40	p<0.05
3−4	−19.14	−42.86	p<0.05
3−5	−14.33	−31.74	p<0.05
4−5	5.02	11.12	p<0.05

To measure pointer effects across all data, we performed an F-test on the difference in square error of the distance between pointer movement data and all subject fixation-point movement data for the pointer and no-pointer groups. However, at this time, the data of the narration only, text (no narration) and still images + text (no narration) doesn't contain in no-pointer groups. Table 2 lists the results of this test. The difference in the distance between subject fixation point and the pointer is smaller in the significance level 1% when a pointer is used compared to the case of no pointer. This result indicates that the use of a pointer can control a learner's fixation point but does not assure that the learner sees the part that the contents that the content creator intended. Even if the distance between the pointer and the fixation point is small, it is possible that the learner does not see the intended part. Then, we used learner's fixation-point movement data to determine what ratio of the content playing time the learner's fixation point lies at the part of the clause and the image that the pointer showed. The measurement was done visually. If the learner was gazing at a correct part (the intended clause the text), it was judged correct answer. Then, there is a possibility that the standard changes depending on those who measure it. However we are measuring it like keeping the consistency of the criteria in the experiment. For instance, In the video format of experiment 2 shown in Figure 2, if there is a fixation-point in "Person's foot" or "Brake that touches it" when the narration is "When stepping on the brake pedal of the car," we judge the correct answer, and judge the rest to be a wrong answer. An analysis of variance was done by two factors (the presence of the pointer and the contents format) about the ratio to the playing time of the measured contents fixation-point time. Figure 5 shows the result of an analysis of variance. As a result, there was a significant difference of the significance level 1% for a contents (df=(4, 219), F=105.37, p<0.01) and pointer factor (df=(1, 219), F=246.40, p<0.01), and there was not interaction (df=(4, 219), F=－146.95, p>0.10). When the factorial effect is evaluated in two factor analysis of variance, the multiple comparison of one factor might be applied. When there are five levels per two factors as there were in this experiment, however, decentralization in the factor grows compared with the decentralization between factors, and there is often no difference between factors. We tested the effect of the presence of the pointer of each contents form by t-test often used. As a result of the t-test, in all contents except the video contents, the fixation-point time of the learner to the part that had been intended with the pointer in the significance level 1% became long (text: df=46, d=10.31, t=6.95, p<0.01, still images: df=43, d=12.55, t=5.26, p<0.01, still images + text: df=42, d=33.89, t=13.62, p<0.01, video + text: df=46, d=9.00, t=5.33, p<0.01). However, the reason why the effectiveness of the pointer is not confirmed in the video contents is interpreted as the effect of a similar pointer is caused because video can be created to control learner's fixation point. To confirm this, we performed multiple comparison against the fixation point time between contents without the pointer by the Tukey’s honestly significant difference test. Table 3 shows the result in the significance level 5% or less with a significant difference. Incidentally, the number in the table corresponds (1-5) to the contents form in chapter 4.2. The video contents were gazed at long time by the significance level 5% than other contents, and the above-mentioned character of the video contents was confirmed.

The above results demonstrate that a pointer is an effective means of controlling subject fixation point. They thereby are consistent with the premise that a pointer reduces the learner’s cognitive load caused by the searching for visual information in multimedia materials and helps to synchronize the auditory and visual channels.

5.3. Learning Effect with Pointer

Effect of a Pointer on Memory Retention and Content Comprehension

We performed an analysis of variance on results of the memory and comprehension tests against the two factors of content presentation format and pointer use. Figure 6 shows analysis results for the memory tests, and Figure 7 shows analysis results for the comprehension tests. In the memory test there was a significant difference of the significance level 5% for a contents (df=(4, 290), F=3.11, p<0.05) and pointer factor (df=(1, 290), F=4.22, p<0.05), and there was not interaction (df=(4, 290), F=－0.95, p>0.10). In the comprehension test there was a significant difference for a contents (df=(4, 290), F=10.34, p<0.01) and pointer factor (df=(1, 290), F=6.70, p<0.05), and there was not interaction (df=(4, 290), F=－5.28, p>0.10).

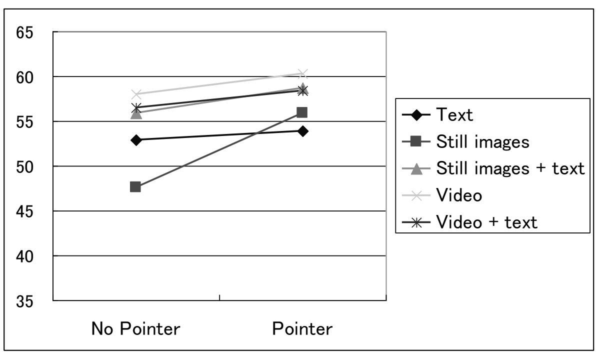

Figure 6: Difference in memory-test scores for contents learned with and without a pointer.

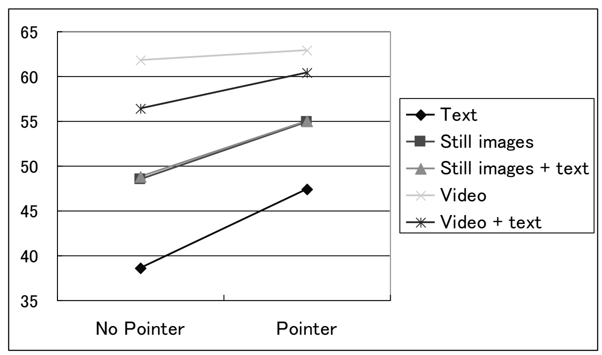

Figure 7: Difference in comprehension-test scores for contents learned with and without a pointer.

In addition, we performed multiple comparison against each of two test results of contents without the pointer by the Tukey’s method. Table 4 shows the result in the significance level 5% or less with a significant difference. In the memory test, only the image contents of the correct answer rate were the lowest in the significance level 5%, and the difference was not seen in another contents. This result shows that the difference between contents is hardly seen in a simple memory. [Note: Unclear.] On the other hand, in the comprehension test, the correct answer rate rose in the significance level 5% in order of contents that use video, contents that use still images, and text contents.

Moreover, we performed multiple comparison against each of two test results of contents with the pointer by the Tukey’s method. Table 5 shows the result in the significance level 5% or less with a significant difference. In the memory test, there is no significant difference in all contents. However, in the comprehension test, the order of the correct answer rate is the same as the case of contents without the pointer. Consequentially, the order of the test result between contents has not been intentionally changed by introducing the pointer.

Next, to examine the effect in the presence of the pointer in each contents form as well as chapter 5.2, we performed a t-test against the difference of the mean value of the test result. As a result, in the memory test, the correct answer rate of the still images contents with the pointer is high in the significance level 5% (still images: df=58, d=8.29, t=2.17, p<0.05). In the comprehension test, the correct answer rate of the text, still images and still images + text contents with the pointer is high in the significance level 10% (text: df=58, d=8.80, t=1.64, p<0.10 still images: df=58, d=6.44, t=1.46, p<0.10 still images + text: df=58, d=6.20, t=1.42, p<0.10). It is necessary to understand not only the memory of a surface word but also the content deeply to answer the comprehension test. Consequently, the experiment result can be interpreted that pointer presentation promoted comprehension not only by activating the interaction between sound and visual content but also by reducing the cognitive load for temporally and spatially synchronizing multimedia and by allocating working-memory resources more efficiently.

Table 4: Result of Multiple Comparison of the Test Results for Contents Presented without a Pointer

	Test statistics HSD	Mean difference d	Significance level
Result of memory test			
2－4	−2.95	−10.47	$p<0.05$
Result of comprehension test			
1－2	−3.14	−9.85	$p<0.05$
1－3	−3.24	−10.17	$p<0.05$
1－4	−7.39	−23.21	$p<0.05$
1－5	−5.65	−17.72	$p<0.05$
2－4	−4.26	−13.37	$p<0.05$
3－4	−4.15	−13.04	$p<0.05$

Table 5: Result of Multiple Comparison of the Test Results for Contents Presented with a Pointer

	Test statistics HSD	Mean difference d	Significance level
1－4	−5.18	−23.21	$p<0.05$
1－5	−3.95	−17.72	$p<0.05$
2－4	−2.98	−13.36	$p<0.05$
3－4	−2.91	−13.04	$p<0.05$

Memory Retention Tested after 3 Days

To show that the effect of the pointer is not temporary, we administered tests again with the same questions three days after. Figure 8 shows two tests scores when retaking the tests three days later for subjects that viewed content with and without a pointer. For the memory test, there was no significant difference (df=150, d=2.91, t=1.26, $p>0.10$）, but for the comprehension test, a significant difference revealed at the 5% level (df=150, d=3.99, t=1.31, $p<0.10$). That is, we see that the pointer was effective in memory retention of not only the working-memory but also the long-term memory.

In addition, there was no significant difference when we performed a t-test against the difference between the following memory and comprehension test result by the pointer or not pointer on immediately after the experiment and three days (memory : df=150, d=0.07, t=0.06, $p>0.10$ comprehension : df=150, d=1.04, t=0.58, $p>0.10$). Moreover, there was no difference through we performed a $\chi 2$-test ($\chi 2$ =0.003, P=0.96). As a result, the presence of the pointer doesn't influence the rate of forgetfulness.

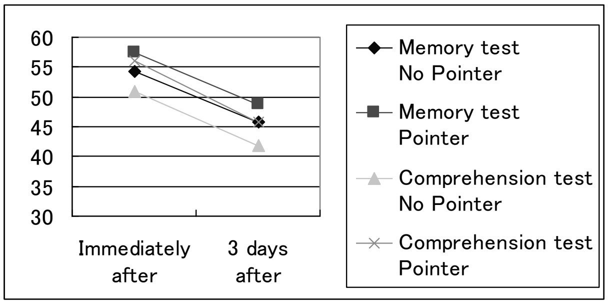

Figure 8: Result of memory retention test after 3 days.

5.4. Questionnaire Results

The questionnaire we used asked about “ease of understanding,” “ease of finding the location that must be viewed,” and “feeling of fatigue while viewing content.” The format of the questions and responses was as follows.

- Evaluate the ease of understanding content presented in the specified format. Use the following scale: 1 for hard to understand, 2 for somewhat hard to understand, 3 for as easy to understand as most things are, 4 for somewhat easy to understand, and 5 for easy to understand.

- Evaluate the ease of finding the location that must be viewed? Use the following scale: 1 for hard to find, 2 for somewhat hard to find, 3 for as easy to find as most things are, 4 for somewhat easy to find, and 5 for easy to find.
- How tired did viewing content make you? (1=tired, 2=somewhat tired, 3=as tired as most things make me, 4=not so tired, 5= not tired)

Table 6 lists the average values of the questionnaire results. The average scores for “ease of understanding,” “ease of finding location that must be viewed,” and “feeling of fatigue while viewing content” decreased n the following order: video > still images > text. Furthermore, the results of a t-test on scores revealing significant differences between use and no use of a pointer for text, still images, still images plus text, and video plus text indicated that pointer presentation makes content easier to understand and follow without fatigue. The results of a questionnaire on the need for a pointer for each type of content are listed in Table 7 (where 1= unnecessary, 2=somewhat unnecessary, 3=cannot say, 4=somewhat necessary, 5=necessary). These results indicate that feel a pointer most helpful when content is presented using still images.

In short, the results of the two questionnaires indicate that a pointer reduces cognitive load while taking an e-learning lesson and thereby increase comprehension.

Table 6: Questionnaire Results (Significant Difference at **1% and *5% Levels)

Content format	Ease of Understanding		Ease of Searching		Fatigue While Viewing	
	No Pointer	Pointer	No Pointer	Pointer	No Pointer	Pointer
Text (no audio)	2.2	—	2.5	—	3.0	—
Still images plus text (no narration)	2.9	—	2.8	—	2.7	—
Narration only	1.2	—	1.0	—	2.2	—
Text	2.2 **	3.2 **	2.0 **	3.7 **	2.9 *	3.2 *
Still images	3.3 *	3.7 *	2.7 **	3.9 **	3.1	3.3
Still images plus text	3.1 *	3.6 *	2.9 **	4.0**	3.0 *	3.5 *
Video	4.0	4.3	4.3	4.5	4.0	4.1
Video plus text	3.9	4.1	3.8 *	4.3 *	3.6 *	4.0 *

Table 7: Questionnaire Results on Need for Pointer Presentation

Content format	Degree of need for pointer
Text	3.6
Still images	4.2
Still images + text	4.1
Video	2.8
Video + text	3.2

6. Summary and Future Issues

Hypothesizing that multimedia materials make the allocation of resources for working-memory capacity more efficient and maximize information propagation by synchronizing the presentation of visual content (text, images) with audio content (narration) and a pointer, we experimentally evaluated the effectiveness of pointer presentation in e-learning environments with content presented in various formats: narration, text with and without narration, still images, still images plus text with and without narration, video, and video plus text. We also measured subject fixation point by using an eye-mark recorder, conducted memory-retention and content-comprehension tests, and surveyed subjects by using questionnaires..

- Analysis confirmed the effectiveness of multimedia leaning material. Test results obtained after the presentation of only visual content were better that those obtained after the presentation of only audio content, but test results obtained after the presentation of audio content accompanied by still images were better than those obtained after the presentation of only visual content.
- Fixation-point data obtained with an eye-mark recorder, confirmed that a learner's point of fixation can be controlled by synchronizing the presentation of audio and visual information and that such synchronization is facilitated by pointer presentation.
- Synchronizing the presentation of audio and visual information was found to increase the learner’s deep understanding but not to facilitate the acquisition of superficial knowledge
- Comprehension tests showed that a learner’s deep–level understanding of content presented in image format is

significantly ($p<0.05$) better that that of content presented in text format, that the a learner's deep-level understanding of content presented in video format is significantly better than that of content presented in image format, and that this order or improvement in a learner's deep-level understanding is independent of whether or not a pointer is used.

- Testing memory retention immediately after e-learning and three days after e-learning showed that pointer presentation improved both working-memory and long-term memory.
- Questionnaire results indicated that a learner's cognitive load is reduced when a pointer is used in the presentation of multimedia teaching material.

We have therefore shown that using a pointer to guide a learner's fixation point reduce cognitive load and efficiently synchronizes the auditory and visual channels of information processing. This synchronization enables working-memory resources to be allocated more effectively and facilitates the comprehension of meaning.

Although we used only one type of pointer format in this study, we think that the effectiveness of a pointer will differ according with the method used to guide the fixation point "line drawing," "circling," etc.). The most effective method remains to be determined.

References

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education, *Educational Psychology Review*, 3, 149–210.

Mayer, R. E. (1989). Systematic thinking fostered by illustrations in scientific text. *Journal of Educational Psychology*, 81, 240–246.

Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *Journal of Educational Psychology*, 83, 484–490.

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology*, 83, 484–490.

Mayer, R. E., & Gallini, J. K. (1990). When is an illustration worth ten thousand words? *Journal of Educational Psychology*, 82, 715–726.

Mayer, R. E., Steinhoff, K., Bower, G., & Mars, R. (1995). A generative theory of textbook design: Using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development*, 43, 31–43.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology*, 88, 64–73.

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

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

Mochida, N., Fukuzoe, M., Nakayama, M., & Shimizu, Y. (1996). Experimental research on learning text presentation methods – focusing on the effects of summarized displays and pointers; *Japan Society for Educational Technology Journal*, 19-4, pp. 189–196. (in Japanese)

Paivio, A. (1986). Mental representations: A dual coding approach. Oxford, England: Oxford University Press.

Sato, K., & Akahori, K. (2005). Effect of board-mediated communication on an interactive blackboard to enhance social presence and affective learning of the learners, *Japan Society for Educational Technology Journal*, 29, 501–513. (in Japanese)

Shimizu, Y. (1993). *Use of educational information media*, Tokyo, Japan: Dai-ichi Hoki Publishing. (in Japanese)

Shimizu, Y., Yanagida, S., & Yoshizawa, Y. (1981). Effects of using pointers in OHP presentations, *Japan Society for Educational Technology Journal*, 6, 11–17. (in Japanese)

Sweller, J. (1999). *Instructional design in technical areas*. Melbourne, Australia: Acer Press.

Sweller, J., & Chandler, P. (1994). Why some material is difficult to learn. *Cognition and Instruction*, 12, 185–233.