The Effects of Multimedia Elements on Learning Achievements in Digital Content

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Abstract: - Because of e-learning environments characteristics of learners include isolation from the instructor or peer learners, therefore providing social cues or emotional feedback has been seriously considered by inserting pedagogical agents into digital contents. However, there exists controversies for introducing pedagogical agents into digital contents, pros are fostering learner motivation and learning outcomes, and cons include the potential to distract learners from the learning content. Measuring the differences of cognitive load needed for e-learning, we have applied learners' eye movement data taken from eye-tracker, and identify the impact of applying a pedagogical agent. The 45 high school students have been divided into three groups, each group focuses on one of the three types of e-learning contents; image and text based multimedia with a pedagogical agent (G1), multimedia as a figure and text with narration (G2), and multimedia only (G3). While learners use the contents, their eye-movement data was recorded and analyzed with EyeWorks software. Also, self-reported cognitive loads and learning achievements were used to analyze learners' performance. From these experiments, we found that the group of individuals using pedagogical agents and narration (G1 and G2), outperformed the multimedia only group (G3), these results show the positive impact of narration and pedagogical agents' in e-learning environments.

Key-Words: - Pedagogical agent, Narration, Multimedia learning, Contents design, Eye-tracking, Cognitive load

1 Introduction

The importance of providing appropriate interactions between *i*) learner and content, *ii*) learner and other learners, and *iii*) learners and instructor [1] are crucial aspects of e-learning systems. The interaction between the learner and the content needs to take into consideration the learner's isolation status from other learners or the instructor[2]. The computer tutor needs to provide human educators' teaching strategies such as observing students' progress and giving appropriate feedback. For providing more vivid interactions, research was carried out to apply pedagogical agents into an e-learning environment. The pedagogical agent is a software program working as a helpful aid in computer based learning. Unlike agents used for simulation [3] and optimization [4], the pedagogical agent has the characteristic capabilities of gesture and emotional [5] expression.

Usually an animated character with a persons' gestures and emotions is inserted into typical e-learning contents, to help learners to interact with the contents. The main reasons for applying a pedagogical agent is to reduce the learners feelings of isolation towards an instructor and to provide encouragement towards the content. Providing encouragement allows learners to feel as if the learning is more personalized like it would be with a human instructor or a one on one tutor. Wouter and his colleagues [6] have reported that pedagogical agents may provide more social interactions between learners and content, therefore improving the learners motivation and engagement in the learning process. However, there exist different opinions on the effects of pedagogical agents. For example, Heidig and Clare reported that [7] the agents may have a positive effect on affective characteristic to learners, but not reflect positively on the scholastics achievements. Dogmagk [8] also reported similar results, and suggested that the social agency theory needs to be modified.

Because of pedagogical agents appearing in the same display with learning contents, the learner's attention may be split between both objects. Some researchers explained this to create less effective learning outcomes [6] [9]. To overcome such distraction, presenting text information and figures needs to be converted into an audio format according to Mayer's multimedia principle [10].

It is necessary to identify the effects of pedagogical agents on reducing cognitive overload in multimedia contents from evidence based methods. In this paper, we have applied the eye movement measurement technique to analyze the effects of pedagogical agents on learners visual attention. Also, we want to find the most effective interactions between learners and contents using pedagogical agents.

2 Experiment Procedure

2.1 Contents Design

Three types of contents have been designed incorporating multimedia. The multimedia includes text and figures. Pedagogical agents were also designed using computerized characters.

The selected topic for the content was the 'human organ of scent,' and this subject was selected taking into consideration the test subjects grade level. The topic was selected from the 10th grade science topics since all the test participants were in the 11th grade. The designed content contained 2 frames, one for the structure of the scent organ, and the other was the sensory system that delivers information to the brain.

The narration for explaining the content on each page was designed using TTS from Oddocast. The animated agent was created using CrazyTalk Animator Pro, in order to imitate a human's emotions and expressions. The designed frames are shown in Fig. 1.

Fig.1. Designed contents

The test subjects in G1 were given a pedagogical agent as shown in the upper two squares of Fig. 1. The subjects in G2 were given a narration of a media file instead of a pedagogical agent as shown in the bottom two squares of Fig. 1. The subjects in G3 were not given either a pedagogical agent or narration media file as shown in Fig. 1

2.2 Participants

The test subjects were randomly selected from high school students in 11th grade, the subjects consisted of 9 males and 36 female students. The 45 students were divided into 3 groups with 15 students in each group. To assure the same learning capabilities between groups we performed a pre-test, and the results are as follows. Students prior knowledge level was homogeneous among the 3 groups, according to the ANOVA analysis, F-value=.041, p-value=.960.

Table 1. ANOVA analysis results of the pre-test of priori knowledge between groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.057	2	.028	.041	.960
Within Groups	29.007	42	.691		
Total	29.003	44			

**Association is significant at the 0.05 significance level*

2.3 Experiments

The playing time of the narration file embedded in the 1st page is 1 minute and 52 seconds, and in the 2nd page is 1 minute and 49 seconds. These are the minimum times that should be spent on each page, if a user needs additional time they can proceed to the next page at their own pace.

While they use the contents, their eye movements have been captured and recorded with Facelab 4.6 eye tracker. The eye movements were captured 60 frames/sec, and the captured data was stored immediately for processing. The data was analyzed with EyeWorks Analyzer 3.7 Premiere Software. The experiment consists of the following steps;

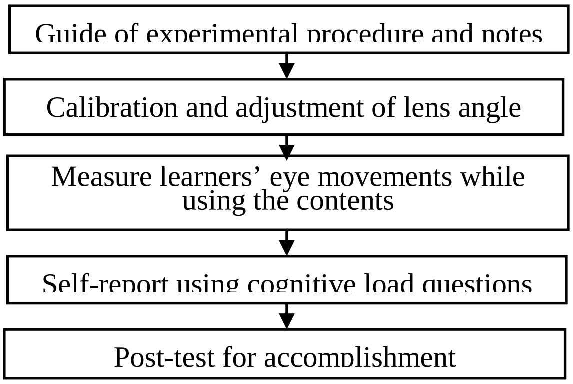


Fig. 2. Experimental procedures

2.4 Measurement of Cognitive Overload

Among the measurement techniques of cognitive load such as physiological measurement, double task, and questionnaire survey, we have applied the questionnaire test of self-reporting style for allocation during the test period. Although controversies exists surrounding self-reporting depending on individual perception, it is also reported that this technique is useful for understanding cognitive process [11].

The questionnaire was originally designed by Ryu and Lim [11], and has been modified by Lim[12]. It uses the 7 Likert scale levels, and has 5 sub factors such as physical effort, mental effort, task difficulty, self-evaluation, and usability. The cognitive load sub factors, and their reliability are given in Table 2.

Table 2. The sub factors of cognitive load

Factor	Meaning	Item reliability
Physical effort	Physical fatigue and consumption of physical strength	0.850
Mental effort	The perceived amount of mental activities	0.807
Task difficulty	The individually perceived task difficulty	0.832
Self-evaluation	The sense of accomplishment after studying	0.870
Usability	The effect of instructional design to learner's understanding	0.909

After the experiment, subjects were asked to take post-tests for their retention and level of understanding of the tasks. There was no time limitation for the paper and pencil test of accomplishments.

3 Data analysis and Discussion

3.1 The Results of the Cognitive Load Questionnaires

To check the cognitive load differences of users according to different types of contents, we have tested cognitive load and analyzed with MONOVA. The technical statistics of each contents are given in Table 3.

Table 3. The technical statistics of cognitive load of each content

Factor	G1	G2	G3	Total
	Mean (S.D.)	**Mean (S.D.)**	**Mean (S.D.)**	**Mean (S.D.)**
Physical effort	3.31 (1.09)	2.98 (1.08)	3.10 (1.22)	3.13 (1.12)
Mental effort	5.35 (0.89)	5.03 (0.80)	4.63 (1.11)	5.00 (0.97)
Task difficulty	4.45 (0.97)	4.56 (0.97)	5.41 (1.12)	4.81 (1.09)
Self-evaluation	4.85 (1.11)	5.10 (1.16)	4.28 (1.00)	4.74 (1.11)
Usability	4.98 (1.11)	5.03 (1.02)	4.00 (1.03)	4.67 (1.14)

Among the three types of contents, users expressed the least physical effort from the narration inserted content in G2. The most mentally challenging activity content type was in G1, where the pedagogical agent was inserted. The highest task difficulty was found in G3, where the only text and images were used. The highest self-evaluation and usability factors are found in the G2 content with text, image and narration.

Table 4. The MANOVA results of cognitive load

Factor	Wilks' Lambda	SS	MS	F	Sig. (p<.05)
Physical effort	.66 (p=.095)	0.85	0.42	0.33	.720
Mental effort		3.86	1.93	2.14	.129
Task difficulty		8.35	4.17	3.96	.027
Self-evaluation		5.25	2.62	2.25	.118
Usability		10.18	5.09	4.52	.017

The sub factors of Task difficulty and Usability show significant differences among the groups. In the post comparison analysis of task difficulty between G1, G2, and G3, only in G1 and G3 does p-value = .035, showing a statistically significant difference with the significance level of 0.05. Usability analysis also shows that G1 and G2 show statistically significant differences towards G3 (G1 & G3 : p-value=.039; G2 & G3 : p-value=.029). From these results, we can say that the narration applied in the pedagogical agent might affect the task difficulty and usability of the content.

3.2 The Results of the Accomplishment Test

To check the accomplishment results of the three types of contents, the subjects have taken a post-test, and their statistical results are given in Table 5.

Table 5. The technical statistics of accomplishment

Content	G1	G2	G3	Total
Mean	23.13	22.40	19.46	21.66
S.D.	3.52	3.33	2.82	3.54

Table 6. The ANOVA results of the accomplishment test

	SS	df	MS	F	Sig. (p<.05)
Between Groups	112.93	2	56.46	5.37	.008
Error	441.06	42	10.50		
Total	554.00	44			

We have applied ANOVA for checking the significant differences between the content types. Based on this data, it shows that there exist significant differences among the three types of contents.

The statistical analysis of accomplishments between G1 and G3, and G2 and G3 show a significant difference level of 0.05. Between G1 and G3, M.D. was 3.66 and the p-value =.009 and between G2 and G3, M.D was .293 and the p-value =.045. This indicates that the narration used in the pedagogical agent affected the accomplishment difference between contents

3.3 The Eye Movement Analysis

While users viewed the different types of contents, their eye fixation characteristics were tracked.

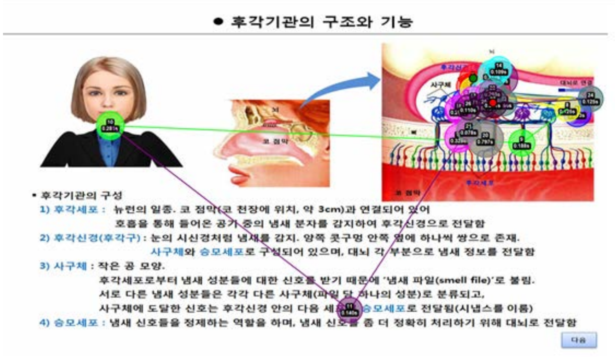


Fig. 3 The eye fixations to specific elements in the content

From the measurements, it was found that the users spent more time on the text messages and visual exploration guide provided in G1 and G2, than in G3 where no narration was used. This indicates that users pay more attention to explanative figures without splitting their attention to text elements. However, when users used the contents in G3, they frequently switched their focus from text to image and vice versa. This means they might spend more time on text reading instead of figures.

To check the effect of narration in G1 and G2 contents, we have analyzed the gaze path according to the time slot while users viewed the contents.

When users viewed the pedagogical agent embedded content inG1, user gazes stayed with the pedagogical agent before the narration started (Refer Fig. 4 (a)). Once narration was started, users' eyes moved to a specific area of the content according to the explanation. When the narration was stopped after a sentence, users' eyes moved to the pedagogical agent again.

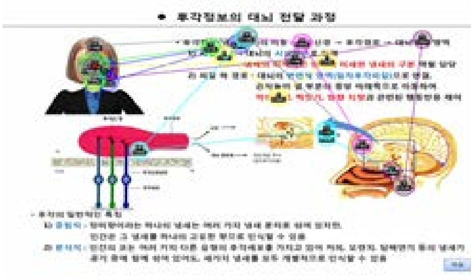
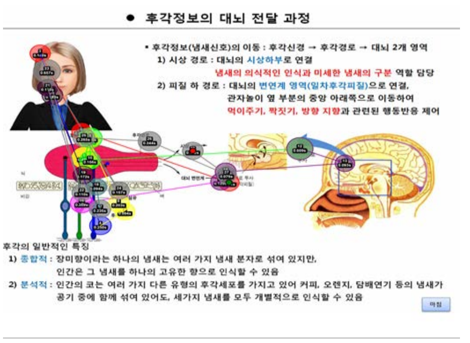
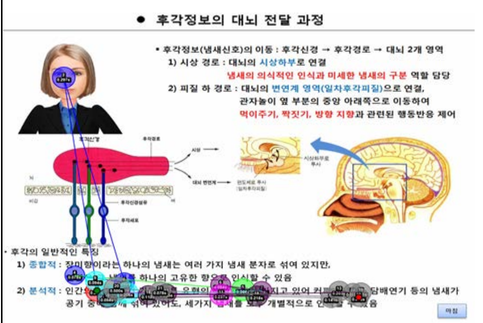
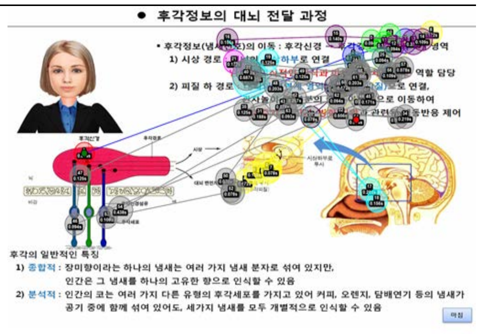
Time slot (sec)	Content type: G1
(a) 0-17 Guide for using the content	
(b) 17-46 The olfactory delivery path	
(c) 75-109 General character istics	
(d) After narration is ending	

Fig 4. The gaze paths of users' with content in G1

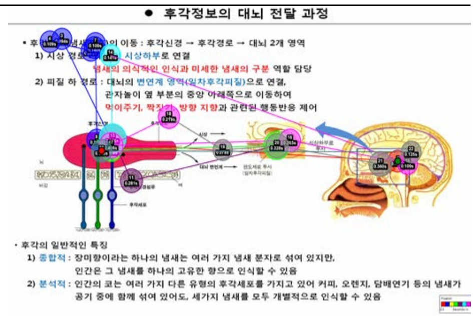
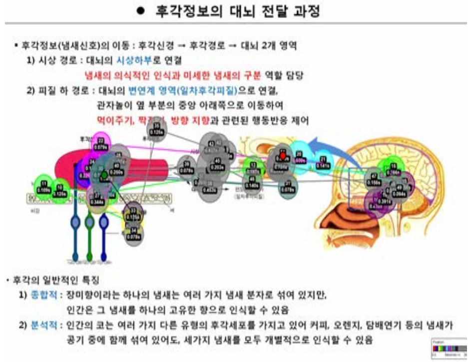
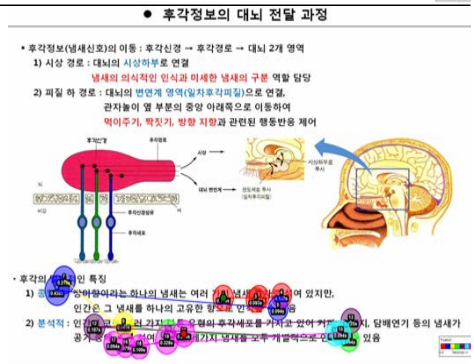
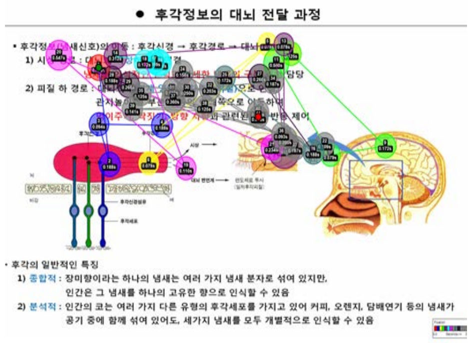
Time slot (sec)	Content type: G2
(a) 0-17 Guide for using the content	
(b) 17-46 The olfactory delivery path	
(c) 75-109 General characteri stics	
(d) After narration is ending	

Fig 5. The gaze paths of users' with content G2

This indicates that users naturally gaze at the pedagogical agent as a means of social interaction in face to face human communication. Almost 10% of attention occupation was observed towards the pedagogical agent, but this does not impose additional cognitive load to a user according to the analyzed results of the cognitive load questionnaire and accomplishment test.

Compared with the contents in G1 and G2, the eye movement patterns of the content in G3 has two characteristics; one is reading text and quickly passing by the figures and returning to the text again as shown in the top of Fig 6., and the other is reading text and referring to figures often causing frequent gaze movements.

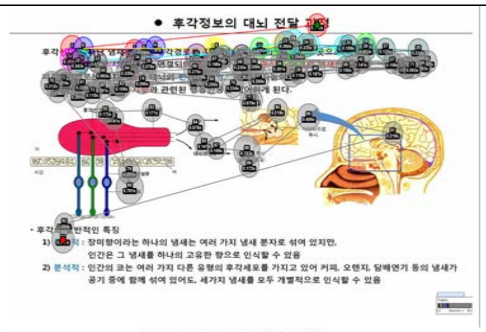
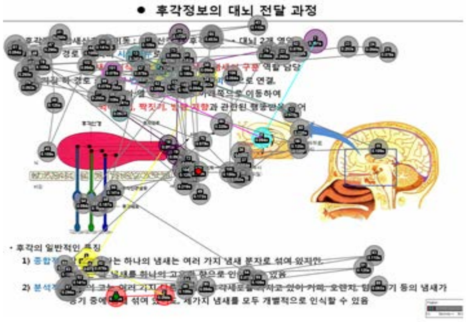
Pattern 1	
Pattern 2	

Fig. 6. The two eye movement patterns in G3 content

These patterns can be explained through observing that users use both text and image information to process information simultaneously in the cognition process as Mayer described [10].

Comparing the heat maps of three types of contents as in Fig. 7, G1 and G2 spent more time on figures, and listening explanations from the narration than G3. The narration helps users focus on figures, and the result is an easy integration of audio and visual information compared to G3. This caused positive results in terms of cognitive load and accomplishment tests for G1 and G2.

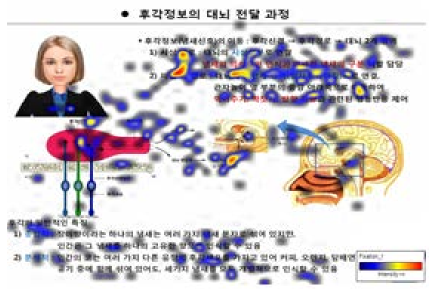
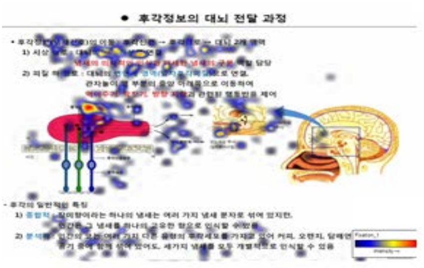
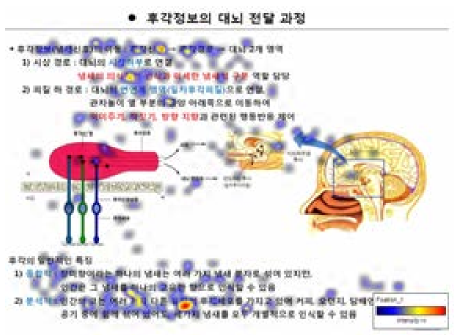
Content	Heat map diagram
G1	
G2	
G3	

Fig. 7 Heat map diagram of G1, G2, and G3 content

4 Conclusion

Although the purpose of a pedagogical agent application in multimedia learning contents is fostering a learner's motivation and eventually enhancing learning outcomes, sometimes the pedagogical agent is blamed for distracting learners attention.

From this rationale, we have designed three types of learning contents, and tested them in various ways including eye tracking techniques to observe learners' attention points by measuring eye movements.

From the eye fixation time analysis, a heat map diagram and gaze path observations, the pedagogical agent helps the user to provide social interactions with content. Even though the existence of a human image of pedagogical agent's does cause significant differences in learning outcomes and cognitive load compared with content using narration, text and image, users frequently spend time looking at the human image. This implies that if the image conveyed more human-like feedback, it may contribute positively towards learners' overcoming the sense of isolation associated with an e-learning environment.

Also, when considering the outperformance of learning content with pedagogical agents and narration, the pedagogical agent itself does not distract a user's attention, but rather can have a positive effect on creating a better e-learning environment.

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