Cognition in Alphabet-Letter-Searching on Visual Display Terminal -A Comparison between Junior High School Students and University Students

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Abstract - With an eye to finding the most appropriate VDT (Visual Display Terminal) monitor design for junior high school students and improving computer education, this study examined the differences in visual cognition between junior high school students and university students. In our experiment, a computer monitor was divided into nine equal areas, and a single letter of the alphabet was displayed randomly in each area; the speed at which participants could search out a particular letter and their ability to recall the positioning of letters were then tested. Results revealed that both junior high and university students had better recall for letters appearing in the upper-left area of the screen and worse recall for letters appearing at the bottom right and that university students had faster recognition and better recall than junior high students. A similar gap was found among junior high students of different grades.

Keywords - VDT, junior high school students, text reading, letter searching, monitor configuration, cognition

1 Introduction

It is important that we set an appropriate working environment on a VDT in order to make "information and computer" education more effective. When people work with a VDT, the design of the VDT influences their work. If the design is good, their desire to work grows, the number of mistakes decreases, and the speed of processing information becomes faster. On the other hand, if the design is not good, the working speed becomes slow, and people feel that machine operation is complicated[1]. The design on a VDT involves human recognition, and a recall of memory and re-recognition are important[2].

There are various methods of evaluating human interface, such as subjective evaluation by questionnaires, workload evaluation by measuring heartbeat fluctuation, ratio of mistakes, reaction time, and so forth. Among these, the ratio of mistakes in human performance has a wide range depending on the person. Therefore, the reaction time to stimulus is useful as an indicator of workload cognition[3]; that is to say, two elements are important, 1) time elapsed? after information is displayed on a VDT, and 2) accuracy of information processing. We have recently? been researching a suitable VDT monitor environment for school age learners[4]-[7], which focuses on the size of characters for easy recognition, or the proper environment of lighting, but we hadn't examined the relation between visual cognition of characters and character locations on a VDT. Earlier studies about displaying characters on a VDT have reported that 1) a layout on a monitor has some presentation effects[8] [9], 2) the relation of the structure of sentences and the character size influences readability[10], 3) the types of characters have some relationship with color and brightness[11] [12] [13], and so forth. But there is no research on a comparative study of the characteristics of reading characters/letters of adult and junior high school students as far as we know. Therefore, we decided to pursue this study using a computer monitor as a VDT.

2 Methodology

2.1 Participants

A total of 152 students participated in this study. They are 31 college students and 121 junior high school students (41 seventh graders, 40 eighth graders, 40 ninth graders). Their eyesight is 20/20 or better with/without glasses or contact lenses.

2.2 Conditions

a) The participants had not had any food for two hours before the experiment, and they had a quiet time/meditation for about three minutes just before the experiment.
b) The experiment was held in a computer classroom. Each participant? sat in front of a computer and adjusted the height of the chair. The distance between the computer monitor and their eyes was 40 cm, as measured by a special ruler. This distance, 40 cm, is an average distance for students[14].
c) Computer monitor: 17 inch LCD (1280x1024 pixels, flat, non-glare)
Character: gothic, 48 point, black
d) Background color: white (brightness is 70cd/m^2)
e) Room lights: The brightness of the desk lamps were set to 700±101x. In order to avoid reflections on the computer monitors, we set a louver for each lamp and set the desks in front of a white wall apart from the windows.
f) We used a computer program which is an experimental device that we had written using Visual BASIC and that we had used previously[6), 7).]

2.3 Experiment

2.3.1 Experiment 1: Measuring the searching time for a character

In the first experiment, we measured how long it took for participants to search for a character on a computer monitor. We divided the computer monitor into nine equal areas and randomly located one alphabet character in each area (3x3). Before deciding the conditions for the experiment, we conducted a pre-experiment with college students using four characters (2x2), nine characters (3x3), and sixteen characters (4x4). According to the comments that the student subjects gave after the pre-experiment, four characters were too easy for them to memorize and sixteen characters were too many for them to memorize. Considering their comments and George A. Miller's theory that the human capacity of memory is 7 ± 2, we decided to use nine characters in our experiment. We conducted another pre-experiment on the character size, in which we found that between 12 points and 60 points, 48 points was the most easily viewable size for a character. Figure 1 shows a sample monitor with nine characters.

L	B	N
A	K	S
C	M	J

Figure 1. Example of the character display

Before the experiment, the participants put the keyboard in a place where they could easily use it, and they set their thumbs on the "enter" key. Then we told the participants which character they should search for. We didn't give any instructions other than to press the enter key as soon as they found the character. They started searching for the character when the monitor showed the characters. We measured the time from the appearance of the characters on the monitor to their pressing the enter key. We randomly shuffled the characters and did the same experiment in five sets, 45 times (9x5). Assistant graduate students helped with the experiment.

2.3.2 Experiment 2: Measuring the number of correct recollections of characters

In the second experiment, we measured the accuracy of the participants' recollections from their memories of the characters displayed on the computer monitor. In this study, the memory being examined is short-term memory[16]. The display method of the characters was the same as in Experiment 1, with one alphabet character in each of the nine areas (3x3).
In the experiment, those characters were visible? on the screen? for ten seconds while the participants were memorizing which area had which character. After ten seconds of this activity, the characters were hidden with a masking display, and the participants wrote on paper the character(s) that they had memorized.

Figure 2 shows the procedure of the experiment. Before and after showing the characters, we used a

masking display in order to avoid visual interference. As an instruction, we only told the participants to memorize the characters and didn't give other instructions. Figure 2 shows the procedure for this experiment. We repeated this procedure ten times, and collected the number of correct recollections in each area on the computer monitor. The total time of Experiment 1 and Experiment 2 was shorter than thirty minutes, and the participants didn't feel tired according to the survey that we did after the experiments.

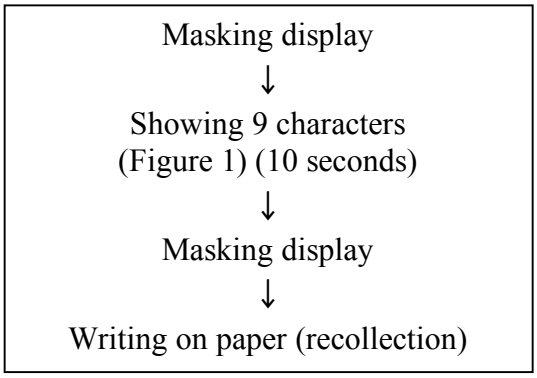

Figure 2. Experiment procedure

3 Results

3.1 Results of Experiment 1

Figures 3, 4, 5, and 6 show the average of the character searching time of each group in each area of the computer monitor. The numbers in the parentheses are SD (Standard Deviation). As shown in those Figures, the average of the character searching time in the upper center is the shortest of all of the groups (underlined) and the SD in the upper center is relatively small in all of the groups. The figures also show the results of Student's t-test between the character searching time in each area and the character searching time in the upper center that was the shortest searching time. There were significant differences in character searching time between the upper center and the four corners and the lower center (*t*-test, $p < 0.01$).

0.991** (0.149)	<u>0.706</u> (0.052)	0.921** (0.145)
0.778 (0.085)	0.721 (0.144)	0.881 (0.167)
0.992** (0.203)	0.976** (0.141)	0.920** (0.136)

$p < 0.01$ **, $p < 0.05$ *

Figure 3. Character searching time in each area on a computer monitor (college students)

1.150** (0.142)	<u>0.810</u> (0.105)	1.121** (0.281)
0.951 (0.045)	0.831 (0.214)	0.891 (0.145)
0.882** (0.172)	0.971** (0.167)	0.953** (0.223)

$p < 0.01$ **, $p < 0.05$ *

Figure 4. Character searching time in each area on a computer monitor (ninth graders)

0.986** (0.151)	<u>0.816</u> (0.127)	1.122** (0.201)
0.951 (0.056)	0.831 (0.113)	0.959 (0.172)
1.122** (0.234)	1.105** (0.114)	1.154** (0.155)

$p < 0.01$ **, $p < 0.05$ *

Figure 5. Character searching time in each area on a computer monitor (eighth graders)

1.056** (0.145)	<u>0.951</u> (0.045)	1.161** (0.137)
0.998 (0.172)	0.961 (0.121)	1.059 (0.145)
1.182** (0.155)	1.079** (0.203)	1.193** (0.147)

$p < 0.01$ **, $p < 0.05$ *

Figure 6. Character searching time in each area on a computer monitor (seventh graders)

3.2 Results of Experiment 2

Figures 7, 8, 9, and 10 show the average of the numbers of correct recollections. The numbers in the parentheses are SD. As shown in those Figures, it was the upper rows where the participants recalled the most correctly.

The area that showed the highest number in all groups was the upper left (underlined). The SD in this area is also relatively small compared to other areas. The results of Student's t-tests between the upper left and other areas are also shown in the figures. There were significant differences between the upper left and other areas in the middle and bottom rows (t-test, $p < 0.01$, $p < 0.05$). The area where the number of correct recollections was the smallest was in the bottom right.

8.80 (0.81)	8.45 (1.84)	7.81 (1.95)
7.20** (1.58)	5.55** (1.74)	5.73** (1.67)
6.13** (1.57)	7.05* (0.89)	5.15** (1.54)

$p < 0.01$ **, $p < 0.05$ *

Figure 7. The number of character recollection in each area on a computer monitor (college students)

8.05 (0.76)	6.35 (2.31)	7.05 (1.45)
6.91** (2.01)	5.05** (1.32)	5.05** (1.45)
5.82** (1.55)	6.40* (0.78)	4.85** (1.42)

$p < 0.01$ **, $p < 0.05$ *

Figure 8. The number of character recollection in each area on a computer monitor (ninth graders)

8.02 (0.71)	5.82 (1.04)	6.12 (1.95)
6.21** (0.84)	5.05** (1.76)	4.55** (1.41)
5.13** (1.55)	5.60** (1.32)	4.25** (1.89)

$p < 0.01$ **, $p < 0.05$ *

Figure 9. The number of character recollection in each area on a computer monitor (eighth graders)

8.05 (1.01)	6.31 (1.81)	4.67 (1.92)
6.70** (1.21)	4.17** (0.95)	4.35** (2.07)
4.35** (2.23)	5.13** (1.63)	4.13** (1.31)

$p < 0.01$ **, $p < 0.05$ *

Figure 10. The number of character recollection in each area on a computer monitor (seventh graders)

3.3 Relation between searching time and correct recollections of characters

Figures 11, 12, 13, and 14 show the relationships between the searching time for characters and the number of correct recollections of characters. As shown in these figures, there is no consistency of data, and we couldn't get a fixed coefficient of correlation between the character searching time and the number of correct recollections.

Figure 11. Character searching time and the number of correct recollections (college students)

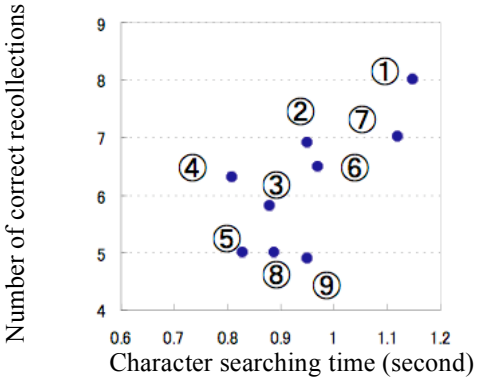

Figure 12. Character searching time and the number of correct recollections (ninth graders)

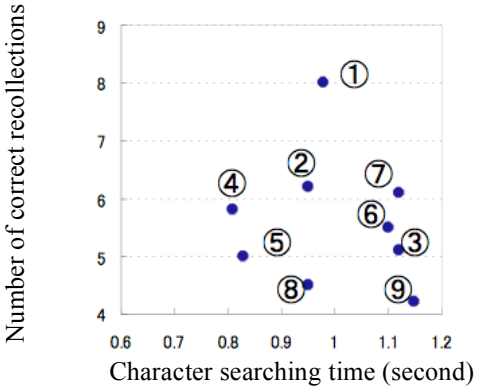

Figure 13. Character searching time and the number of correct recollections (eighth graders)

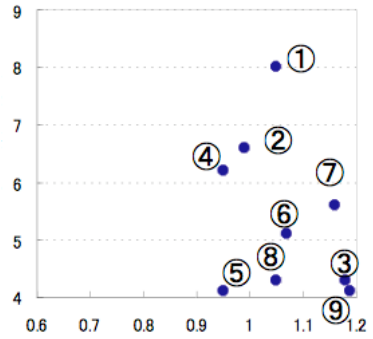

Figure 14. Character searching time and the number of correct recollections (seventh graders)

3.4 Data analysis by row and by column

There were solid consistencies in all of the groups as shown in the averages in Figures 15 and 16 when we focus on the rows and the columns. In terms of the character searching time, the middle row is the fastest among three rows, and the center column is the fastest among three columns. In terms of the number of correct recollections, the upper row is the highest among three rows, and the left column is the highest among three columns.

					Average in row			
	Computer monitor	**Left**	**Center**	**Right**	**College students**	**Ninth graders**	**Eighth graders**	**Seventh graders**
	Upper	①	④	⑦	0.873	1.027	0.975	1.056
	Middle	②	⑤	⑧	**0.793**	**0.891**	**0.914**	**1.006**
	Bottom	③	⑥	⑨	0.963	0.935	1.127	1.151
Average in column	**College students**	0.920	**0.801**	0.907				
	Ninth graders	0.994	**0.871**	0.988				
	Eighth graders	1.020	**0.917**	1.078				
	Seventh graders	1.079	**0.997**	1.138				

Figure 15. Average time to search for a character by row and by column

					Average in row			
	Computer monitor	**Left**	**Center**	**Right**	**College students**	**Ninth graders**	**Eighth graders**	**Seventh graders**
	Upper	①	④	⑦	**8.35**	**7.15**	**6.65**	**6.34**
	Middle	②	⑤	⑧	6.16	5.67	5.27	5.07
	Bottom	③	⑥	⑨	6.11	5.69	4.99	4.54
Average in column	**College students**	**7.38**	7.02	6.23				
	Ninth graders	**6.93**	5.93	5.65				
	Eighth graders	**6.45**	5.49	4.97				
	Seventh graders	**6.37**	5.20	4.38				

Figure 16. Average number of correct recollections by row and by column

4 Discussions

The upper rows in all of the groups marked the highest number in the correct recollections. That is to say, the upper area on the computer monitor is the area where people can perform high recollection. And in the middle row, the left column shows relatively high performance in recollection. These areas are ①, ④, ⑦, and ② out of nine areas on the computer monitor. According to the survey we conducted after the experiments, most of the participants said that they moved their eyes in the order of "Z-style movement"[18] (Figure 17). The areas of ①, ④, ⑦, ② in a computer monitor follow the beginning part of the Z-style movement. This phenomenon implies that there are some relationships between a human's eye movement and recollection on a VDT.

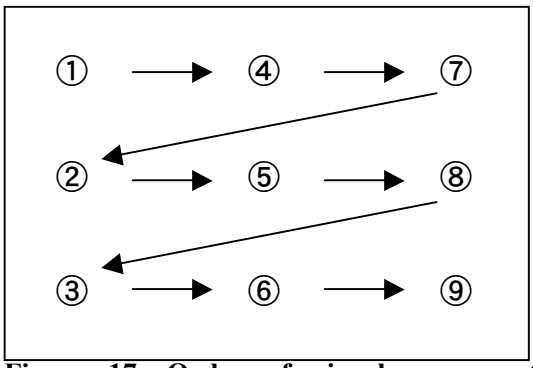

Figure 17. Order of visual movement (Z-style movement)

Closely observing Figures 11, 12, 13, and 14 in order, we found interesting tendencies; the younger the participants are, 1) the longer the character searching time became, 2) the fewer the number of character recollections there were. They are considered as data that show differences of character recognition attributed by age. This phenomenon fits the theory of text reading by Yamaguchi 6) that junior high school students should be recommended to read text more slowly than college students in order to enhance their comprehension in reading. Among junior high school students, there are differences in the character searching time and the recollection. Therefore, we suggest that teachers need to find an instruction method suitable to a student's attributes of cognition by paying attention to the way contents are shown on a VDT.

5 Conclusion

In this study, we experimented and examined the character searching time and character recollection on a computer monitor. We believe that the findings can contribute to the design of the layout of contents on a computer monitor. Our main findings are that; 1) there are areas on a computer monitor where college and junior high school students can search for a character faster and more slowly, and where they memorize and recall a character better, 2) college students or students in higher grades can perform better than younger students in searching for and memorizing a character on a computer monitor, 3) there are some relationships between memorizing a character and a Z-style eye movement on a computer monitor.

To conclude this study, we would like to suggest for future research; 1) conducting further experiments dividing a computer monitor into four or sixteen areas, 2) collecting data from different age groups, 3) conducting experiments with a word, a number, an object, etc., 4) comparing the results? with data regarding long term memory.

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