Brain Wave Analysis in Optimal Color Allocation for Children's Electronic Book Design

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ABSTRACT

In this study, brain wave was applied to the observation of the color allocation of electronic book. Through electronic book content of different color allocation, this study has observed, during the user's reading process, the user's sensitivity to color allocation, the brain wave change, and the realization situation after reading. The research target is mainly based on elementary school student, that is, four students with high and low learning achievements are selected respectively for brain wave data analysis so as to understand the color allocation of the optimal children's electronic book. Meanwhile, from the test results of brain wave instrument and through the information provided by brain wave instrument, the optimal color allocation for electronic book was found out, and student's attention was enhanced too.

Keywords: brain wave, electronic book, color allocation, attention

I. INTRODUCTION

Color had played an important part in human's vision. Along with the advancement in information technology, in the future, people might have to get lots of information through internet, and then the reading is done through electronic book reader. When the user is collecting data or observing an article, it is usually needed to browse the data using computer for a long time. According to the past research, bad color combination in the screen will lead to the reduction of work efficiency and visual fatigue, and good color allocation can bring more focused attention to the user and bring good reading color allocation environment [1, 7, 10].

However, in the past color allocation research, for a long time, questionnaire survey way was relied on to know the subjective preference of the user indirectly. However, explicit data such as observable student's behavior and test score usually cannot display objectively and accurately the real visual history and brain's thinking and realization process during student's learning and realization process. Therefore, this study has used Neurosky brain wave measurement instrument to replace the survey questionnaire. Neurosky's brain wave instrument, non-invasive way was usually used, each brain wave section so as to understand the attention, realization and recognition process.

In addition, there are no researches aiming at the suitable color allocation of electronic book available. Therefore, if the best combination of the background and text color during the electronic book browsing can be found, then when people are browsing text on the electronic book, they will have multiple choices for helping people to focus their attention. However, since different people has different preference on the color, it is important to let the person designing the content of electronic book be able to make good combination on the background and text, because this can reduce the color combination trouble on the designer's side.

In this research, brain wave measurement were used to observe the simulated reading process of electronic book of elementary school student on the computer screen, meanwhile, assisted with reading realization instruction and test method, data collection and analysis was performed. In this research, it was hoped that through the information provided by brain wave instrument test, good color combination can be found out, and the loading of the user on browsing the data can be reduced too. Meanwhile, this result can be used as color allocation reference for future researchers in designing digital teaching material.

II. LITERATURE REVIEW

A. Color allocation

Many past researches had proved that different color allocation will affect the level of visual fatigue of the reader. Under dark background, please do not use red and blue word, meanwhile, red and blue word could easily cause fatigue on the operator [7], and it was also recommended that do not use too much colors, the contrast between word color and background color should be enhanced, and "Do not use color combination of (1)red/blue(2)red/green(3)blue/green, etc." [9]. In the word display of single color Visual Display Terminal (VDT) work station, the person under test, under the black background situation within VDT, used green, amber, yellow, red, blue and white color to display symbol and to search target word. Here, Green color>yellow color>blue color. Under the use of different color, the number of search error shows significant difference. Yellow color generated the least error, white color generated the most errors [5]. The color combination on the screen showed significant effect on the visual performance and subjective preference of the person under test, among them, the combination of dark color (blue and black color) as background is the best, meanwhile, the use of green background red word combination should be avoided.

Complementary color design could easily lead to influence on the eye. The display of white document on blue color background will generate optimal performance. However, in a research performed by Tsu-Hsiang Chu and Li-Jen Tsao (1994) for the influence of target/background color combination on CRT display performance, it was found that for the background, dark color is better, for the target, the light color is better[1, 6, 11]..

B. Brain wave and BCI (Brain Computer Interface)

The activity of brain nerve cell can be detected by nerve electrophysiological method to get brain wave. The waveform measured from brain wave mainly reflects the cortical potential response. According to the frequency of brain wave, brain wave can be divided into four types, which are named respectively by Greek letter alpha, beta, theta and delta [4]. Based on such classification, each brain wave of different frequency will have different meaning and characteristic.

The attention value mentioned in this research comes from eSense patented algorithm as developed by Neurosky company using data parameter way. Neurosky used specific number in the range 0-100 to represent the level of attention of person under test [2]. When the value was in the range of 40-60, it meant that the value at the moment was in the middle range, when the value was in the range 60-80, it meant that the parameter at the moment was in the high value range, that is, a little bit higher than the normal level, when the value was in the range 80-100, it was in high value region, which meant that the attention was in the highest level, that is, it stayed at the very focused state. Similarly, if the value was in the range of 20-40, it meant that the parameter at the moment stayed at higher value region, but when the value was in the range 0-20, it meant that the value stayed at the low value region. These two regions had spiritual state reverse to the spiritual state in the above mentioned region, and it meant different level of nervousness, distractedness and anxiety, etc.

III. RESEARCH METHOD

Desktop PC screen was selected to simulate electronic book equipment and interface. Brain wave BCI tool was used to understand the user's attention and brain electric wave change. The main research item is: The brain electric wave change and attention value of color allocation of different background and word. After the completion of the experiment, the mean and standard deviation of equipment will be calculated to perform comparison and ANOVA test.

A. Participants

According to the research problems in this project, the target under test is the students in the adjunct elementary school of National Taichung University of Education. Bearing on the research ethics standard, since person under test is not legal adult, the project leader thus asks the agreement of the parent of person under test before performing eye movement study. The test sample contained 8 persons, four were males, four were females, and according to the score in the class, it was divided into two groups of high and low. The article was content that the person under test never read before so as to meet the experiment rule and fairness.

TABLE I. PARTICIPANTS

Learning score (High)		**Learning score (Low)**	
Male	***Female***	***Male***	***Female***
1	1	1	1
1	1	1	1

B. Material

According to the research subject of this research, the project leader had collected two fairy tales and edited the visual material needed for eye movement data. To act in accordance with Eye Tracker and experiment, the spec and function of software was designed, and the interface of electronic book was simulated. Fig. 1 and Fig. 2 were the word and background color allocation variable as designed in this experiment, that is, the color allocation of 9 white background and black word as well as 9 black background and white word, and the word font used in the experiment was Hsin-Hsi-Ming-Ti. Meanwhile, in each section of color test planning, one wrong word was added, and in the experiment process, the person under test was allowed to find the wrong word, and the response time was recorded (micro second was used to calculate the time for the start of reading the article and the time for finding the wrong word), and the upper limit was made to be 1000 mm seconds (it was defined as not found).

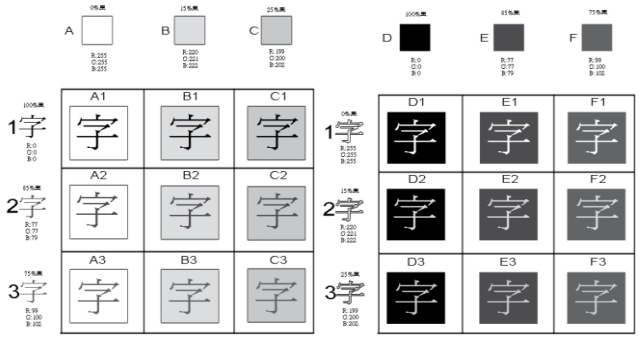

Figure 1. Color allocation design

Figure 2. Simulation illustration of electronic book

C. Experiment environment and equipmen

In this research, brain wave measurement tool manufactured by Neurosky was adopted, which was one type of non-invasive brain wave measurement instrument. It was used to detect neuron electric triggering activity, and it has the earphone appearance. Meanwhile, three sensors were used to contact three locations on the skin: Two ears at the lower sides and the forehead. Forehead is a location that can be placed with sensor easily, and cortex is also the source with high cognitive signal and consciousness [2].

Neurosky brain wave measurement system has been studied and applied in the game and in the study of athlete [3]. Its convenience, comfort ability and usability can be confirmed [8]. Neurosky can measure each brain wave section for data in each millisecond, the brain wave section that can be measure was 0Hz~63Hz, which covered all the brain wave sections and can measure two physiological values regarding Attention and Meditation. Meanwhile, Neurosky itself was also wireless Bluetooth earphone device. Its earmuff design can easily exclude the voice interference factor during the experiment.

Brain wave data collection method had 4 steps:

1) When person under test comes to the lab, person under test will be first introduced with eye movement data collection step and method. If there is any question, person under test can ask to clarify the question before carrying out the eye movement experiment.

2) Put Neurosky equipment on the correct position of person under test and explain the data to be collected. Then check if the test instrument is under normal operation, and if brain wave value display is normal.

3) The experiment will start. Use the designed color allocation combination for electronic book to let the user view two paragraphs words for a total of 18 color allocation combinations, and brain wave will be recorded simultaneously. Meanwhile, the user will find the wrong word, and the response time should be recorded. Between each combination, pure black screen will be used to let the user take a break, then it will enter the next color combination. Brain wave instrument will record the user's attention and all kinds of brain wave frequency section value.

4) Brain wave data will be convert into digital information record for statistical analysis.

D. Experiment design

This research design a test accompanying reading test, that is, in each experimental article of word background color allocation, one error word was added, and the user, during the article reading process, was asked to click the wrong word using mouse interface, and program was used to record the response time of each color allocation. Meanwhile, this value was integrated with attention value provided by Neurosky's brain wave BCI interface for assessment.

Independent variable: (1) Desktop computer, notebook computer and Eye Tracker (2) Gender: 4 boys and 4 girls.

Dependent variable: Read two articles: Grandpa must have his way (1200 words) and Happy birthday to you (1500 words) for 10 minutes each, and the values measured by Neurosky's brain wave instrument: (1) Attention, and (2) Response time for wrong word search.

Before the experiment and after color allocation of each paragraph of words, the followings will be investigated respectively (1) Attention, (2) Response time for the search of wrong word. The values of attention and the response time for wrong word search will be used for examination and will also be used as index of thinking and attention. The experimental process is shown in Fig. 3

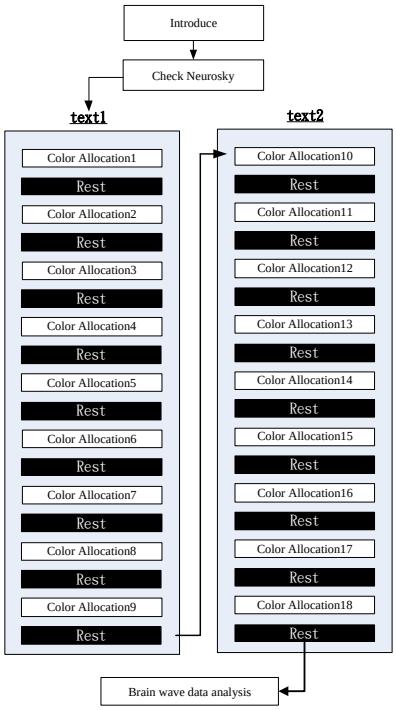

Figure 3. Experimental process

E. Statistical method

In this experiment, analysis of variance will be performed for the influence of each independent variable on subjective preference scoring. The main effect of the target color among color combinations will be analyzed.

IV. DATA ANALYSIS

After the text edit has been completed, the paper is ready for the template. Duplicate the template file by using the Save As command, and use the naming convention prescribed by your conference for the name of your paper.

A. Brain wave attention analysis

In the attention measurement (Table2), that F3(Background: 75% black, word: 25% black) is the highest(M=62.56), and E1(Background: 85% black, word: 0% black) is the lowest(M=45.57) in attention (F=17.23), and there was significant difference.

TABLE II. MEAN OF BRAIN WAVE ATTENTION

No. of color allocation	Mean
A1 (Background: 0% black, word: 100% black)	56.14
A2 (Background: 0% black, word: 85% black)	53.47
A3 (Background: 0% black, word: 75% black)	59.40
B1 (Background: 15% black, word: 100% black)	55.43
B2 (Background: 15% black, word: 85% black)	56.09
B3 (Background: 15% black, word: 75% black)	54.93
C1 (Background: 25% black, word: 100% black)	53.71
C2 (Background: 25% black, word: 85% black)	52.94
C3 (Background: 25% black, word: 75% black)	60.28
D1 (Background: 100% black, word: 0% black)	60.56
D2 (Background: 100% black, word: 15% black)	51.52
D3 (Background: 100% black, word: 25% black)	57.54
E1 (Background: 85% black, word: 0% black)	45.57
E2 (Background: 85% black, word: 15% black)	57.10
E3 (Background: 85% black, word: 25% black)	61.92
F1 (Background: 75% black, word: 0% black)	61.19
F2 (Background: 75% black, word: 15% black)	57.02
F3 (Background: 75% black, word: 25% black)	62.56

F=17.723, Significance=0

B. The response time of wrong word search

From Table 3, it can be found that the response time from the start of the test to the finding of wrong word was F1 (Background: 75% black, word: 0% black), and there was significant difference, And for the response time column in table 6, 1000 ms meant that wrong word was not found.

TABLE III. THE RESPONSE TIME OF WRONG WORD SEARCH

No. of color allocation	Time(ms)
A1 (Background: 0% black, word: 100% black)	876.25
A2 (Background: 0% black, word: 85% black)	931.25
A3 (Background: 0% black, word: 75% black)	1000
B1 (Background: 15% black, word: 100% black)	1000
B2 (Background: 15% black, word: 85% black)	887.50
B3 (Background: 15% black, word: 75% black)	965.00
C1 (Background: 25% black, word: 100% black)	953.75
C2 (Background: 25% black, word: 85% black)	883.75
C3 (Background: 25% black, word: 75% black)	897.50
D1 (Background: 100% black, word: 0% black)	1000
D2 (Background: 100% black, word: 15% black)	977.50
D3 (Background: 100% black, word: 25% black)	1000
E1 (Background: 85% black, word: 0% black)	1000
E2 (Background: 85% black, word: 15% black)	1000
E3 (Background: 85% black, word: 25% black)	903.75
F1 (Background: 75% black, word: 0% black)	856.25
F2 (Background: 75% black, word: 15% black)	902.50
F3 (Background: 75% black, word: 25% black)	1000

F=63.740, Significance=0

C. Eye movement analysis chart

Table 4 is a ranking of the level of attention and the response time of wrong word search, and the color allocations used in the real test were arranged in sequence to make a table. Meanwhile, based on the level of its value in the past literature and research, it was labeled with score, and for each variable, the best color allocation item was labeled with a score of 18, then based on the descending ranking, the score will be reduced, and so on, and the most inappropriate color allocation item will be labeled with the lowest score, and if some were of the same ranking, the same score will be given.

TABLE IV. THE RANKING OF ATTENTION AND RESPONSE TIME

	Attention ranking (From hi to low)	Response time (Form fast to slow)
18	F3	F1
17	E3	A1
16	F1	C2
3	C2	Not found
2	D2	Not found
1	E1	Not found

Fig. 4 was the distribution chart of attention and the response time of wrong word search among different color allocations. According to the past researches, we can judge that the higher the attention, the higher the sustaining power, and the time for finding wrong word will be faster and better, which was the area 4 as in figure 10. In this region, there were six color allocations within it, namely, A1, B2, F2, C3, E3, F1. This explained that in distinguishability and attention, these six color allocations all showed very good effect.

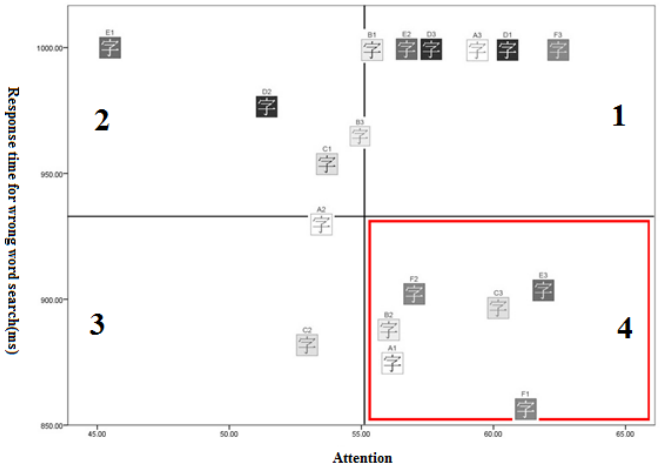

Figure 4. The distribution chart of attention and response time.

D. *Attention and response time in different sex*

In the attention and the response time for wrong word search, factor sex had significant difference. In attention, boys were higher than girls. In response time for wrong word search, girls were faster than boys.

TABLE V. ATTENTION AND RESPONSE TIME IN DIFFERENT SEX

	Sex	**Mean**	F	p
Attention	Boy	58.42	61.450	.000
	Girl	54.62		
Response time	Boy	951.11ms	7.609	.006
	Girl	941.67ms		

E. *Attention and response time in different learning achievement*

In the attention and the response time for wrong word search, factor learning achievement had significant difference. In attention, low learners were higher than high learners. In response time for wrong word search, high learners were faster than low learner.

TABLE VI. ATTENTION AND RESPONSE TIME IN DIFFERENT SEX

	Sex	**Mean**	F	p
Attention	Boy	52.54	279.685	.000
	Girl	60.50		
Response time	Boy	917.78ms	293.136	.000
	Girl	975.00ms		

V. DISCUSSION AND SUGGESTION

In this research, the attention data provided by Neurosky's eSense patented algorithm was used to investigate which of the word and background color allocation on electronic book will let the user highly focus on the content of the electronic book. According to attention value and the response time for wrong word search, the best one is F1Background: 75% black, word: 0% black color allocation.

The result of this research can let the software suppliers who want to have further development on the product have reference basis. When the product is used in learning environment, it should be able to catch the attention of the user, or it should be able to get the continuous focus from the user and learner. When correct color allocation is selected, the effect can be easily seen, but when wrong color allocation is selected, it will lead to inappropriate utilization environment.

For the subsequent researches, it is hoped that the experimental sample number can be increased, and it is also hoped that experimental design can be improved and visual fatigue can be added. Meanwhile, the experimental time for watching the reading text will be increased so as to study the correlation between rate of pupil change and the level of fatigue. Furthermore, test aiming at gender and learning achievement and test aiming at the attention of wrong word recognition will be added. It is hoped that on digital related reading equipment, more multi-element measurement goal can be achieved.

References

[1] M. Bruce and J.J. Foster, "The visibility of colored characters on colored background on view data displays," Visible Land, Vol. 32, pp. 382-390, 1982.

[2] Christopher Peters, Stylianos Asteriadis, and Genaro Rebolledo-Mendez, "Modelling User Attention for Human-Agent Interaction," Image Analysis for Multimedia Interactive Services, 2009. WIAMIS '09. 10th Workshop, Vol. , pp. 266 - 269, 2009.

[3] P. Diefenbach, et al., "A Study in Brain-Computer Interface Game Development," Vol. 2004.

[4] F.H. Duffy, H. Als, and G.B. McAnulty, "Infant EEG spectral coherence data during quiet sleep: unrestricted principal components analysis--relation of factors to gestational age medical risk, and neurobehavioral status," Clin Electroencephalogr, Vol. 34, pp. 54-69, 2003.

[5] S.M. Luria, D.F. Neri, and C. Schlichting, "Performance and preference with various VDT phosphors," Applied Ergonomics, Vol. 20, pp. 33-38, 1989.

[6] F.H. Mahnke and R.H. Mahnke, Color and light in man-made environments. New York: Van Nostrand Reinhold, 1987.

[7] M.L. Matthews, "The influence of colour on CRT reading performance and subjective comfort under operational conditions," Applied Ergonomics, Vol. 18, pp. 323-328, 1987.

[8] G. Rebolledo-Mendez, et al. *Assessing NeuroSky's Usability to Detect Attention Levels in an Assessment Exercise*. 2009: Springer.

[9] M.S. Sanders and E.J. McCormick, Human factors in engineering and design. Singapore:McGraw-Hill, 1993.

[10] K.K. Shieh and M.T. Chen, "Effects of screen color combination, work-break schedule, and workpace on VDT viewing distance," International Journal of Industrial Ergonomics, Vol. 20, pp. 11-18, 1997.

[11] H.L. Snyder, Image quality. In: Helander, M. (Ed.), Handbook of human-computer interaction. Amsterdam: Elsevier science publishers, 1988.