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Ergonomic Design Evaluation of University Webpage Based on Eye-movement Analysis

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Abstract: This paper firstly provides brief introduction about the concept and development of eye-movement analysis methodology, which will be applied to the eye-movement experiment on the old version and new version of a university webpage. The analyzing result suggests few differences in ergonomic design, but the old version of webpage, though whose layout and navigation design suit user, possesses less conciseness than new webpage.

Keywords: Eye-movement Analysis; Evaluation; Ergonomics; Web Design

1. Introduction

The springing of the internet has made itself the "quaternary media" after paper, radio, and television. The number of webpage grows so fast that there is no regulated evaluation for availability. Hence, the establishment of webpage Human Computer Interface (HCI) evaluation is of great value.

Currently, the webpage design evaluations, domestically and internationally, are fixing on subject with broad audience, such like government webpage, library webpage. These subjects, however, are too general to evaluate, causing the evaluation progress subjective.

80% of information human acquire rely on visual sense, and the visual sense is, ipso facto, the most direct way in the HCI. Therefore, the application of eye-movement analysis into the subject-specific university webpage design evaluation, where the fixation trajectory and fixation time are recorded by technical instrument, is expected to present user's fixation feature more objectively, thus creating a more viable way to evaluate HCI design.

2. A Review of Eye-movement Analysis

2.1. Classification of Eye-movement

The movement of human oculus is generally classified as: fixation, saccade, and smooth pursuit movement[1].

2.1.1. Fixation

Fixation is the progress of focusing the center of oculus onto an object, which costs more than 100ms, average 200-900ms. The purpose of fixation is to acquire and process current visual point and other information within sight range. There are at least three ways processing in a quintessential 250-300ms fixation progress[2]: (1) encodes and process current visual information, classifies the scene. (2) targets a certain peripheral site of current fixation point for next fixation. (3) plans and prepares for the saccade. These ways may occur simultaneously.

2.1.2. Saccade

Saccade is the quick simultaneous movement of oculus between two fixation points. The time of saccade is generally 30-120ms, covering 1°-40°with the highest speed of 400-900°/s. The purpose of saccade is to quickly change fixation point by shifting the center of oculus from one object to another. The oculus during saccade cannot acquire any information.

2.1.3 Smooth Pursuit Movement

Smooth pursuit movement is the continuous movement of oculus following a moving object. It only occurs in the progress of tracking moving target, different from saccade which only occurs in shifting fixation point between static objects. The purpose of smooth pursuit movement is to keep the image of moving object within foveal, with maximum speed of 30°/s[3].

2.2. The History of Eye-movement Analysis

Eye-movement analysis abroad has been developing for more than a century. Early stage of studies had mainly focused on paper reading. Later, with advancing technology and emerging fields, eye-movement analysis has been applied to the field of advertisement, piloting, praxeology, ergonomics, webpage visual browsing and virtual reality. Rayner[4] has divided the development of eye-movement analysis into four periods:

First period began from 1897, when Emile Javal, professor of Paris University, discovered an immediate fixation

and saccade other than smooth movement during paper reading[5]. It was later proved by Huey[6], Dodge and Dearborn. In this period, apparatus are relatively primitive.

Second period came along with the time of what American experimental psychology called Behaviorism, where scientists were interested in combining eye-movement analysis with psychology. Eye-movement analysis in the field of paper reading had been theoretical induction.

Third period started in the beginning of 1970s, which was motivated by eye-contingent display change paradigm. On visual cognition, Tinker[7] argued that future study of eye-movements in reading does not appear to be too promising, and eye-movement approach to the study of the reading process has probably made its major contributions, but his view was finally disproved by further studies. In this period intensive studies on eye-movement and psychological processing had been made.

Fourth period have been led by the development of advanced eye-movement stimuli paradigm, the prominent of which are Reiche's E-Z reading paradigm[8], and Nielsen's F type webpage browsing mode[9](Figure 1). In this period, the advancing of eye-tracking technology has been rendering eye-movement studies shift from cognition, psychology to virtual reality, ergonomics, game, and webpage.

Figure 1. F-pattern of browse

In domestic China, eye-movement development had been postponed since the Second World War. But the earliest eye-movement study by Chinese scientist was the study about mandarin in 1925, conducted by Shen youqian, at Stanford University. Till 1950s, there were only a couple of psychology reports on eye-movement study in China. It was after the 1970s that China has actually committed to intensively study eye-movement technology and exchange results internationally.

Eye-movement technology has been dramatically studied and developed in China for the last two decades. The fields have not only been theories or paper reading, but also including ergonomics, sports, aesthetics, advertisements. Xian University has made greater advance in independent eye-tracker development, and Tianjin Normal University has got numbers of positive results in eye-movement applications. However, eye-movement technology in China still needs more intensive studies and international cooperation.

3. Eye-movement Analysis Experiment on University Webpage

3.1. Design

3.1.1. Experiment Purpose

Test user experience about layout, navigation design etc. cognition differences of old webpage and new webpage of Harbin Engineering University using eye-tracking device and eye-movement analysis.

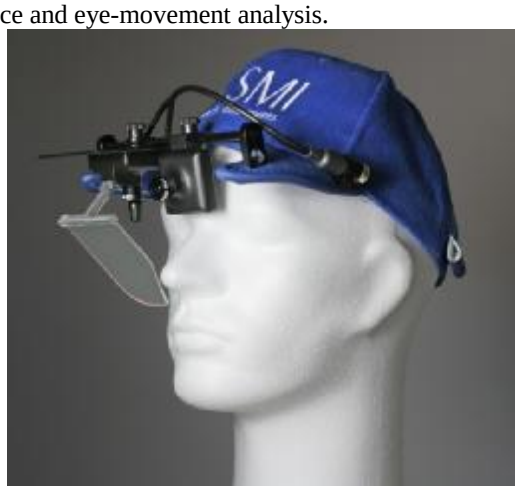

Figure 2. SMI eye-tracking instrument

3.1.2. Test Subject

8 undergraduates of Harbin Engineering University (4 male, 4female) are randomly chosen (each 2 from freshmen to senior), with average age of 21, 1.0 naked vision or correct vision, color sense normal. Four of them (2 male and 2 female) are assigned to complete task first on the old webpage, the other four are assigned to completed task first on the new webpage, then each group swap the procedure.

3.1.3. Instruments

The testing uses SMI HED eye-tracking device (50Hz) with data recorder and mobile work station, designed by SensoMotoric to collect and analysis eye movement data(Figure 2). The webpage for experiment are presented on 17 inch LED screen (90Hz, 1440×900).

3.1.4. Subject Tasks

Subject Tasks are typical Tasks listed in Table 1:

Table 1. Description of Typical Task

Typical Task	Description of Task
1	Acquaint the university history and cultural
2	Find the information of employment
3	Inquire himself/herself arrangement of timetable
4	Enter the Qihang webpage, and look for latest competition notice
5	Acquaint the system of scholarships
6	Find the activity introduction of Qihang Lecture
7	Acquaint the party honest construction of our university
8	Enter the webpage of College of Mechanical and Electrical Engineering and browse information
9	Enter the forum of university
10	Find the lending informatiom of the book named How the Steel Was Tempered

3.1.5. Experiment Environment

Experiment is to be conducted in a laboratory in Harbin Engineering University, where quiet, isolated area abates disturbance and raises data viability (Figure 3).

Figure 3. Experiment environment

3.1.6 Experimenting procedure

(1) Subjects are brought to laboratory to accommodate environment and familiarize Tasks and notices.
(2) Subjects are instructed to wear eye-tracker and sit 90cm in front of screen.
(3) Patch eye-tracker to mobile workstation; initiate system; adjust camera to the best position that can capture pupil movement.
(4) Use 5 point method to calibrate instruments; prepare for the test.
(5) A typical task is asked by laboratory staff, which should be confirmed by subjects. Subjects switch recorder on when hear "test begins", then open webpage to complete task. Eye-tracker will automatically record eye-movement data.
(6) Laboratory staff switch recorder off when subject complete Tasks in 90s, which is considered task accomplished. Or laboratory staff switch recorder off when task time is over 90s, which is considered task failed. Both kinds of data will be kept.
(7) Loop step 5-6 until all 10 Tasks are finished.
(8) Loop step 2-7 until all subjects are tested.

3.2. Analysis of Eye-movement Data

3.2.1. Data Analysis of Old Webpage

Statistic results are given below about 8 subject finishing 10 typical Tasks on the old webpage, as listed in Table 2. Descriptive statistics show that while task times vary through different subjects, average time of a single task is generally around 13s, which is shown in Figure 4.
One-way anova calculation suggests subtle difference in completing the same task on the same webpage by different individual [$F(7, 72)=0.278$, $P=0.961>0.05$].
The cause of subtle difference in completing typical tasks via respective subjects can be summarized into two factors. Firstly, some subjects have been frequently using old webpage of Harbin Engineering University, leading to voluntary fixation at target zone. Secondly, the old webpage is basically using plate design, dividing numerous zones on the layout, and each zone has its subordinates, creating a hyponym relation. This could help user quickly locate target information.

Table 2. Descriptive Statistics of Old Web

Subjects	N	Mean	Std. Deviation	95% Confidence Interval		Minimum	Maximum
				Lower	Upper		
Subject 1	10	12.510	10.957	4.672	20.348	2.943	36.758
Subject 2	10	13.130	6.107	8.761	17.499	5.776	23.531
Subject 3	10	11.621	3.6231	9.029	14.213	7.674	17.578
Subject 4	10	12.600	4.116	9.655	15.545	8.704	20.730
Subject 5	10	12.553	2.578	10.709	14.397	9.772	17.205
Subject 6	10	14.024	5.121	10.360	17.687	7.361	23.108
Subject 7	10	14.670	6.506	10.016	19.325	7.059	28.791

Subject 8	10	14.169	6.805	9.300	19.039	6.301	29.099

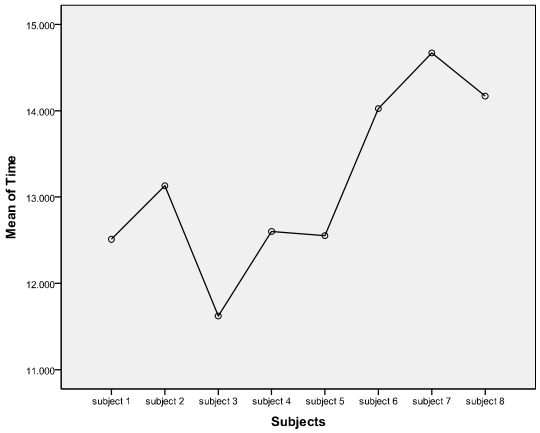

Figure 4. Mean analysis of old web

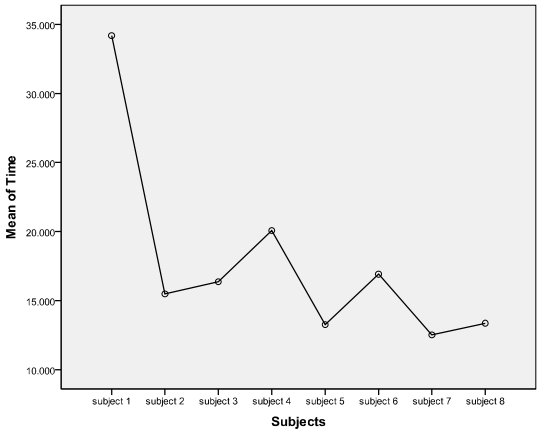

Figure 5. Mean analysis of new web

Table 3. Descriptive Statistics of New Web

Subjects	N	Mean	Std. Deviation	95% Confidence Interval		Minimum	Maximum
				Lower	Upper		
Subject 1	10	34.190	32.425	10.254	10.994	3.891	90.000
Subject 2	10	15.476	10.169	3.216	8.201	4.367	32.094
Subject 3	10	16.371	11.237	3.553	8.332	4.982	37.092
Subject 4	10	20.065	25.778	8.152	1.624	3.871	90.000
Subject 5	10	13.267	7.237	2.289	8.090	4.701	25.419
Subject 6	10	16.912	9.074	2.869	10.421	3.918	32.778
Subject 7	10	12.515	10.196	3.224	5.221	4.918	40.417
Subject 8	10	13.360	7.752	2.451	7.815	4.336	29.312

Note: For the subject failed to complete the task, the time he spent in the experiment is 90 seconds in the statistical analysis.

Figure 6. Scan path of new web

The eye-movement trajectory of subjects with longer task time indicates that subject ignore the first level title and directly search in the second level title, which raises time cost. This could be resulted from that first level title has fewer words than the second level title, thus first level title should be considered as “information point” andsecond level title be considered as “information plane”. Users, however, are easier attracted by “information

plane" than "information point". Hence they are prone to spend more time on this website. Besides, identical title color makes it hard to distinguish different levels of title. One improvement method is to use eminent color to help distinguish title information and reduce searching time.

3.2.2. Data Analysis of New Webpage

Statistic results are given below about 8 subject finishing 10 typical Tasks on the new webpage, as listed in Table 3. Descriptive statistics show that differences are manifest in task completion on new webpage of Harbin Engineering University, in which both subject 1 and subject 4 have not finished one of ten tasks under 90s. Figure 5 indicates that average tasks time of respective subject ranges from 12s to 34s, suggesting eminent discrepancy.

One-way anova calculation still suggests subtle difference in completing the same task on the same webpage by different individual [$F(7, 72)=1.783$, $P=0.104 > 0.05$]. Although the discrepancy is relatively subtle, there are two subjects who failed to complete a certain tasks. Therefore, the key lies on subject 1 whose mean of time is the highest and whose tasks are incomplete in order to provide improvement for webpage design by studying eye-movement trajectory.

BeGaze software is used to analyze eye-movement trajectory of subject 1 when doing task 1.

The circles in Figure 6 are fixation points of subjects; the size of circles stands for fixation time, bigger the circle, longer the fixation time; numbers of circles are fixation sequence; lines are saccade amplitudes; all of which compose scanning paths and eye-movement trajectory of subject 1.

Fixation times of subject 1 when doing task 1 are analyzed using BeGaze. Thermal distributions are presented in Figure 7.

Figure 7. Heat map of new web

Longer fixation time results in red thermal distributions, while shorter fixation time results in blue thermal distributions. Thermal distribution gives clear dynamic fixation data.

Task 1 done by subject 1 belongs to searching information about university history. Data show that subject 1's vision first fixed near the title "about us", but immediately jumped to bulletin board at right side of webpage, and soon it jumped again to "quick links" at the bottom of webpage, circling around it till task time was up. Fixation time is also mainly distributed at the bottom, indicating subject intended to gain information from quick links.

The reason of relatively subtle difference in completing typical tasks via respective subjects could be that subjects have preliminary experience of new webpage of Harbin Engineering University, which leads to task failure by some subjects. Therefore, layout design should abate quick links in the new webpage, otherwise numerous quick links would consume more time for user to acquire target information.

3.2.3. Comparative Analysis

Eye-movement data of new and old webpage are compared, thus analyzing differences of each task time done by the same subject under two versions of webpage, the efficiency of which is then measured. Data are undergone paired sample T test and presented in Table 4.

Table 4. Paired Samples Test

Group (Old - New)	Task	df	Sig. （2-tailed）
Group 1	Task 1	7	0.940
Group 2	Task 2	7	0.003
Group 3	Task 3	7	0.931
Group 4	Task 4	7	0.000
Group 5	Task 5	7	0.001
Group 6	Task 6	7	0.159
Group 7	Task 7	7	0.022
Group 8	Task 8	7	0.196
Group 9	Task 9	7	0.000
Group 10	Task 10	7	0.010

Note: 0.000 means the value of two tailed significance is less than 0.001.

Table 4 shows that group 2, 4, 5, 9 possesses significant difference (Sig. $<\alpha$, α=0.01). Mean of time of these four groups are then analyzed in detail to seek the cause.

Task of group 2 is to search for employment information, which can be found under the first level title of "admission and career". This title on old webpage is positioned in the middle and word size is bigger than that of new webpage, easier attracting users' attention thus saving half of searching time. Hence, the new webpage should be improved to position important or frequently browsed information at the middle of the page.

Task of group 4 is to search for information about "qihang.hrbeu.edu.cn". In new version webpage, this link is located at the bottom of quick link zone, easy to find; while in old version webpage, the link is located at bottom-right corner of quick link zone, which takes more time to find.

Task of group 5 is to search for information about university's scholarship system. In old version webpage, it can be accessed directly through quick links which is at the bottom of webpage. In new version webpage, it is a sub-title under "student activities", which means it would take more time completing this search in old version than that in new version. However, considering seldom access in old version, it is reasonable to relocate this link for better layout.

Task of group 9 is to search for university forum, which is located in quick links on both versions of webpage. However, there are 20 quick links on new version webpage, larger than that of old version webpage which is only 8. This would take more time for users to search. Given the eye-movement data which suggest searching trajectory is generally from up to down and from left to right, the quick links on new version webpage should be arranged by frequency of use from left to right and up to down.

Conclusion

By conducting eye-movement analysis old and new versions of a university webpage, it could be concluded that though the difference of information searching by subjects is subtle, the old version webpage, though whose layout and navigation design suit user, possesses less conciseness than new version webpage.

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