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Discovering Legible Chinese Typefaces for Reading Digital Documents

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Abstract

More and more fonts have sprung up in recent years in digital publishing industry and reading devices. In this paper, we focus on methods of evaluating digital Chinese fonts and their typeface characteristics to seek a good way to enhance the character recognition rate. To accomplish this, we combined psychological analysis methods with statistical analysis. It involved an extensive survey of distinctive features of eighteen popular digital typefaces. Survey results were tabulated and analyzed statistically. Then another objective experiment was conducted using the best six fonts derived from the survey results. These experimental results reveal an effective way of choosing legible digital fonts most suitable for comfortable reading of books, magazines, newspapers, and for display of texts on cell-phones, e-books, and digital libraries, and finding out the features for improving character legibility of different Chinese typefaces. The relationships among legibility, eye-strain, and myopia, will be discussed.

Keywords

Chinese fonts, Typeface characteristics, Legibility, Digital Documents, and Information display

I. INTRODUCTION

As known, different fonts may lead to different eye-stress levels. Bad design of text not only makes things harder to read but can also cause eye strain and fatigue, and high legibility typeface would relieve eyestrain effectively. We spend more time indoors on reading and using the computers or watching television, thus people are going to become just as myopic. Myopia in Asia has reached extraordinary levels, thus how to increase legibility and make text easy to read is a problem.

Nowadays, e-books become cheaper and more popular, especially when IPad II comes out. Meanwhile, more and more libraries provide more e-book facilities to save cost and space. Obviously a good typeface display is of paramount importance. All these new phenomena impel us to consider the importance of legible digital fonts that are suitable for comfortable reading and improving character legibility.

However, the large number of Chinese characters, different structures and strokes, and very similar shapes of some Chinese characters make their recognition and Chinese document analysis very challenging comparing with other languages. At the same time, the rapid emergence of a substantial number of digital Chinese typefaces in recent years tremendously increases the difficulties in the Chinese character recognition and document analysis. More research is needed on the character patterns and radical analysis these days. In the document analysis community, a paper on conspicuous character patterns has been presented by [1], and legibility of English typefaces [2].

In this paper, we concentrate on analyzing the legibility of eighteen most popular Chinese fonts. Firstly, a survey was conducted and administrated to individuals who voluntarily participated in the study. This survey was created to determine the legibility of digital Chinese fonts in different styles and different structures. After obtaining sufficient data, our second experiment aimed at analyzing the single character's legibility of the six fonts found most legible, comfortable and formal in the survey. We used standard statistical methods to evaluate the experimental results to measure the font legibility quantitatively, and to examine the font design characteristics such as font size, font style, and font structures, etc.

II. FONT CHARACTERISTIC SURVEY

A. Proposed Method

In this study, we have conducted an extensive survey of various typefaces commonly used in text books, newspapers, e-books and other digital devices. Out of sixty typefaces produced by different font companies, we have chosen eighteen different Chinese fonts for in-depth studies using five characteristics which are pertinent to reading.

1) Studied Typefaces

In our study, eighteen digital Chinese fonts were chosen from more than 60 used in digital publishing (Table I). They were selected to represent a wide range of physical characteristics from HeiTi, SongTi, YuanTi, KaiTi to Mei ShuTi. Some of them are popular fonts used in newspapers, magazines, books and websites. For example, WRYH is used as the default font of Windows 7 and Vista. Also some specific fonts are used for commercials and special occasions, such as MNJYY and FZSS.

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TABLE I. EIGHTEEN CHINESE TYPEFACES AND THEIR ACRONYMS

Font	ACRONYMS	Font	ACRONYMS
微软简楷体	WRJKT	方正卡通	FZKT
华文中宋	HWZS	微软雅黑	WRYH
方正宋三	FZSS	迷你简秘笔黑	MNJZBH
方正准圆	FZZY	方正隶书	FZLS
方正仿宋	FZFS	汉仪综艺体简	HYZYTJ
微软简中圆	WRJZY	迷你简丫丫	MNJYY
方正魏碑	FZWB	方正黑体	FZHT
迷你简雪君	MNJXJ	微软简标宋	WRJBS
汉仪菏坡体简	HYLBTJ	经典平黑简	JDPHJ

2) Typeface Characteristics

We selected five typeface characteristics: Legible, Formal, Comfortable, Artistic and Attractive, based on previous studies. Typeface studies have frequently referred to such adjectives to describe typefaces in the publishing literature.

Legible and Comfortable are the most important typeface characteristics, which means capable of being read or deciphered and comfortable to read. Formal typefaces are mostly used for the texts in books magazines and legal documents. The purpose of attractive typefaces is to get noticed and to draw attention. Artistic typeface is creative and aims to communicate more than just the basic meaning of the words.

3) Rating Scale

We used a five point Likert Scale with the categories as 0~20%, 21~40%, 41~60%, 61~80% and 81%~100%. The scale was used to reflect a range of different responses from participants to the eighteen typefaces.

4) Participants

A total of 61 participants completed the survey, 33 females and 28 males. Approximately 43.3% of participants were between 20-29 years of age, and 30.0% between 30-39 years. The remaining 26.7% participants were older than 40 years. Approximately 38.3% of the respondents reported having a bachelor degree, 41.7% a master's degree and 6.7% a doctorate. The education backgrounds of the remaining 13.3% participants include High School, Technical School and Junior College.

5) Materials and Procedures

Pangrams used in the experiment are composed of four sentences. The first one is a piece of news quoted from a popular Chinese newspaper. The second one is composed of 30 Chinese characters, in which the first 20 are the most frequently used, 7 are moderate frequently used and 3 are least frequently used [3]. The third sentence consists of characters with different structural compositions. There are 19 common compositions that form the Chinese characters, and each composition consists of different radicals in various positions and sizes. For example, two parts of equal size are placed side by side as character "村", the second part is placed below the first one as character "霜". The characters in the third sentence are examples of these 19 different compositions. The fourth sentence is a popular poem "Jing Ye-si" written by the famous Chinese poet Li Bai in Tang Dynasty. Fig.1 illustrates a sample of the pangrams used in this study.

As we know that different fonts will have different heights even they are in the same point sizes. In order to avoid any effects due to this difference and thus influence on the survey's results, normalization was necessary for processing the area height of pangrams of these eighteen fonts in our survey. We calculated the average height of the pangrams of these eighteen fonts, and we normalize the images of eighteen fonts based on the average height. The heights of the pangrams offered in the survey of these eighteen fonts are all in the same size after normalization.

6) Data Collection Method

We used the online survey tool- freeonlinesurvey[4] to create the survey form.

B. Analysis of Survey Results

The statistical program used to analyze the survey data was SPSS (v.17.0).

We examined the mean values, minimum values, maximum values and standard deviations of rating scores of each typeface based on each characteristic. Table II presents the mean values of rating scores of eighteen typefaces related to five characteristics.

2010 年，房地产调控政策频频出炉，但一线城市的房价依然"高烧不退"。
的一是在了不和有大这主中人上为们地个用工绸矣忧啡芥蚂萃髓鼾馗
米曰品森思华霜花基想意褒裹村联伟搞刚郭街坳滩傲圆国医庆尾匀句遍建闻函
床前明月光，疑是地上霜。举头望明月，低头思故乡。

Figure 1. Pangrams used in the survey in font FZZY

TABLE II. MEAN VALUES OF RATING SCORES OF EIGHTEEN TYPEFACES RELATED TO FIVE CHARACTERISTICS

Typeface	Legible	Comfortable	Attractive	Artistic	Formal
WRJKT	3.89	3.62	3.52	3.25	3.46
FZKT	3.23	3.08	3.30	3.15	2.00
HWZS	3.95	3.38	3.36	2.80	4.23
WRYH	3.97	3.23	3.36	2.92	3.54
FZSS	4.00	3.39	3.57	3.10	4.21
MNJZBH	3.08	2.89	2.84	3.15	2.10
FZZY	3.93	3.44	3.39	3.00	3.33
FZLS	3.56	3.89	3.52	3.87	3.18
FZFS	3.64	3.18	3.38	2.95	3.80
HYZYTJ	3.03	2.62	2.59	2.74	2.75
WRJZY	3.62	3.30	3.41	3.10	3.28
MNJYY	2.07	1.89	2.02	2.33	1.33
FZWB	3.98	3.93	3.77	3.74	3.59
FZHT	3.93	3.44	3.36	2.98	3.77
MNJXJ	2.93	3.31	2.79	3.84	2.10
WRJBS	3.59	2.92	2.72	2.61	3.34
HYLBTJ	1.82	1.97	1.90	2.57	1.23
JDPHJ	3.82	3.18	3.30	2.84	3.56

FIVE TYPEFACES THAT WERE MOST ASSOCIATED WITH EACH OF THE FIVE CHARACTERISTICS

Characteristic	Typeface				
Legible	FZSS	FZWB	WRYH	HWZS	FZZY, FZHT
	4.00	3.98	3.97	3.95	3.93
Comfortable	FZWB	FZSS	WRJKT	FZLS	WRJZY
	3.77	3.57	3.52	3.52	3.41
Attractive	FZWB	FZLS	WRJKT	FZZY	FZHT
	3.93	3.89	3.62	3.44	3.44
Artistic	FZLS	MNJXJ	FZWB	WRJKT	FZKT, MNJZBH
	3.87	3.84	3.74	3.25	3.15
Formal	HWZS	FZSS	FZFS	FZHT	FZWB
	4.23	4.21	3.80	3.77	3.59

We calculated the top five typefaces that were the most and those of the least associated with each of the five characteristics (Table III).

Based on our objectives, we focus on the fonts which are the most associated with the three characteristics: Legible, Comfortable and Formal. We did not conduct further research on the fonts that are the least associated with these three characteristics and the fonts which are the most associated with the two characteristics of Attractive and Artistic. But we also took the physical characteristics of different Chinese typefaces into consideration. Then, the following six fonts: WRJKT, HWZS, WRYH, FZSS, FZWB and FZHT, formed the objects of our in depth research.

III. LEGIBILITY ANALYSIS

Legibility, says the dictionary, mindful of the Latin root of the word, means the quality of being easy to read. Legibility refers to perception, and the measure of it is the speed at which a character can be recognized; if the reader hesitates at it the character may be poorly designed [5]. Thus, unlike the survey above, this time, we used single characters to find out which features of typeface lead to good legibility.

To find out which features of single characters improve legibility, we use single characters to accomplish this experiment.

A. Data Collection

1) Five Fundamental Structures

There are several ways to define the structures of Chinese characters, and each way could be subdivided and redefined recursively sometimes, for example, character "滩", can be defined as left-right structure at first level, then the right part "难"could be divided into two parts again according left-right way at the second level division, for this is left-right structure character as well. Thus, we finally used the five very fundamental structures to group Chinese characters, which can cover all Chinese character components: left-right, up-down, half-cover, full-cover and single structure. These very fundamental structures were defined as the very first level (one level) character division based on the major division feature, ignoring the remaining features (Table IV).

To guarantee the accuracy of this test, we have to use enough characters for balancing, and meanwhile every character must represent and display one font structure. According to these five fundamental structures, we began to filter Chinese characters following rules:

1. There should be five groups of characters and each group represents one typeface structure.
2. Each group must include the characters with different strokes.
3. Each font covers all these five different structures of characters.
4. There should be equal quantity of characters with same structures and same strokes distributing over these six different fonts.

Thus, we prepared 600 characters for these six different typefaces, which mean each font had 100 characters. Then, in each 100 characters of the same font, we used 5 different font structures with the same number of different characters. Thus, in this experiment database, we had 5*20*6 = 600 characters. Concerning the amount of full-cover characters is small; we allowed duplication lower than 5%.

B. Participants

Fifty one participants (16 males and 35 females) in this experiment were all students from Beijing Normal University, age ranging from 18-28 years old (mean age was 22 years old), background covered undergraduates, masters and doctorates. Every participant was qualified for the requirement of eye sight (twenty- twenty, and no problem with color perception), and all participants had been paid after test as compensation.

C. Materials and Equipment

1) Data preprocessing

Different fonts have different styles, though as same characters in different fonts, they have different character height and width. To keep the design of different fonts, and to reduce the unnecessary visual effect when reading, we just adopted the linear normalization method to make all fonts with same height, because Chinese character point weight was measured by height.

TABLE III. FIVE DIFFERENT FONT STRUCTURES DISPLAYED IN WRYH

Right-left	加	**Up-down**	导	**Single**	之
Half-cover	适 旬		**Full-cover**	回	囵

Moreover, we calculated the black white contrast and height and width contrast for further analysis. In Chinese, the biggest characters are all from full-cover structure, hence we use full-cover characters to get the values of these two contrasts.

TABLE IV. TWO DIFFERENT CONTRAST VALUES OF 6 DIFFERENT TYPEFACES

	FZHT	FZWB	HWZS	WRJKT	WRYH	FZSS
H/W[a]	1.0780	1.1427	1.0979	1.2168	1.0387	1.1337
B/W[b]	51.65%	48.78%	41.73%	34.45%	48.24%	36.46%

a. H/W means height width contrast. b. B/W means black white contrast

2) Equipment

This experiment was computerized, and all computers had CPU P4 2.8GHz and 17'GRT monitor. Resolution of screen was 1024*768 Pixels and vertical refresh frequency was 85Hz. During the experiment data were displayed by software E-prime1.0 (made by Microsoft) [6].

Based on the above explanation on legibility, we decided to use the Single Character Flashing Response Test (SCFRT) method in this experiment.

D. SCFRT Procedure

Firstly, a focus point was displayed at the center of the screen for 500 ms, then this point disappeared, then the stimulator (recognition target of single character, which was displayed in a random order chosen from our database of 600 characters with different typefaces) appeared at that position for 100 ms. And then the response stimulus (a pair of characters with similar structure and partly similar look, such as "澡" and "燥", and this pair of characters were displayed in same typeface which was different from all these six fonts used above, for guaranteeing that participants really recognized this character rather than guessing by character shape) displayed on screen instead of stimulator for 1500 ms after 100 ms time interval, which was used to avoid masking effect stimulator made on the response stimulus. All the participants were asked to respond to the single stimulator character as soon as possible while keeping high accuracy, i.e. if the participant thought the previous single stimulator character was displayed on the left position of response stimulus (a pair of partial similar characters), just press Q button, and if shown on the right position, pressing P button. Moreover, to help participants keeping high accuracy and to reduce visual fatigue, there was a 1000 ms free time between every two questions, and that the whole experiment was under time control was hidden from all participants to make them relaxed and unstrained.

E. Analysis Method

To guarantee the effectiveness of the experiment result, we set a threshold. If the participant's accuracy is lower than 95%, we just ignore this data. After filtering, we got 47 effective results for analysis. Meanwhile, we measured all participants' response time of recognizing every single stimulator character, and then we calculated the mean recognition time of different typefaces and different structures. Descriptive Statistical analysis is presented below:

1) Tests of Within-Subjects Effects

Then, to make sure whether different fonts, different structures, and different fonts with different structures would influence the speed of recognizing characters by humans, we did the Tests of Within-Subjects Effects. We used four different analytical methods to analyze and compare results with each other, and fortunately, we got consistent results and they all showed that those fonts and structures' main effect and interaction between fonts and structures were all above the significance level, which meant that they all had capacities to affect the speed of recognizing conspicuously (Fig.2, Fig.3 and Fig.4). Detailed analysis will be shown later.

2) Pairwise Comparisons

In this part, we did two different comparisons, one was based on every two different fonts, and another one was based on every two different structures.

In different fonts' comparison, we calculated the mean speed of single character recognition and standard error value as preprocessing firstly, and then we used these data to do pairwise comparison. Data is shown below:

According to these data, because of the significant main effect, we found that participants read fastest on FZHT and FZWB than on any other typefaces.

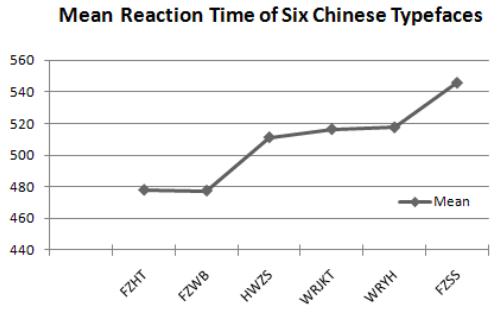

Figure 2. Mean Reaction Time of Six Chinese Typefaces

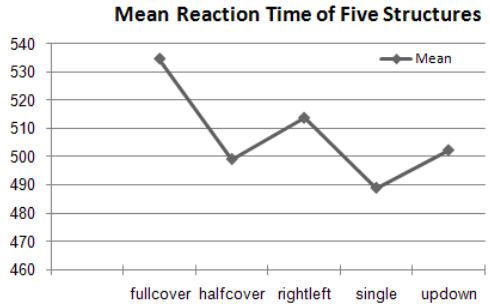

Figure 3. Mean Reaction Time of Five Structures

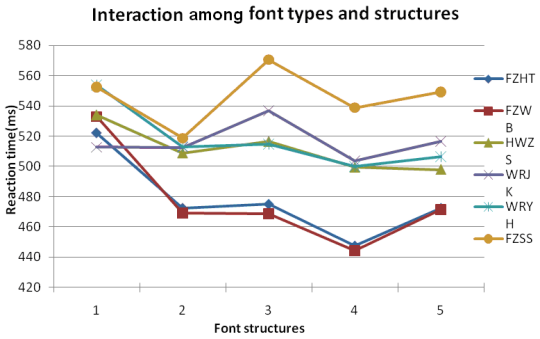

Figure 4. Interaction among six fonts and five structures

IV. FINAL DISCUSSION

Combining the two results of two different pairwise comparisons, we could easily draw the conclusion that FZHT and FZWB performed best in terms of overall situation, though in full-cover structure, they were a little bit slower than WRJKT. FZHT is a kind of standard sans serif HeiTi typeface. As a standard sans serif HeiTi, FZHT makes words look much clearer. When words are not big during display, because sans serif fonts focus on single characters, while, for WRYH, though belonging to category of HeiTi as well with FZHT, it modified the standard structure - not only for HeiTi structure, but also Chinese character writing structure - making the inner central part of character much bigger to keep character clear enough when it was displayed in small size. Obviously, this modification did not get people's hearts (because it was ranked out of the top five), and it is not superior in recognition speed as well, thus we can deduce that people like the ordinary structure of characters.

SongTi, whose serif characteristics are obvious and character structure is similar to handwriting Kai Ti which was the first character model for almost all Chinese children, is considered to be the perfect font of elementary books. Thus, no matter FZSS or HWZS, it still maintained the SongTi design style. However, because of its emphasis on Heng(横) and Shu(竖) contrast, the horizontal line would be weakened when it is seen from distance, which leads to a lower rate of character recognition. Though hinting, anti-aliasing, and subpixel rendering methods have partially mitigated the legibility problem of serif fonts on screen, the basic constraint of screen resolution — typically 100 pixels per inch or less — and small font size continues to limit their legibility on screen, especially for fast reading.

Because of the low black white contrast (34.45%) comparing with the other four fonts, WRJKT cannot perform well. When reading fast, the strokes would be overlooked. However, as the most two outstanding typefaces, their black white contrast were all above 45%.

FZWB, one special typeface, is neither serif nor sans serif typeface, with strong black white ratio which is enough to attract people's eyesight, moreover keeping enough spaces among different strokes. Though in this font, characters look short and a little bit fat, but both subjective and objective proofs show that this typeface indeed performs well in single character display. Thus, by now we can say FZWB is quite suitable for titles.

Thus, FZHT and FZWB get the highest legibility on single character display and cause less fatigue and eyestrain relatively, comparing among these six best typefaces.

In this paper, we have made an attempt to discover the legibility of Chinese digital fonts for reading digital documents and information. We hope this study will stimulate more research in this area so that one day, we can identify the most legible digital typefaces for both human and machine reading.

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