Eye-scan patterns of Chinese when searching full screen menus

W. C. Lau, Ravindra S. Goonetilleke*, and Heloisa M. Shih

Human Performance Laboratory
Department of Industrial Engineering & Engineering Management
Hong Kong University of Science and Technology
Clear Water Bay, Hong Kong

With the rapid globalization of Information Technology, it is important not only to evaluate performance, but also to understand the underlying causes of performance differences among populations when using computer interfaces. In this study, the search strategy of three different groups of users (Mainland Chinese, Hong Kong Chinese and Non-native Chinese readers) was assessed. A full screen search task was used to understand the search strategies and their relationship to cultural and linguistic aspects. The stimulus materials were high or low complexity Chinese words having one of three layouts: Row, Column or Uniform separation. The search patterns were recorded using an eye tracking system. To categorize these patterns, a new measure called HV-ratio was developed. Analysis of variance on HV-ratio showed that the search patterns between Hong Kong Chinese and Mainland Chinese are significantly different. The HK Chinese used predominantly horizontal search patterns in all three layouts. In contrast, Mainland Chinese changed their search pattern depending on the screen layout. HK Chinese used a more systematic horizontal search pattern. These strategies explain the overall performance findings in relation to search time.

1. INTRODUCTION

As China enters the information technology era, it becomes important to understand Chinese users in an effort to produce software that is efficient and usable. It is known that primitives such as culture and language play an important role in interfaces made for people. In this study, we attempted to understand the impact of the Chinese language on visual search patterns.

Despite the fact that Chinese are one of the largest ethnic groups in the world, little is known about their visual search performance and search patterns. Most past studies have focused on visual search performance of Western populations even though differing language backgrounds may have differing scanning patterns (Nielson, 1990). The English language reader has an effective visual field or perceptual span that is asymmetric, extending about 4 characters to the left of the letter being fixated and about 15 characters to the right (Rayner et al., 1981). Pollatsek et al (1981) has shown language dependencies in relation to this asymmetry. The Chinese language is somewhat different as it can have two different orientations (a horizontal or 'Z' type orientation, starting in the top left corner of the paper and a vertical or inverted 'N' type of orientation, with text starting in the top right corner of the page) and the Chinese people are accustomed to both these orientations. It is well known that a search field that can fit the visual lobe more efficiently can facilitate visual search performance. Hence, this presents us with an important parameter that needs investigation in relation to the visual search process of Chinese users. We hypothesized that the cultural difference could possibly interact with different types of layouts and have an impact on search performance.

In one of our previous publications (Lau et al, 2000), we presented the effect of culture when searching full screen menus and showed that Hong Kong Chinese, Mainland Chinese and non-native Chinese readers had significant differences in terms of preference and search time. In general, Hong Kong Chinese had significantly better performance on the top horizontal area of the search field, while Mainland Chinese had better search performance on the top left side of the screen. Non-native Chinese readers had no "preference" on any particular area.

Differences in search performance however did not provide a complete picture of the cultural effects on search strategy. In this study, we report the eye tracking data results in an attempt to quantify search strategies and understand the differences in search performance among the three "cultural" groups.

2. METHODOLOGY

2.1 Experimental task

The objective of the task was to find a Chinese word (target word) in a full screen search field. This was a two-step process; the target word was shown on the screen first (target word screen). After the subject "studied" this word, the search screen was shown. The search screen had the target word among many other words. The target word screen had the same layout as the search screen and had one target word laid out all over the screen. The reason for filling the screen with the target word was to prevent any starting position bias when the target word screen changed to the search screen. The experimental time was about 1 hour.

2.2 Experimental design

The independent variables of the experiment were population (Hong Kong Chinese, Mainland Chinese, and Non-native Chinese), Layout (Row, Column and Uniform), Word-complexity (High and Low). The experiment was a 3 (Population) × 3 (Layout) × 2 (Word-complexity) × 10 (Trial) design. Each participant completed a total of 60 trials (10 trials each for the 3 Layouts and 2 Word-complexities). The experiment was "blocked" by the 6 conditions (three Layouts and two Word complexities) with each block having 10 trials. The sequences were balanced among participants by using the six conditions to form a Latin square-like design.

The difference between the three layouts was the separation between row and columns. The format of the “Row” layout was similar to the horizontal writing format ("Z" type) of Chinese text, while the Column layout was similar to the vertical writing format ("N" type). The third layout was called “Uniform separation”` where the horizontal and vertical separations between words were the same. In all these three layouts, the numbers of rows and columns were divisible by three thereby giving nine macro areas as shown in Figure 1.

1	2	3
4	5	6
7	8	9

Figure 1. The nine areas in the search field.

The Chinese words used in the experiment were selected based on their word complexity. Two word complexities (High and Low) were used in this experiment. ‘Low complexity’ words were those that had 10 to 12 strokes. ‘High complexity’ words were those that had 16-18 strokes. According to the Chinese dictionary (Hu-pei tzu shu chu pan she, 1989), low complexity words comprise 15-34 percentiles while High complexity words correspond to 60-81 percentiles of the total word distribution. Only Chinese words with a left-right format (for example  for "Talk") were selected. Those Chinese words with a top-down format (for example  for "leaf") were not selected as Chinese words with a left-right format are generally much clearer on a computer display. The size of the Chinese words were 9mm*9mm, equivalent to a visual angle of 1 degree.

2.3 Participants

In this experiment, three groups (Hong Kong Chinese, Mainland Chinese, and Non-native Chinese readers) of 6 participants (a total of eighteen) were tested. Their age range was 13-36 years. All participants recognized all the Chinese words.

2.4 Materials and Equipment

The experiment was programmed using Visual Basic 6.0 and run on a Pentium 200MHz computer in the Microsoft Chinese Windows 98 environment. The subject responses were acquired through a touch screen monitor and two external push buttons. The Applied Science Laboratories (ASL) 5000 eye tracking system was used to record the subject's eye movement.

2.5 Procedure

Prior to the actual experiment, each participant was given three practice trials. In all trials, the target word screen was shown first. After the participants had memorized the target word, they were asked to press the external "Continue" button to proceed to the search screen. When the search screen was shown, the participant had to find the target word as fast as possible. The time limit for each trial was set to 90 seconds. Once the participants found the target word, they were asked to "touch" that word on the touch screen monitor. If they were unable to find the target word or thought that the word did not exist on the screen, they were asked to press the external "Give up" button to end the trial.

3. RESULTS AND ANALYSIS

The performance results of this experiment were reported in Lau et al (2000). This paper focuses on the eye tracking data. Researchers have categorized search into two main types - systematic search patterns and random search patterns. In this experiment, the systematic search patterns were most frequent (about 90%) and the random search patterns were less seen (about 10%).

In the context of our experiment, systematic search patterns are those performed row by row or column by column, until the target is identified. In this experiment, participants usually started a search at specific starting points (usually in the top left or top right corner) and then searched that row or column. After finishing that particular row or column, participants searched the next row or column respectively.

Eye scan patterns are generally not quantified and are very subjective. As a result, a new measure was developed to quantify the search patterns. The quantified variable is denoted as the HV-ratio. The direction of a saccade can be identified based on the coordinates of two consecutive fixations. To determine the HV-ratio, each saccade was divided into a vertical movement and a horizontal movement (Figure 2). The sum of all the absolute values of the vertical movements within a trial corresponds to the total vertical movement. The sum of all the absolute values of the horizontal movements within a trial corresponds to the total horizontal movement. The total vertical movement was then normalized with respect to the height of the search field and the total horizontal movement was normalized by the width of the search field. The ratio of these two quantities was defined as the HV-ratio.

$$\text{HV-ratio for a trial} = \frac{\Sigma \text{ (Horizontal movement i)/ (width of the search field)}}{\Sigma \text{ (Vertical movement i)/ (height of the search field)}}$$

If the scan pattern of a participant in a particular trial was dominantly horizontal (that is a search performed row by row), the HV-ratio would be large. If the scan pattern was dominantly vertical (column by column search), the HV-ratio would be low.

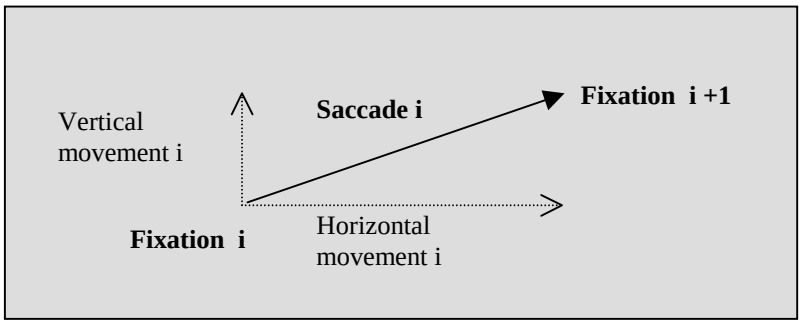

Figure 2. Components of the HV-ratio calculation with respect to the computer screen.

A 4-way (Population × Layout × Word complexity × Target position) ANOVA on HV-ratio showed a significant effect for Population ($F(2, 709) = 118.93$, $p<0.0001$). The *post-hoc* Student Newman Keuls (SNK) analysis showed Hong Kong Chinese had a significantly higher HV-ratio than both Mainland Chinese and Non-native Chinese readers. There were no differences between Mainland Chinese and Non-native Chinese readers. Layout was also significant ($F(2, 709) = 4.75$, $p<0.009$). The Row layout had a higher HV-ratio than both Column and Uniform

separation layouts. The interaction between Population and Layout was also significant ($F(4, 709) = 5.49$, $p<0.0002$). Figure 4 shows the interaction plot between Population and Layout.

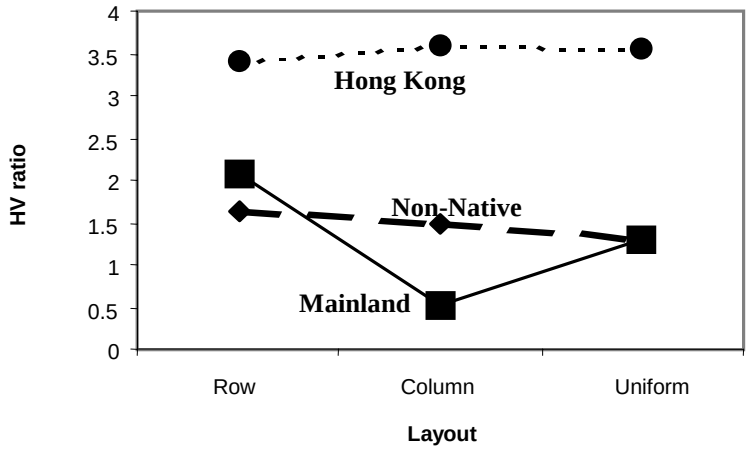

Figure 3. Interaction plot of POPULATION * LAYOUT.

Due to the significant interaction, a simple effects ANOVA was performed for each Population group (Table 1). It was found that the Layout effect was not significant for the HK Chinese and Non-native Chinese reader groups. However, the Layout effect was significant for the Mainland Chinese group ($F(2, 243) = 48.21$, $p<0.0001$), with each of the three layouts being significantly different from each other. For the Mainland Chinese group, the Row layout had the highest HV-ratio. On the other hand, the Column layout had the lowest HV-ratio, and the Uniform separation had a value between those of the Row and Column layouts.

Table 1. Simple effect ANOVA of HV-ratio for each Population group.

Population groups	F value (df) (probability)	SNK grouping of Layout* *HV-ratio increases from left to right (→)*
HK Chinese (H)	F (2, 257) = 0.09 (0.91)	R E C (3.42) (3.53) (3.57)+
Mainland Chinese (M)	F (2, 243) = 48.42 (0.0001)	C E R (0.5) (1.29) (2.07)
Non-native Chinese readers (N)	F (2, 209) = 0.88 (0.42)	E C R (1.29) (1.47) (1.64)

+ The mean values are in parenthesis ( ).

*Levels sharing the same underline indicate no significant difference.

4. DISCUSSION AND CONCLUSIONS

HK Chinese had relatively high HV-ratios in all three layouts implying that they mainly used a horizontal search pattern independent of layout (Table 1). The Non-native Chinese readers also had no significant difference in HV-ratio among the three layouts. For this group of subjects, the HV- ratio is around 1, implying that the Non-native Chinese reader group, in general, had no preference towards a horizontal or vertical search pattern in all three layouts. Mainland Chinese on the other hand seem to change their search patterns in different layouts. For the Row layout, Mainland Chinese used more horizontal search and in the Column layout, they used more vertical search (HV-ratio < 1 has been regarded as a vertically dominant search pattern), and for the Uniform Separation layout, Mainland Chinese have a HV-ratio that is in between the value of other two layouts.

The differences in strategies between the two Chinese groups may be due to many different factors. Some of which are:

1. Differences in reading materials: Nowadays, in Hong Kong, the most common Chinese reading materials are newspapers and magazines printed having a vertical format. In Mainland China on the other hand, most of the reading materials (including newspaper and books) are printed in a horizontal format even though there is other reading material (e.g. Fiction) printed with a vertical orientation. The reading materials in Mainland China are a mix of both orientations and as a result Mainland Chinese adopt a pattern depending on the stimulus material.
2. Another possibility may be related to the differences in computer usage. Hong Kong Chinese subjects have immense experience with the use of computers. The software packages that are frequently used in Hong Kong include Microsoft Office and Windows based software, which generally have a horizontal structure in their menu layouts. The icons in these packages are square in shape and have a pictorial format, a characteristic similar to Chinese characters. Therefore the search pattern of HK Chinese on the Chinese full screen menu may be influenced by the format of icon menus in computer software. The Mainland Chinese subjects had less experience with computers before they came to Hong Kong and as a result, they may have chosen a search pattern based on the reading pattern of a given Layout.

Thus, it may be concluded that the search patterns between Hong Kong Chinese and Mainland Chinese are significantly different. The HK Chinese used predominantly horizontal search patterns in all three layouts. In contrast, Mainland Chinese change their search pattern depending on the screen layout. HK Chinese used a systematic (about 90%) horizontal search pattern. This caused the HV-ratio of HK Chinese to be significantly higher than that of Mainland Chinese. The changing patterns of Mainland Chinese in the three layouts led to a significant interaction between Population groups and Layout (Figure 3). These results explain the findings of our previous study (Lau et al., 2000) that Hong Kong Chinese had better performance when the target was in the top horizontal area of the search field.

For interfaces similar to the ones we used in this experiment, it may be appropriate to consider horizontal layouts as Hong Kong Chinese have a horizontal scan pattern, and the Mainland Chinese tend to show flexibility in their search patterns depending on the layout. The results of this study have important implications for designers. Even though different population “groups” are familiar with similar characteristics (in this case, Chinese words), their performance on any given interface can be different depending on the underlying mechanisms that govern their usage. Understanding the underlying differences between "similar" groups or cultures and catering to such differences is the key to producing optimized interfaces.

ACKNOWLEDGMENTS

The work was supported with funding from a HKUST Direct Allocation Grant (DAG99/00.EG14).

REFERENCES

Han yu ta tzu tien pien chi wei yuan hui 漢語大字典編輯委員會 (1989). *Han yu ta tzu tien漢語大字典*, Hu-pei tzu shu chu pan she湖北辭書出版社, Wu-han 武漢。

Lau, W.C., Shih, H. M., and Goonetilleke, R. S. (2000). Effect of cultural background when searching Chinese menus. In *Proceedings of the 4th APCHI / 6th SEAES Conference 2000 (Ed. K. Y. Lim)*, (pp. 237-243), Amsterdam: Elsevier.

Nielsen, J. (1990). Usability testing for international interfaces. In J.Nielsen (Ed.), *Designing user interfaces for international use* (pp. 39-44) Amsterdam: Elsevier.

Pollatsek. A., Bolozky, S., Well, A.D., and Rayner, K. (1981). Asymmetries in the perceptual span for Israeli readers. *Brain and Language*, *14*, 174-180.

Rayner, K., Inhoff, A. W., Morrison, R. E., Slowwiaczek, M. L., and Bertera, J.B. (1981). Masking of foveal and parafoveal vision during eye fixations in reading. *Journal of Experiment Psychology: Human Perception and Performance*, *7*, 167-179.