Chapter 29

Determining the Parameters for the Scrolling Text Display Technique

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This paper reports on empirical efforts to determine the threshold values and the feasible ranges of the parameters for scrolling text display technique (i.e., Times Square scrolling). Parameters associated with the technique, such as speed of scrolling and maximum possible length of a sentence for one scrolling, were examined through the use of an Eye Link System, and answers to the following research questions were experimentally provided: (1) how fast should the text scrolling be?; (2) how well do experimental subjects retain the text at different speeds?; (3) at what speed do the subjects fail to comprehend the scrolling text?; and (4) how many Japanese characters can subjects read at a time?

Introduction

With the recent rapid advances in multimedia, a variety of visual presentation techniques have been developed. Horizontal right-to-left scrolling text display (i.e., Times Square scrolling) is one major technique, in which linguistic information (i.e., characters) is presented, as in the case of an electric bulletin board, scrolling from right to left at a certain speed, in a limited visual display area on a monitor.

Previous studies, such as Elson (1982), Granaas, McKay, Laham, Hurt, and Juola (1984), Chen, and Tsoi (1988), Kang, and Muter (1989) and Juola, Tiritoglu, and Pleunis (1995), have dealt with scrolling text either by RSVP or the Times Square method, but none of these have focused on eye movement, recorded by computer. Kolers, Duchnicky, and Ferguson (1981) have indeed studied eye movement when scrolling text moving upward was shown. In our experiment, we studied text scrolling smoothly from right to left, pixel by pixel.
The parameters associated with scrolling, such as speed of scrolling, and maximum possible length of a sentence for one scrolling have, however, so far been determined, working mainly from the mere experience and intuition of programmers, and thus without empirical underpinnings.\(^1\)

In this experiment, therefore, efforts were made to determine basically and empirically the optimal scrolling speed and the maximum possible sentence-length for one scrolling.

In reading text under ordinary conditions, the alternation of fixations and saccades is repeated from the beginning to the end of the text. Information is extracted during fixations, and the saccades occur to move on to the next source of information.

When reading the text scrolling from right to left, the locus of the eye movement is as shown in Figure 29.1, in which the X-axis shows the time, and the Y-axis indicates location of the eye. Ideally, the eyes follow the scrolling text and recognize it during smooth pursuit eye movement, which is then followed by a saccadic eye movement to a new position — a process that is repeated to the end of the text.

**Purposes**

The purposes of this paper are to answer the following four research questions concerning the parameters of the text scrolling:

1. How fast (or slow) should the text scrolling be?
2. How well do the subjects retain the text at different speeds?
3. At what speed do the subjects fail to comprehend the scrolling text?
4. How many Japanese characters can the subjects read at a time?

**Experiment**

**Apparatus**

An EyeLink System (sampling rate: 250 MHz) produced by the SMI Corp. was used for this experiment. The system is made up of a subject PC (Compaq Deskpro 4000) for presenting the stimuli and collecting the data from the eye camera mounted on each subject, and an operator PC (Compaq Deskpro 4000) for regulating the stimulus presentation, and accumulating the data collected from the subject PC.

**Materials and Display Method**

The twelve texts used for this experiment were selected from the *Vox Populi, Vox Dei* column in the *Asahi* Newspaper, a major Japanese newspaper. They were written in standard Japanese with hiragana (i.e., the Japanese cursive syllabary) with a moderate amount of Chinese characters scattered through the texts. They were of approximately 200 words in length.
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The texts were displayed in a window on the monitor. The window was 24° in width. This width was derived experimentally, with the object of not hindering natural reading in scrolling texts (Kamei & Kikuchi, 1997). The distance between the monitor and the subject was 41 cm, and the size of one character displayed was 1° horizontally and vertically measured as a visual angle. The scrolling speeds chosen for the experiment were 3, 5, 7, 10, 13, 16, 19, 22, and 25°/s. The scrolling speeds and the texts were randomly combined and displayed to the subjects, so that any influence from differences among the texts could be cancelled out.

Subjects

Five subjects (20–26 years old) with normal vision participated in this experiment. They were college students at Kansai University, whose native language is Japanese.

Procedure

Prior to the experiment, it was explained to the subjects how the texts were to be presented on the monitor, and they were instructed to read and retain their informational content. The subjects were then asked to write down what they had retained on paper provided. What they had written was then checked by a member of our research team, using a 10-point scale based on idea-units predetermined for each text. An example of the idea-units can be found in the Appendix.

The subjects were also asked to supply, by using a one-to-five Likert scale, their own rating of the relative easiness of reading at different scrolling speeds. One on this scale meant “the least ease of reading”, and three “the average ease”, while five indicated “the most ease".
Results

Scrolling Speed and Relative Easiness of Reading

Figure 29.2 shows the relationship between the scrolling speed and the subject-reported relative ease of reading. Given a scrolling speed below $10^\circ$/sec, the subjects found the texts to be relatively easy to read, while they found them difficult or uncomfortable to read when given a scrolling speed above $10^\circ$/sec.

Scrolling Speed and Retention of Content

A minimum score of five points (out of a maximum of ten) on the retention of predetermined idea-units was adopted as the threshold level of retention of content. For example, as Figure 29.3 shows, subject B’s score for retention dropped below five at a scrolling speed of $10^\circ$/sec.

Scrolling Speed and Loci

Compare Figures 29.4–1, 29.4–2, and 29.4–3 for the relation between scrolling speed and loci. These are examples of a subject that behaved typical to the other subjects. The loci in Figure 29.4–1, which shows the eye-movement curve at a scrolling speed of $3^\circ$/sec, are mainly pairings of fixation and saccade. This indicates that the speed for scrolling is too slow. The loci in Figure 29.4–2 (at $7^\circ$/sec) are mainly pairings of smooth pursuit eye movement and saccadic eye movement. On the other hand, the loci in Figure 29.4–3 (at $22^\circ$/sec) are combinations of not only smooth pursuit eye movement and saccadic eye movement, but also fixation, which suggests that the subject gave up reading at this scrolling speed.

![Figure 29.2: Relation of scrolling speed and relative easiness of reading.](image)

Note: $1^\circ$ is equivalent to one character.
A similar behavior (Merrill & Stark, 1963), termed OKN (optokinetic nystagmus), must be mentioned here. From a moving train, a man is taking a look outside, absent-mindedly, and suddenly notices a shrub in the desert outside the train. His eyes follow the shrub for a short moment. This eye movement, OKN, is totally involuntary and is not related to the eye movements examined in this article. Some researchers, such as Honrubia, Downey, Mitchell, and Ward (1968) and Jürgens, Becker, Reiger and Widderich (1981), indicated that the range and the speed of the smooth pursuit eye movements of OKN are far too larger than those of our experiment result. This is because the voluntary eye movement in our experiment is concerned with cognition of reading.
Table 29.1 is a summary of the relationships between the scrolling speeds and eye-movement properties. This table shows that between the speeds of 7 and 10°/sec, all our subjects repeated smooth pursuit eye movements and saccadic eye movements in the direction opposite to that of the scrolling display, which is a sign of ease of reading.

Average Velocity of Smooth Pursuit Eye Movements

Figures 29.5–1 (3°/sec), 29.5–2 (7°/sec), and 29.5–3 (22°/sec) respectively show the relation between the scrolling speed and the smooth pursuit eye movement velocity.
Table 29.1: A summary of the relationships between the scrolling speeds and eye movement properties (1° is equivalent to one character.)

<table>
<thead>
<tr>
<th>Scrolling speed [deg/sec]</th>
<th>Fixation</th>
<th>Smooth pursuit eye movement</th>
<th>Opposite direction of scrolling display</th>
<th>Direction of scrolling display</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>F</td>
<td>R</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>5</td>
<td>L</td>
<td>L</td>
<td>F</td>
<td>L</td>
</tr>
<tr>
<td>7</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>10</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>R</td>
</tr>
<tr>
<td>13</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>L</td>
</tr>
<tr>
<td>16</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>19</td>
<td>R</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>22</td>
<td>L</td>
<td>F</td>
<td>F</td>
<td>L</td>
</tr>
<tr>
<td>25</td>
<td>L</td>
<td>F</td>
<td>F</td>
<td>L</td>
</tr>
</tbody>
</table>

Note: F: Frequent, L: A few, R: Rare.

Figure 29.5–1: Percentage of frequency of smooth pursuit eye movement velocity.
Note: Scrolling speed: 3°/sec. 1° is equivalent to one character.

As is typical, the X-axis indicates the velocities of smooth pursuit eye movements, with the percentage of frequency shown on the Y-axis. As can be seen in these figures, regardless of scrolling speed, the velocity of smooth pursuit eye movements is around 2 to 4°/sec. In Figures 29.5–1 and 29.5–2, the velocity over 15°/sec seemingly appears,
but it is the accumulation of tiny saccades and small smooth pursuits, whereas in Figure 29.5–3, it is the accumulation of OKN.

In other words, smooth pursuit eye movements invariably center around the velocity of 2 to 4°/sec in reading the scrolling text. This generalization led us to compute the average velocity of the smooth pursuit eye movements made by our subjects, as shown in Figure 29.6.

In this figure, the solid line is the hypothetical line projected for a situation in which the smooth pursuit eye movement velocity and the scrolling speed are identical in speed. All subjects showed smooth pursuit eye movement velocities that fell lower...
than this hypothetical line. Excepting subject B, who showed different smooth pursuit eye movement velocities, the remaining subjects clustered around 1 to 5°/sec.

**Relative Smooth Pursuit Eye Movement Velocity**

The concept of relative smooth pursuit eye movement velocity, original to the authors, was adopted, and this relative velocity was calculated according to the formula shown below.

**Formula 1**

\[
\text{(Relative smooth pursuit eye movement velocity)} = \text{(scrolling speed)} - \text{(smooth pursuit eye movement velocity)}
\]

Figure 29.7 shows the plotted results of the calculations, indicating that the relative smooth pursuit eye movement velocity at the circled area was below 10°/sec. From the information shown in Figures 29.2 and 29.3, it was evident that the subjects in this circled area comprehended the text by 50% or more. In other words, when the relative smooth pursuit eye movement velocity is over 10°/sec, all the subjects failed to comprehend the text. This is because such relative smooth pursuit eye movement velocity produces only blurred images on the retina, resulting in incomprehension. When the relative smooth pursuit eye movement velocity is 0°/sec, there is no blur of the image. The greater the relative smooth pursuit eye movement velocity, the more blurred the image becomes. So the image of the text on the retina can no longer be recognized once the relative smooth pursuit eye movement velocity rises above 10°/sec.
Figure 29.7: Relative smooth pursuit eye movement velocity.

*Note:* $1^\circ$ is equivalent to one character.

**Number of the Characters Read During a Single Smooth Pursuit Eye Movement**

The number of Japanese characters to be covered in one smooth pursuit eye movement can be calculated using the following formula:

\[
(\text{Number of characters}) = (\text{relative smooth pursuit eye movement velocity}) \times (\text{smooth pursuit eye movement time in length})
\]

Note that $1^\circ$/sec is equal to 1 Japanese character/sec.

The average number of the characters read during one smooth pursuit eye movement made by each subject is shown in Figure 29.8. The circled area in this figure shows scrolling speeds of $10^\circ$/sec or less, within which range all our subjects read a maximum of five characters. We may, therefore, safely conclude that the scrolling text allows readers to read at most five Japanese characters at one smooth pursuit eye movement.

**Conclusions**

The results of our experiment showed that (1) the maximum possible scrolling speed (in which reader’s comprehension is ensured) was $10^\circ$/sec; (2) smooth pursuit eye movements in the direction of scrolling and saccadic eye movements in the opposite direction were repeatedly and constantly alternated during the reading of the scrolling sentences presented at speeds of between 7 and $10^\circ$/sec; and (3) when the relative velocity between the smooth pursuit eye movement and the scrolling (interpreted as the velocity of scrolled images on the retina) was more than $10^\circ$/sec, our subjects failed to comprehend the sentences. Lastly, (4) the number of Japanese characters (the mixture of hiragana and Chinese characters) that could be read in one smooth pursuit eye movement, was five at maximum.
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Figure 29.8: Average number of characters to be read during a smooth pursuit eye movement.

Note: 1° is equivalent to one character.

Notes

1 Dyson and Haselgrove's study in 2001 and Komine and Isono's study in 1996 are two rare attempts at empirical validation. Also, at our own laboratory, Kamei and Kikuchi (1997) conducted research in the same vein through the use of a lower precision/resolution EMR-7 produced by the NAC Corp.

2 Ikeda and Saida (1978) reports that the average number is around 8 or 9 English characters at one fixation and 3 or 4 Japanese characters in reading texts presented statically.

References


**Appendix: An Example of Predetermined Idea Units**

*A sample sentence* (Translation ours. Original sentence written in standard Japanese with a mixture of Hiragana and Chinese characters.)

When Kyoko found Kazuo on the opposite side of the road and tried to call him, a white dog jumped onto the road, and the driver of a green trailer truck that was running at top speed on the road, noticed it and hit his brake hard.

**Idea Units Derived from the Sentence**

- Kyoko found Kazuo.
- Kazuo was on the opposite side of the road.
- Kyoko tried to call him.
- A dog jumped onto the road.
- The dog was white.
- A trailer truck came up.
- The trailer truck was running at full speed.
- The driver noticed it.
- The driver braked hard.