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The effects of Chinese typeface design, stroke weight, and contrast polarity on glance based legibility

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ABSTRACT

Modern interfaces increasingly rely on screens filled with digital text to display information to users. Previous research has shown that even relatively subtle differences in the design of the on-screen typeface can influence to-device glance time in a measurable and meaningful way (Reimer et al., 2014). Here we outline a methodology for rapidly and flexibly investigating the legibility of typefaces on digital screens in glance-like contexts, and apply this method to a comparison of 5 Simplified Chinese typefaces. We find that the legibility of the typefaces, measured as the minimum presentation time needed to read character strings accurately and respond to a yes/no lexical decision task, is sensitive to differences in the typeface's design characteristics. The most legible typeface under study ("MT YingHei") could be read 33.1% faster than the least legible typeface in this glance-induced context. A second study examined two different weights of the MT YingHei type family (medium and bold), as well as two contrast polarity (color) conditions to investigate how these variations impact legibility thresholds. Results indicate that bold weight text is easier to read in this enforced glance-like context, and that positive polarity text (black on white) is easier to read compared to white on black text under the lighting conditions considered. These results are discussed in terms of contextual factors that may mediate glance-reading behavior, as well as how type design interacts with the practical limitations of a moderate density pixel grid.

1. Introduction

The meteoric rise of the smartphone, and the incorporation of electronic displays into an increasing number of technologies (in-vehicle devices, wearables, subway signage, advertising, etc.) have made digital screens essential to daily life. Use of these information sources has resulted in a new kind of reading behavior, markedly different from traditional long-form or "embedded" reading. Instead, more and more text is now read in short bursts of attention or otherwise performed in brief glances. Where once text might have been static and predictable, as in the dependable columns of a newspaper, a sign papered on the wall, or the display of text in a vehicle instrument cluster, it is now dynamic, shifting and changing to suit the next article, function, or app. While high-resolution displays (300-400PPI) have become increasingly common in smartphone hardware specifications, most desktop displays and in-vehicle device screens continue to rely on lower pixel densities (80-110PPI) [1,2]. Combined with the diverse environments in which displays may be used, it becomes clear that the display's readability may vary considerably, dependent on a large number of interacting factors.

As the interfaces that display information to us become more complex and the characteristics of what we can display become more flexible, it becomes necessary to form an empirical understanding of what makes text easier to encode, understand, and retain. Clear information presentation, particularly in the context of at-a-glance reading behavior, will be essential to global technology development, deployment, and marketing.

Previous research has shown that even something as subtle as a display's typeface can significantly impact reading behavior and task completion time [3]. That study compared two seemingly similar sans-serif typefaces: a humanist style typeface, and a square grotesque. In a fully simulated driving environment, drivers spent less time glancing at an in-vehicle display set in a humanist style typeface as compared to a square grotesque typeface, particularly

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among males. The differences governing the design of these typefaces, relatively subtle outside the world of typography, nevertheless had a significant and real impact on driver behavior.

The results of this study led to the development of a simplified psychophysical technique—a lexical decision task used in combination with a thresholding procedure—for assessing typeface legibility, the results of which were consistent with the results obtained from the original driving simulator study [4]. This simplified method allows for multiple interacting typographic factors to be examined and compared simultaneously in a more controlled framework. The method greatly increases the speed and flexibility of investigation while providing results that extend beyond the automotive context. It was hypothesized that the lexical decision task used would generalize to studies of non-Latin character sets, such as Simplified Chinese. Given the rapid adoption of smartphones, in-vehicle technology, and other types of digital screens by Chinese consumers [5], a psychophysical investigation of Chinese legibility factors was developed to assess this hypothesis.

Chinese typographic styles can be classified into several broad categories, including Kai, Ming, and Hei [6]. Kai typefaces resemble handwritten calligraphy. Ming (also called Song) typefaces were designed for printing, and therefore use simpler stroke patterns, but still contain subtle detailing and fine stroke widths similar to Western serif typefaces such as Times New Roman. Hei typefaces feature thicker, more regular strokes and a minimalistic design aesthetic, placing them on par with Western sans-serif typefaces such as Helvetica.

Several studies have attempted to examine the effect of typographic style on the legibility of Chinese characters. Early work in this area showed that character identification accuracy suffered when a handwriting-like Kai typeface was used to render characters, as opposed to one made for digital screens [7]. Similar work has shown the Kai style to be inferior to the Ming style on digital screens [6]. On the other hand, subsequent research using a reading comprehension paradigm failed to find an effect of typeface style [8]. Other studies of Chinese typography that use paradigms in which text is read with little or no time pressure, such as tests of reading comprehension or character search tasks, have also failed to find an effect of typeface design [9–11]. All of the aforementioned studies typically compare two typeface styles, most commonly Ming and Kai. Shieh et al. [7] reported using a Kai typeface and a "computer" typeface (the exact typeface is not reported, but the paper's figures suggest a Hei typeface). More recent work that examined the typography of digital roadway signage in a simulated driving task found an advantage of Hei-style typefaces [12]. At present, it appears that the relatively subtle differences within Chinese type styles are under-studied, perhaps because the methodologies typically used to investigate legibility lack sufficient sensitivity to reveal differences within styles.

Typographic style interacts with a number of other display factors, including the colors used for the background and foreground of the display. Several studies of the effects of color and/or contrast polarity have shown mixed results, with several indicating legibility benefits for positive polarity (dark on light) displays [8,11], another showing advantages for negative polarity (light on dark) displays [10], and at least one study that failed to show an effect of display color [7]. Recent research suggests that positive polarity displays provide a legibility advantage over negative polarity displays, and that this is most likely due to pupillary dilation in the presence of darker backgrounds, which provide less illumination than a light background [13–15]. The balance of evidence seems to suggest a legibility advantage for positive polarity digital text, consistent with early research on the legibility of printed materials [16].

In addition to text polarity, the weight, or line thickness, of the typeface can affect legibility. Studies of Latin text show that legibility is usually optimal when using typical medium weight fonts, and that legibility can be hindered if the font weight is extremely light or bold [17,18]. However, it should be noted that Sheedy et al's [19] research suggests that bold weight fonts may produce a legibility advantage in difficult "near threshold" reading conditions. To our knowledge, no comparable studies of the effect of stroke weight have been carried out on Chinese typefaces, at least as can be determined from English language literature reviews.

In summary, there has been relatively little research to date on how certain design factors, such as typeface style, font weight, and contrast polarity, affect the legibility of Chinese characters on digital screens. While several studies have compared Ming and Kai style typefaces, there has been little work done with Hei typefaces, and critically, no work to date has examined possible design differences within a single typeface style (such as the many different Hei-style typefaces currently available). The methods used in these studies typically rely on reading comprehension, character search, or serial presentation tasks. Studies have shown that such self-paced methods are not sufficiently sensitive to differences between typeface styles, while techniques that place constraints on evaluation time have been able to reveal such differences [7]. These results suggest that typeface design may play a more prominent role in constrained glance-like reading contexts. At the same time, investigations of the effects of font weight and display contrast polarity on Chinese legibility are sparse.

Here we present two studies that employ a psychophysical technique for enforcing glance-like reading behavior to examine these issues in more detail. Study I examines the relative legibility of five Simplified Chinese typefaces, four of which are within the Hei-style family. Study II expands upon these findings by choosing the most legible typeface from Study I and presenting it in two different weights and in two different contrast polarities.

2. Study I

2.1. Materials and methods

2.1.1. Participants

A total of 34 participants who natively read Simplified Chinese were recruited for this study. Of these, 5 were excluded from analysis due to an apparent failure to understand the task, 6 were excluded because they failed to reach a stable threshold estimate in the allotted time (see Section 2.1.5, and [4] for a fuller explanation of this criterion), and 1 was excluded due to technical problems with the equipment. This left a total of 22 participants between the ages of 30 and 75, equally split between men and women (men: mean age = 43.9, SD = 10.3; women: mean age = 45.5, SD = 10.1). There was no significant difference in age between genders ($t(20.0) = 0.356$, $p = 0.726$). All participants gave their written, informed consent to participate, as outlined by the Committee on the Use of Humans as Experiment Subjects (COUHES) of the Massachusetts Institute of Technology and were compensated for their involvement in the study. All data were collected by trained MIT staff in university-owned facilities.

Owing to cultural/local factors that can affect the interpretation of Chinese script, participants were required to be native readers of Simplified Chinese from Mainland China. Participants also had to be in self-reported reasonably good health for their age. Exclusion criteria included experience of a major medical illness or hospitalization in the last six months, conditions that impair vision (other than typical nearsightedness or farsightedness), or a history of epilepsy, Parkinson's disease, Alzheimer's disease, dementia, mild cognitive impairment, or other neurological problems. All participants had normal or corrected-to-normal vision (glasses or contact lenses) and were tested on site for near acuity using the Federal