RESEARCH ARTICLE

The Role of Text Alignment on Response Speed and Accuracy When Reading Chinese-English Bilingual Traffic Signs

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Abstract: This paper discusses the effect of text alignment on Chinese-English bilingual traffic signs on the speed and accuracy of navigational responses. Two text alignment conditions (centered and left settings) were tested in relation to sign complexity and the separating spacing between place names. Video materials were used to provide a safe way to simulate how and where road signs may appear in a driving scenario, while efficiently testing many variations. A total of 36 participants who read English but not Chinese engaged in this study. The results suggest that left alignment improves speed and accuracy in making decisions when responding to three-directional signs with narrower separating spacing, whereas centered alignment may be beneficial for one-and two-directional signs. These findings highlight the value of including text alignment specification in guidance for bilingual signage, especially when accounting for sign complexity. However, further studies are needed using methods with a higher ecological validity and a broader range of participants before robust recommendations can be devised.

Implications for practice: This study underscores the need for more nuanced typographic guidance in the design of Chinese-English bilingual road signs. The findings highlight the importance of accounting for the complex interactions between typographic and spatial attributes in sign composition for drivers to make quick and accurate decisions. In particular, practitioners and policymakers should specify text alignment, as it impacts drivers' speed and accuracy in navigation. These insights contribute to the development of safer and more efficient road navigation systems.

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1. Introduction

Traffic signage, though experienced as an everyday part of life, presents a number of design and layout challenges compared to more traditional texts. For example, traffic signs are typically highly restricted in their use of space and layout, contain comparatively short text fragments (potentially a single word, but with high degrees of variation), that may appear in combination with schematic elements (arrows and lines) and symbols. The positioning of elements within a sign can also convey navigational cues. Drivers typically have to make very rapid decisions in response to this information while processing other significant safety considerations. In this respect, conventions for traffic sign presentation are highly important and often established in legal guidance.

The use of guidelines ensures that individual signs function coherently within a signage system. Such a system builds a set of conventions that allow sign creators to consistently develop signage for a range of scenarios. Examples include the US *Manual on Uniform Traffic Control Devices (MUTCD)* (Federal Highway Administration, 2009) and *Standard Highway Signs (SHS)* (Federal Highway Administration, 2012) and the UK's *Traffic Signs Manual* (Department for Transport, 2016). When applying the ideas of guidelines to real world road infrastructure, however, huge variations between both junction topology and the naming of relevant roads and destinations present problems not only in designing consistent road signage, but in codifying the signage system to ensure consistency.

The majority of research on traffic signs tends to focus on signs in a single language and script and on factors like typeface choice and size (Beier, 2016; Dobres et al., 2017; Gálvez et al., 2016; Waller, 2007). While existing Chinese-English sign guidelines, such as the *Technical Guidelines for the Replacement of National Expressway Network Related Traffic Signs* (Research Institute of Highway Ministry of Transport & Beijing Communications Highway Survey and Design Institute, 2007), *Technical Guidelines for the Adjustment of National Highway Network Traffic Signs* (Research Institute of Highway Ministry of Transport et al., 2017), and *GB 5768.2-2022: Road Traffic Signs and Markings* (State Administration for Market Regulation and Standardization Administration of China, 2022) are based on research, such guidelines may not always lead to optimal outcomes in practice for bilingual signs (Figure 1), as the standards are typically based on monolingual design research. When the guidance is provided for bilingual design,

Figure 1. A Chinese-English bilingual traffic signage. Photographed in Beijing, China, 2024 by the first author.

it often overlooks the complex typographic nuances of different scripts (see detailed discussion in Section 1.1). In this context, there is scope for additional research that considers specifications for bilingual signs.

Studies have confirmed that drivers require more reading time for bilingual signs because of the doubled information provided (Rutley, 1972). To minimize reading time, the findings and solutions of studies focus on distinguishing the two languages to help users quickly locate the needed information (Rutley, 1974). The solution for distinguishing between two languages is more effective when the signs contains two similar scripts (e.g., English and Welsh). However, this approach is less useful for signs that feature distinctly different writing systems, like English and Arabic, where the scripts are inherently easy to differentiate. Therefore, bilingual sign legibility research requires additional considerations to address challenges unique to such contexts. Eid (2009) and Petretta (2014) suggest considering text spacing, script alignment, information sequence, and the role of pictorial elements when designing Arabic-English signs. Nevertheless, there is limited research on sign legibility that addresses the design challenges of combining the logographic Chinese script with the alphabetic Latin script.

In both Chinese and English contexts, there is research to support that text spacing can be arranged to assist in sign legibility (Chan et al., 2014; Garvey & Kuhn, 2004; Hsu & Huang, 2000; Tejero et al., 2018). More recently, the authors' previous studies have

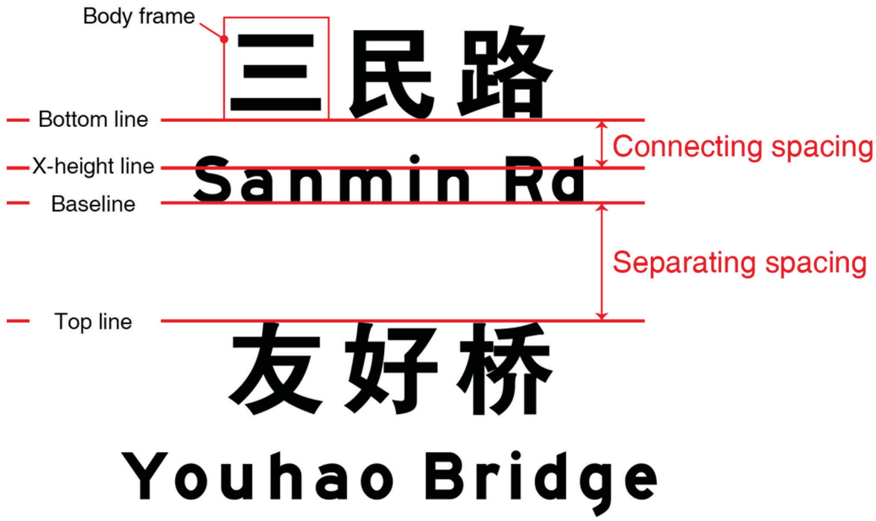


Figure 2. Connecting spacing between Chinese and English text and separating spacing of two bilingual place names. Connecting spacing is "line spacing" between the two languages and separating spacing is "line spacing" that separates two different place names.

demonstrated that the interline spacing* has impact on the legibility of Chinese-English bilingual traffic signs (CEBTS) (Zhang, 2021; Zhang & Moys, 2022). Specifically, the kinds of interline spacing analyzed include connecting spacing — the vertical spacing connecting a Chinese location name to its English translation (Zhang & Moys, 2022) — and separating spacing — the vertical distance allocated to distinguish between two bilingual names within a single direction (Zhang, 2021) (Figure 2).

However, there seems to be comparatively less research on the role of alignment of two scripts in CEBTS. There are four basic alignments: left-aligned, right-aligned, justified, and centered. Left-aligned text maintains uniform word spacing, aligning all lines to a common vertical point on the left while leaving the right edge uneven. Right-aligned text, on the other hand, aligns all lines to the right, resulting in an uneven left edge. Justified alignment adjusts the word and letter spacing so that all lines are of equal length, creating a uniform, block-like appearance. Centered alignment positions each

* The term *interline spacing* in Latin typography is similar to *line spacing,* but the definition of line spacing differs in the Chinese context. In Chinese typography, since Chinese characters do not contain descenders, line spacing refers to the vertical distance between either the bottom or top lines of the square characters to the corresponding bottom or top lines of the next row, rather than being based on the baseline as in Latin typography. To address the challenges of accurately defining spacing in bilingual text combining Chinese and English, the term "interline spacing" was adopted to ensure clarity and precision. This distinction is particularly important to avoid ambiguity when discussing spacing conventions across different typographic systems and will be used in the following sections to ensure consistent terminology.

line symmetrically, with equal spacing on both sides, resulting in a balanced but ragged appearance on both the left and right edges.

Studies of typography for print and screen indicate that text alignment can play an important role. For example, Ling and Van Schaik (2007) demonstrate that text should be left-aligned rather than justified when information is presented that needs to be scanned quickly, particularly on web browsing. Similarly, Hartley et al. (1975) advocate for the use of left-aligned texts in tables as centered alignment took longer to create and produced more errors. Although the contexts of these studies are different, both consider information that people are more likely to scan and take in at a glance.

For continuous reading, there are early studies that support the importance of left-aligned and uniform spacing (Gregory & Poulton, 1970; Hartley & Mills, 1973). However, earlier work examining the influence of text alignment on use of printed material found no advantage of left alignment (Fabrizio et al., 1967). Nevertheless, professional standards within information design tend to advocate for text that is left aligned rather than justified or centered for continuous reading (Luna, 2018). This premise is often attributed to an understanding that the text is easier to read because the spacing between words is more even. However, Dyson (2018) suggests that since the research is neither substantial nor conclusive this may be an aesthetic convention. There is an aesthetic rationale for using left-aligned text to ensure uneven gaps between words in justified text do not form “rivers” on the typeset page.

While this aesthetic consideration is less applicable to sign design than continuous text, there has been relatively little research into the role of alignment in signage. Barker and Fraser (2004) recommend left- and centered-alignment for alphabetic signage. In terms of bilingual sign scenarios involving Arabic and English, Eid (2009) and Petretta (2014) suggest vertically staggering the two scripts to improve legibility for shorter messages. Guidance in China such as *Technical Guidelines for the Adjustment of National Highway Network Traffic Signs* (Research Institute of Highway Ministry of Transport et al., 2017) and *5768.2-2022: Road Traffic Signs and Markings* (State Administration for Market Regulation and Standardization Administration of China, 2022) recommend vertically staggering Chinese and English on signs, with Chinese placed above. They also suggest using left- or centered-alignment on traffic signs.

1.1. Real World Examples

To ensure that the materials developed for the testing reported in this paper would be reasonably representative of real signs, a reference sample of current CEBTS in Chinese urban areas was collected. The sample comprises 143 signs from four cities in China: Beijing (25/143), Shanghai (23/143), Wuxi (16/143), and Dalian (79/143), photographed between 2017 and 2019. Therefore, the experimental materials are based on the samples observed during this timeframe and the standards published from the 1990s up to the date of sample collection. While there have been some minor changes in the latest issued standard in 2022, the changes did not involve text spacing or alignment, and therefore had no impact on the eligibility and validity of the material design. In addition, although the samples were collected and observed a few years ago, since the current signs remain unchanged as observed in 2024, the material remains representative of what is seen in urban areas in China at the time of writing.

The sample was examined based on: a) the method by which bilingual location names are positioned in relation to one another, and b) the method by which the English translation aligns with its Chinese counterpart within a bilingual place name. The examination of the sample indicates that the two recommended alignment methods (left and centered alignment) in the standard *GB 5768.2-2022* (2022) have not been appropriately implemented, revealing inconsistencies in their application (Figure 3 and Figure 4). The most widely used method is centered (66⁄143) and there seems to be a tendency towards justified alignment (24⁄143). As depicted in Figure 3, all Chinese place names are formatted to uniform line lengths by adjusting (in places quite substantially) the horizontal spacing between words in both scripts, and the widths of letters are altered to achieve this goal.

However, the guidance in *GB 5768.2-2022* (2022) recommending left alignment was found rarely used to align English transliteration to its corresponding Chinese location name and to be applied only when aligning multiple bilingual location names (1⁄143) (e.g., the two bilingual location names are left-aligned on the right-hand side of the sign

Figure 3. Uniform line lengths in bilingual location names achieved through adjusted text spacing. Photographed by the first author in Dalian, China in 2018. The sign remains unchanged as observed in 2024.

Figure 4. The Latin texts are central-aligned with their corresponding Chinese texts, but the two bilingual place names are left-aligned on the right-hand side of the sign. Dalian sample. Photographed by the first author in 2018. The sign remains unchanged as observed in 2024.

shown in Figure 4). Notably, none of the 143 collected samples employed left alignment to arrange the two scripts within a bilingual location name. In contrast, the Latin text tends to be either justified (Figure 3) or centered (Figure 4) to align with its Chinese counterpart.

All the above leads to the main research question of this paper: does text alignment in bilingual traffic signs with two different scripts (and languages) affect how quickly and accurately people might make direction decisions?

Although the analysis of real-world examples has shown a prevalence of justified alignment, its current application compromises legibility, particularly in English texts, as evidenced in Figure 3. Considering the nature of the two scripts — where Chinese characters encode more information per glyph than Latin letters (often resulting in shorter Chinese place names compared to their English counterparts), the disparity in message lengths is not successfully addressed by the justified method in practice. Consequently, justified alignment is excluded from this study. As centered alignment is still widely applied and recommended by standards, this study focuses on comparing left alignment with centered alignment and seeks to determine:

1. whether there is a difference between the two alignments of the bilingual location names, centered- or left-aligned, in the legibility of CEBTS; and
2. if differences are found, which one could improve participants' speed and accuracy when identifying bilingual place names.

2. Method

2.1. Study Setup

The experimental design used 3D video simulations to replicate a driver's view of approaching CEBTS at a constant speed. Participants were shown signs that feature bilingual location names and directional arrows, becoming larger on screen until participants can discern and report their observations. By employing a threshold method (Dyson, 2018), the experiment measured the earliest point at which participants can identify the signs and can use the information they gained to answer a question phrased in the format: "Which direction leads to destination xxx?" As soon as participants felt they can discern the answer from the video they indicated their directional choice by using the arrows on a keyboard. Response time and accuracy were recorded to assess the sign legibility. To emphasize response speed, video clips were displayed for no longer than seven seconds, concluding immediately upon the participant's response. See Figure 5 for further visual details. This experimental approach has parity with the methods used in the studies of separating and connecting space (Zhang, 2021; Zhang & Moys, 2022), enabling clear comparisons to be made across the interpretation of results.

The video stimuli, rendered at a resolution of 1280×1024 pixels, were displayed on a 75-inch monitor with a Full HD resolution and a refresh rate of 60 Hz. The monitor was set to ensure that the video content was scaled appropriately. The presentation, timing, data collection, and storage were managed using E-Prime 2.0 software.

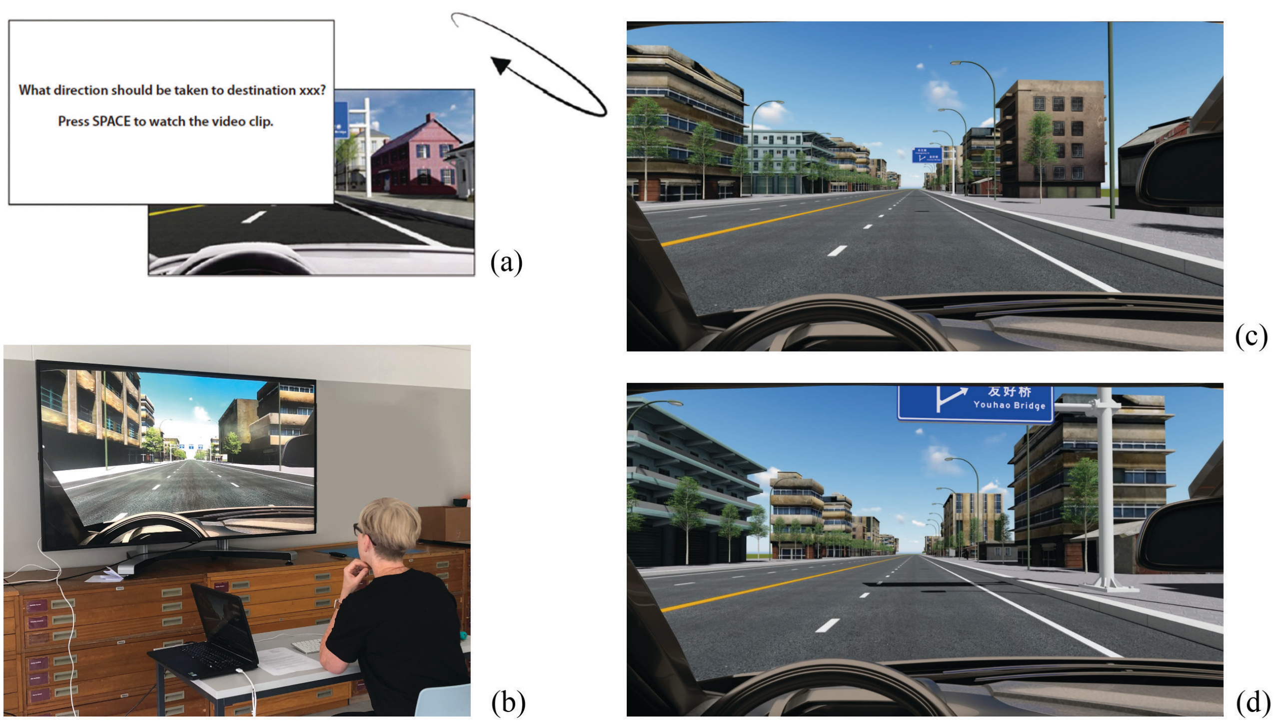


Figure 5. (a) The study procedure presented participants with a question to answer prior to each video stimulus. (b) A participant engaged in the test. (c) A screenshot showing the starting point of the video displayed to participants, where the road sign appears at its smallest. (d) A screenshot showing the ending point of the video, displayed at the seven-second mark.

The study was conducted in a university teaching room (Figure 5b). Each participant was tested individually in a quiet and controlled environment without external interruptions. Participants were instructed to turn off personal devices and other potential sources of distraction before beginning the session.

A pilot experiment was conducted to ensure the equipment and materials were set up appropriately and comfortably for the participants. This involved ensuring the table and chair heights were comfortable, positioning the monitor 1.6 meters away to provide clear visibility of the materials, and confirming that the modified computer keyboard with five directional arrows (Figure 6) was intuitive and easy for participants to understander and use. To maintain consistent conditions, the same room and equipment were used for both the pilot and main sessions, and the setup was aligned with the standards of Zhang (2021) and Zhang and Moys's (2022) previous studies.

2.2. Material Design

Parameter 1: Separating spacing. Previous research has indicated that reading speeds fluctuate across three levels of separating spacing (Figure 2): 0.5H, 0.75H, and 1H (where H represents the height of one Chinese character) (Zhang, 2021). Specifically, faster response times were observed at the 0.5H and 0.75H separation levels (with no significant difference between the two) compared to 1H (which shows a significant difference).

This raises an interesting question about how text alignment might further impact legibility at the 0.5H and 0.75H separation levels (Investigation 1) (Figure 7a,b). Additionally, for signs displaying only a single location name — where separating spacing is not applicable — it is important to investigate how alignment affects legibility independently of separating spacing (Investigation 2) (Figure 7c,d).

Parameter 2: Sign complexity. To ensure the study was reasonably representative of the varying degrees of sign complexity evident in the real-world sign sample (see section 1.1), the research investigated three levels of sign complexity: one-directional

Figure 6. A computer keyboard, adjusted to provide five directional arrows, enables participants to enter their responses.

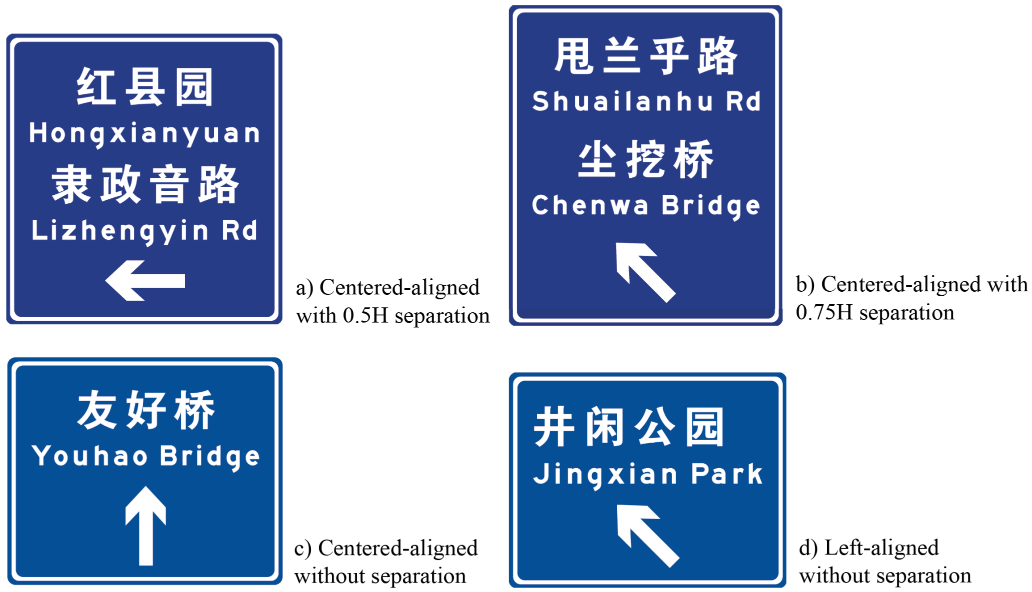


Figure 7. Four stimuli varying in text alignment and separating spacing used in the investigations.

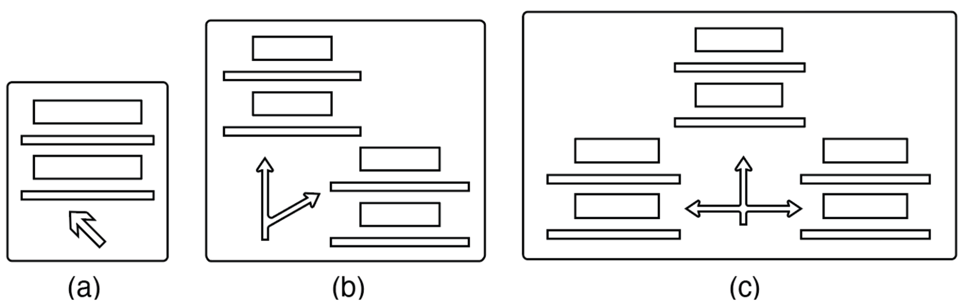
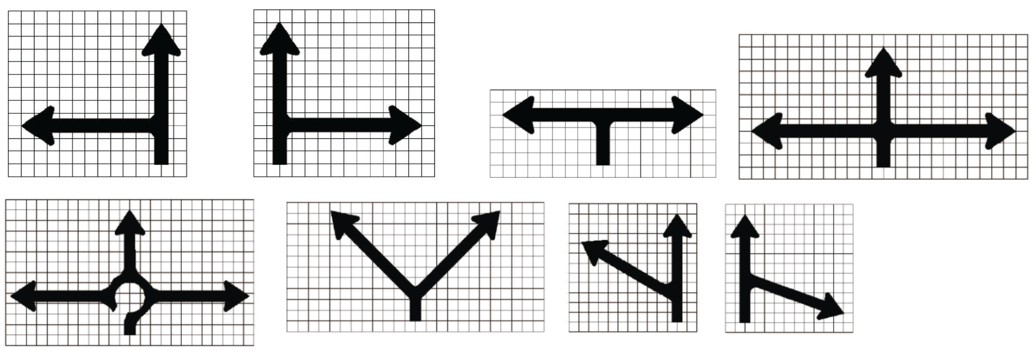


Figure 8. Three levels of sign complexity. (a) one-directional sign; (b) two-directional sign; (c) three-directional sign. Extracted from Zhang (2021).

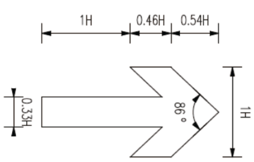
(41 out of 143 samples), two-directional (25/143), and three-directional signs (54/143) (Figure 8).* The three levels of sign complexity adopted were the same as those used in Zhang (2021) and Zhang and Moys (2022) to enable continuity and comparison with our studies considering the impact of both connecting and separating spacings on the legibility of CEBTS.

* Sign complexity was categorized into three levels based on the number of directional indicators displayed. These three categories can encompass a broad spectrum of sign types used on CEBTS.

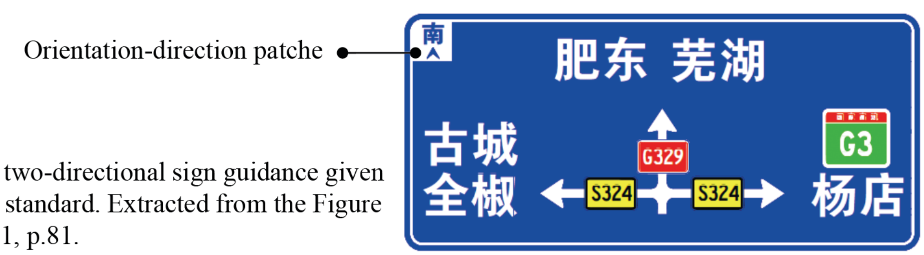
Parameter 3: Schematic elements. The schematic elements (including arrows, route arms, and orientation-direction patches) for the materials were designed to adhere to *Technical Guidelines for the Adjustment of National Highway Network Traffic Signs* (Research Institute of Highway Ministry of Transport et al., 2017) as it was the latest standard at the time of this study before the new 2022 standard was issued, ensuring the findings were relevant to the then-current regulation and practice (Figure 9). Although the new 2022 standard has been issued, it does not affect the validity of this study's materials, as the limited updates related to visual design are irrelevant to the schematic elements used in the two investigations. The schematic elements were controlled throughout the study. Although different forms of schematic elements were used in the stimuli (arrows in the one-directional signs and route arms in the two- and three-directional signs) and different sign layouts (asymmetric two-directional signs and symmetric



(a). Route arm guidance provided in the standard. Extracted from the Figure C.1.2, p.115. Route arms were applied to the two-and three-direction signs in this study.



(b). Arrow guidance provided in the standard.Extracted from the Figure 3.5.3-3, p.16.Arrows were applied to the one-direction signs.



(c). A two-directional sign guidance given in the standard. Extracted from the Figure 7.3.4-1, p.81.

Figure 9. Some of the visual design guidelines extracted from *Technical Guidelines for the Adjustment of National Highway Network Traffic Signs* (2017), which the design of the stimuli in the Investigations adhered to.

three-directional signs) may affect participants' reading performance. All participants read all sign complexity levels and their performance was analyzed and compared according to each level, which enabled the isolation of the effect (see Section 2.3 for detailed testing methods). As with any legibility research involving multiple variables, there must be a balance between the isolation of all possible variables and real-world pragmatics in experimental design that accounts for the variation seen in the relevant materials — traffic signage being an area of such variation.

(a) Left-aligned
One-directional
0.5H separation

(b) Left-aligned
Two-directional
0.5H separation

(c) Centered-aligned
Two-directional
0.75H separation

(d) Left-aligned
Three-directional
0.5H separation

(e) Left-aligned
Three-directional
Without separation

Figure 10. Five stimuli varying in text alignment, sign complexity, and separating spacing used in the study.

Other material design considerations. In addition to the above parameters, the material design also considered the scale of signs, positioning, lane width, and driving speed. Relevant elements were aligned with existing traffic standards and Chinese traffic guidelines to closely replicate drivers' interactions with real-world traffic signs. The material design deliberately excluded familiar location names, employing instead randomly combined Chinese characters and transliterated English counterparts to minimize the influence of prior knowledge, as many studies suggest that familiarity assists in reading signs (Lay, 2004; Zineddin et al., 2003).

Furthermore, the connecting spacing (Figure 2) was standardized to half the height of a Chinese character for both Investigations 1 and 2, because it was demonstrated as a generalizable spacing across sign complexities for the purpose of improving response speed (Zhang, 2021). The English location names in the stimuli were consistently set at 12 letters in length through transliteration. While in the real world this would vary, the limit set here allows for a direct comparison of outcomes and is crucial for distinguishing the effects of text alignment from those of the length of English names. In addressing the impact of the number of place names, for three-directional signs where the number of place names has been shown to influence reading performance (Zhang, 2021), this study maintained a consistent number of place names across all three-directional sign conditions. Figure 10 illustrates some of the stimuli tested in this study.

2.3. Participants and Testing Methods

In total, 36 participants were enrolled to participate in both Investigation 1 (with the separation parameter) and Investigation 2 (without separation parameter), with Investigation 1 first and followed by Investigation 2 for all individuals. Participants were recruited using specific screening questions to ensure they:

a. Had normal or corrected vision.
b. Had driving experience and age between 25 to 55 years old, as both driving experience and age play a role in reading road signs (Cantin et al., 2009). The screening criteria excluded gender due to limited evidence suggesting its influence on signage reading.
c. Did not read Chinese and used English as a first or second language.

Many experimental permutations would be possible in variations around point (c). According to Yang et al. (2020) the users of CEBTS can be grouped based on their language proficiency: Chinese drivers, bilingual drivers who are literate in both Chinese and English, and drivers who cannot read Chinese. In this study, only participants who were unable to read Chinese and relied solely on English information (and schematic cues, i.e., arrows) were included. This was because the distinct visual appearances of the two languages and the larger type size of Chinese text could aid Chinese and bilingual groups in completing the task. According to National Bureau of Statistics of China (2020), the number of foreigners (who may not read Chinese) living in China has been steadily increasing, with the foreign population estimated to be around one million in 2020.

Another reason for focusing on this specific group is that the study was conducted in the UK, where it was challenging to find Chinese drivers with no English skills at all. Research has shown that bilingual individuals may experience additional cognitive processing when reading bilingual information, potentially leading to longer reading times due to interference from the second language (Zirnstein et al., 2018), potentially affecting the findings of this study (see Section 4 for further discussion about this criterion).

In Investigation 1, the participants' tasks were tested in three levels of sign complexity separately. In each level, the two alignments (centered and left) and the two levels of separating spacing (0.5H and 0.75H) were tested. Investigation 1 used a within-subject and between-subject mixed design. All 36 participants viewed both alignment groups: reading stimuli where the location names were centered and also reading stimuli where the location names were left aligned. The order in which participants received each stimulus was random, with the 36 participants being systematically split into two groups:

a. In one group 18 participants were shown both alignments under 0.5H separation.
b. In the other group 18 participants were shown both alignments under 0.75H separation.

Each stimulus was presented three times to each participant.

In Investigation 2, the same 36 participants performed a cross-over design by receiving six stimuli resulting of two alignments across three levels of sign complexity (2 alignments × 3 sign complexities). Each stimulus was presented only once to each participant, and the stimuli were displayed in random order.

3. Result & Analysis

3.1. Investigation 1: The Impact of Variations in Alignment in Interaction with Different Separating Spacings, Measured in Response Time

Investigation 1 examined the effect of the two alignments under 0.5H and 0.75H separating spacing. The mean and SD of response times for the centered and left alignments with both separating space under three levels of sign complexity were calculated and listed in Table 1.

Table 1. Mean and SD of response times (in seconds) for the centered- and left-alignments with both 0.5H and 0.75H separating space under three levels of sign complexity. The two alignment methods achieved a significant difference on response time when the three-directional signs using 0.5H separating spacing, in bold.

	One-directional sign		**Two-directional sign**		**Three-directional sign**	
	0.5H	**0.75H**	**0.5H**	**0.75H**	**0.5H**	**0.75H**
Centered-aligned	M: 5.139 SD: .749	M: 5.049 SD: .794	M: 4.711 SD: .874	M: 4.635 SD: .847	M: 5.433 SD: .592	M: 4.914 SD: .991
Left-aligned	M: 5.234 SD: 1.105	M: 5.482 SD: .912	M: 4.494 SD: .703	M: 4.797 SD: .679	M: 4.984 SD: 1.103	M: 5.281 SD: .764
Interaction effect	$p =$ .339		$p =$ .087		$\boldsymbol{p =}$ **.012**	
Main effect	$p =$ .191		$p =$ .800		N/A	
Comparison	N/A		N/A		$\boldsymbol{p =}$ **.033**	$p =$ .140

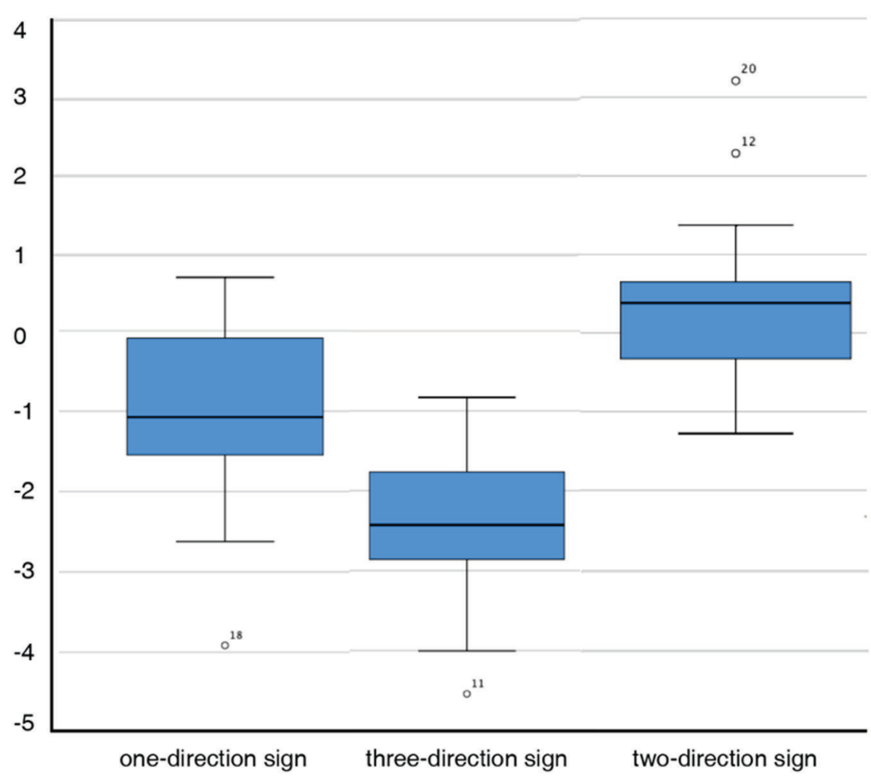


Figure 11. Outliers in three sign complexities shown in a boxplot conducted for a two-way ANOVA examining the effect of the two alignments with the two separating spacing levels on reading speed.

A two-way mixed ANOVA examined the effect of the two alignments with the two separating spacing levels on the participants' reading speed. Outliers were assessed by inspection of a boxplot (Figure 11). One outlier is detected that was more than 1.5 box-lengths from the edge of the box in the one-and three-directional sign conditions, and two outliers were detected in the two-directional sign condition. Inspection of their values did not reveal them to be extreme and they were kept in the analysis. In all three sign complexity conditions, the data was normally distributed, as assessed by Shapiro-Wilk's test of normality ($p > .05$). There was homogeneity of variances ($p > .05$) and covariances ($p > .001$), as assessed by Levene's test of homogeneity of variances and Box's M test respectively.

In both one-and two-direction sign conditions, there was no significant interaction between the separation levels and the two alignments on participants' response times:

one-directional sign condition: $F(1, 30) = .733$, $p = .399$, partial $\eta^2 = .024$;

two-directional sign condition: $F(1, 34) = 3.103$, $p = .087$, partial $\eta^2 = .084$.

The main effect analysis showed that there was no significant difference in mean response times between the two alignments regardless of the separating spacing:

one-directional sign condition: $F(1, 30) = 1.789$, $p = .191$, partial $\eta^2 = .056$;

two-directional sign condition: $F(1, 34) = 0.065$, $p = .800$, partial $\eta^2 = .002$.

In a three-direction sign condition, however, there was a significant interaction between the two independent variables on participants' response time, $F(1, 32) = 7.153$, $p = .012$, partial $\eta^2 = .183$. With 0.5h separation, the speed was significantly faster when the location names are left-aligned rather than centered ($M = .45$, $SE = .19$s, $p = .033$). However, the difference between the two alignments under 0.75h separation was not significant ($M = .37$, $SE = .24$s, $p = .140$).

3.2. Investigation 1: The Impact of Variations in Alignment in Interaction with Different Separating Spacings, Measured in Accuracy

An exact McNemar's test was included to determine if there was a significant difference in the accuracy between the two alignments for reading CEBTS. Table 2 lists the accuracy of the two alignments for each condition. It shows that there was a significant difference between the two alignments in accuracy in the three-direction sign condition with 0.5H separating spacing: $p = .039$ (bold in Table 2). With the location names left-aligned, the number of responses in which no error was made had increased to 16 (94.1%), with a concomitant reduction in the number of participants whose responses with errors to 1 (5.9%).

3.3. Investigation 2: The Impact of Alignment on Reading Performance, Measured in Response Time

Investigation 2 explored whether the two alignments may cause a significant difference in response speed and accuracy when participants reading CEBTS which includes only one location name within one direction. In other words, Investigation 2 examined how the two alignments affect legibility independently of separating spacing. The data was analyzed in terms of the three levels of sign complexity.

Table 2. Accuracy (without any errors) of two alignments on reading stimuli for each sign combination.

0.5H Separation	Centered	Left-aligned	Exact Sig.
One-direction sign	83.3%	72.2%	$p = .625$
Two-direction sign	88.9%	94.4%	$p = 1.000$
Three-direction sign	52.9%	94.1%	**$p = .039$**

0.75H Separation	Centered	Left-aligned	Exact Sig.
One-direction sign	76.5%	58.8%	$p = .180$
Two-direction sign	83.3%	83.3%	$p = .928$
Three-direction sign	77.8%	77.8%	$p = 1.000$

Table 3. Mean and SD of response times (in seconds) for the centered and left alignments under three levels of sign complexity.

	One-direction sign	Two-direction sign	Three-direction sign
Centered	M: 2.486 SD: .679	M: 1.857 SD: .696	M: 4.910 SD: .890
Left-aligned	M: 3.419 SD: .929	M: 4.150 SD: .982	M: 4.787 SD: .896
Analysis	Centered achieved faster responses with a significant difference. 95% CI [.594, 1.270], t (35) = 5.598, d = 0.93. **$p < .0005$**	Centered achieved faster responses with a significant difference. 95% CI [1.995, 2.590], t (35) = 15.634, d = 2.61. **$p < .0005$**	No significant mean difference. 95% CI [−.371, .124], t (32) = −1.013 $p = .319$

Table 4. Accuracy (without any errors) of two alignments on reading stimuli in Investigation 2.

	Central	Left-aligned	Exact Sig.
One-directional sign	94.4%	100%	$p = .500$
Two-directional sign	94.4%	83.3%	$p = .180$
Three-directional sign	94.4%	97.2%	$p = 1.000$

The mean and SD of response times for the centered and left alignments in the three levels of sign complexity are listed in Table 3.

A paired-samples t-test was used to determine whether there was a significant mean difference between the response time when participants read a centered sign compared to a left-aligned sign. The three levels of sign complexity were tested separately.

In one- and two-direction sign conditions, one outlier was detected that was more than 1.5 box-lengths from the edge of the box in a boxplot. Inspection of their values did not reveal them to be extreme and they were kept in the analysis. There were no outliers as assessed by the boxplot in three-directional sign conditions. The assumption of normality was not violated, as assessed by Shapiro-Wilk's test ($p > .05$).

In both one- and two-direction sign conditions, the participants responded faster when reading the sign where the location names were centered-aligned as opposed to the location names were left-aligned. A statistically significant mean increased of .933s in the one-direction sign and 2.293s in the two-direction sign, respectively. However, there was no significant mean difference between the two alignments in a three-direction sign condition.

3.4. Investigation 2: The Impact of Alignment on Reading Performance, Measured in Accuracy

An exact McNemar's test was conducted to determine if there was a significant difference in the accuracy between two alignments when reading CEBTS. Table 4 lists the accuracy of the two alignments for each condition, from the Exact Sig. column, it shows that there was no significant difference between the two alignments in each condition.

4. Discussion

The results suggest that text alignment can have an effect on sign legibility. In Investigation 1, the results show that the participants performed at a faster speed and with higher accuracy when shown the left-alignment than the centered-alignment in a three-direction sign condition with 0.5h separating spacing. However, this difference between the two alignments was not significant when using the 0.75h separation. Additionally, in one- and two-directional sign conditions, the two alignments did not achieve a significant difference under 0.5h or 0.75h separations. This indicates that either centered or left alignment can be used for one- and two-directional signs. Although, in a three-directional sign condition, participants responded faster and with higher accuracy with left alignment. Nevertheless, using a larger separating spacing (0.75h compared with using 0.5h separation) reduced the influence that was caused by using the two different alignments.

In one- and two-directional sign conditions, however, the two different alignments had a strong impact on reading speed in Investigation 2. This implies that the participants responded faster when they were shown the centered-alignment than left-alignment, when reading CEBTS which only indicated one place name per direction. However, this difference between the two alignments was not significant for three-directional signs.

The findings from Investigations 1 and 2 suggest that left alignment can potentially improve driver performance in scenarios where separating spacing is a factor — that is, when multiple bilingual location names are stacked vertically. However, in cases without the influence of separating spacing — where there is only one bilingual location name — centered text can enable drivers to respond more rapidly, particularly when reading one- and two-directional signs.

The findings also indicate that different combination of typographic elements and sign complexity may require different sign specifications for optimum performance. While there is substantial scope for further research, this nevertheless indicates that guidance for sign systems require much more precise typographic specifications for the spacing and positioning of different scripts. Zwaga et al. (1999, p. xvii) have suggested that information designers often “expect very detailed and narrow guidance” in comparison to the “general, broad guidelines” that emerge from research.

The findings of this study are potentially applicable to other writing systems, for example, Japanese-English and Korean-English signs. As both Japanese and Korean scripts incorporate Chinese characters (Kanji in Japanese and Hanja in Korean), the principles of alignment and spacing found effective for Chinese-English signs in this study might be transferable to Japanese-English and Korean-English signage. Future research could explore these variables in different linguistic contexts to develop legible and effective sign guidance. This would contribute to improved dual-script sign systems that support seamless navigation across various cultural and linguistic settings.

More broadly, however, the findings of the study demonstrate that it is important to consider text alignment in different everyday contexts and that different alignments might be more effective in relation to different levels of information complexity. This study has focused on road signs. However, there are a range of everyday contexts in which people need to make quick decisions from signs. The research presented here could be extended to different sign contexts, including other transport contexts, health-care environments and urban spaces in which people may be moving on foot or with mobility aids. Signs in these contexts might be presented at different scales and heights. Thus, we propose that there is significant scope to consider the role of text alignment in bilingual signs for everyday decision-making. Such studies could help complement the existing research that focuses on the role of alignment in continuous reading from print or screen and tends to privilege a singular script or language.

In order to establish the influence of typographic factors, the study reported here only recruited participants who would only be able to read the English text and the findings had a direct impact on improving CEBTS for foreign drivers using these signs while driving in China. Nevertheless, the findings of this study might also benefit Chinese and bilingual drivers, as Yang et al. (2020) found that the use of English place names affects all three groups of drivers (see Section 2.3). The signs used in this study were from a Chinese context, but tested with participants who were could not read Chinese (to control for the inference between the two scripts). As such additional studies could establish the role of text alignment for Chinese and bilingual drivers, as this might be expected to increase cognitive load during decision making and response time. Ultimately, this study aims to improve bilingual sign design guidance for all drivers, not just a specific group. The insights gained here would be instrumental in informing future research exploring the design of more effective bilingual traffic signs, benefiting both international and local drivers.

Typographic research with multiple variables that are interrelated can be time consuming and expensive to conduct. Methodologically, the study demonstrates how video can be used to help narrow down the potential range of typographic variables and combinations that are appropriate to test. Larger scale studies using driving simulation would be essential to confirm the safest range of specifications to use in real-life signs with higher ecological validity. Nevertheless, the approach taken here can be extended to efficiently identify appropriate parameters to test as a preliminary approach. There is also potential to replicate this study using AR/VR instead of video, especially as the video material used in the presented study was generated through 3D modelling.

5. Conclusion

This study evaluates whether there is a difference between the centered and left alignment of the bilingual location name in the participants' speed and accuracy in decision making when encountering Chinese English bilingual traffic signs (CEBTS). It also evaluates if the difference between the two alignments might relate to the changes in the separating spacing (the vertical distance to separate the two bilingual location names) and the sign complexity.

A total of 36 participants who understood English but could not read Chinese engaged in this study. Accuracy and response time were sometimes significantly better for certain text spacing conditions and certain sign complexities: the results suggest that left alignment improves speed and accuracy in three-directional signs with narrower separating spacing, whereas centered alignment may be beneficial when separating spacing is irrelevant and when used on one and two-directional signs.

There is a case to be made for more nuanced typographic guidance for road signs, given the importance of considering the multivariate interactions between typographic and spatial attributes in sign composition combined with the speed with which drivers need to be able to make accurate judgments. However, more research is necessary, which includes research with more ecological validity in real-life situations instead of research behind a computer screen.

6. References

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