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Research article

Vertical is Beneficial but volume is Irrelevant: Optimization of urban guide signs based on spatial representation of road networks

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ABSTRACT

Urban guide signs, a fundamental component of traffic sign systems, convey both directional and locational information. Previous studies mainly focused on the font or volume of information, while little attention was paid to the layout of text-based Chinese guide signs, which is an unregulated area but crucial in practical applications and related to people's travel safety. This study investigates the impact of text layout and information volume on the spatial representation of road networks through two experimental studies, examining the effects of different designs on path determination and global road network knowledge. The results indicate that the text layout of urban road guide signs significantly influences the formation of spatial representation of the road network. Specifically, vertical guide signs displaying road names on both sides proved more effective than horizontal ones. While the volume of road name information does not markedly affect the formation of spatial representation, the arrangement of road names does influence the determination of information volume, with vertical layouts facilitating the presentation of more information. It is anticipated that these design recommendations for road signs can effectively mitigate the incidence of road traffic accidents.

1. Introduction

Urban guide signs, as a crucial element of road traffic signs, serve as vital indicators conveying road direction, location, and distance information. They have maintained an indispensable role in facilitating people's travel [1,2]. The design of these guide signs can substantially decrease the likelihood of road accidents, thereby ensuring the safety of both drivers and pedestrians during their journeys. Consequently, numerous studies have been conducted on the placement of traffic signs [3–5], ergonomic principles [6–8], determination of information volume [9,10], and driver characteristics associated with traffic guide sign comprehension [11,12], among others.

Compared to highways, urban roads, being well-structured networks, necessitate more intricate and extensive signs at pivotal intersections. A significant subset of this complexity is represented by the plane intersection direction sign. This type of sign predominantly employs text space layout to convey directional information. Consequently, comprehending its layout directly influences users' decision-making regarding the correct route selection and speed. The focus of this paper is on such a guide sign, which predominantly convey information via text space layout, thus the design's impact directly influences users' road selection accuracy and their choice between slower or faster routes. The effective design of urban road signs can guide individuals to their destinations with

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precision and speed, enhance wayfinding efficiency, and foster the overall fluidity of urban traffic. The existing national standards in China have established comprehensive regulations concerning the physical parameters influencing visual sign recognition, such as color, font type, size of signs, and their placement. Researchers in related fields have also conducted extensive studies on this topic. Consequently, current research in urban guide signs' text visual recognition primarily concentrates on the text layout and the volume of information.

While the majority of countries utilize a horizontal orientation for their road signs, and numerous studies have demonstrated its superior recognition efficiency compared to vertical layouts [13–16], it is crucial to acknowledge that visual perception does not equate to comprehension. The design of information significantly influences spatial learning [17]. Despite the higher recognition efficiency of the horizontal layout, the alignment of road names on either side often deviates from the actual direction of the road. This deviation can lead to significant misinterpretations. Due to consistent naming conventions, drivers may erroneously perceive the road direction as horizontal. This misperception can result in an inaccurate spatial representation of the road network, compromise the decision-making process of drivers, and potentially put them in harm's way.

Furthermore, as the density of urban road networks increases, the volume of information conveyed by road signs also escalates. In many instances, the continuity and integrity of traffic data are ensured through an increase in sign information volume (number of roads). However, in certain cities, the abundance of information on road guide signs can lead to a brief recognition process during driving. This surplus of information hinders drivers from obtaining pertinent details swiftly. Consequently, drivers must allocate more attention to discerning this information, which may pose challenges in identifying critical data or even compromise driving performance, potentially leading to traffic accidents [18]. Therefore, it is also crucial to maintain a reasonable quantity of layout information for the design of road signs.

1.1. Text layout

Text classifications are typically bifurcated into ideographic and phonetic characters. Epigraphs are the predominant type of script in Western countries, and the text is typically oriented horizontally. However, there are instances where epigraphs can be vertically oriented. Vertical typography for epigraphic text can be categorized into three primary methods: each word is rotated 90° clockwise or counterclockwise within a column, and each character is positioned vertically (Fig. 1). In Eastern cultures (specifically, Chinese and Japanese Kanji), ideographs are employed to convey information, the vertical and horizontal orientations of these ideographs are also depicted in Fig. 1.

Research into text layout reveals that horizontal typesetting outperforms vertical in recognition. For instance, Byrne [15] discovered that both marquee (vertical arrangement of each letter) and rotated (90° clockwise and 90° counterclockwise) vertical typesetting in English were slower than horizontal reading, with the average reading time for vertical rotation being 1.3 times that of horizontal reading. Similarly, Laarni's [16] study on Finnish demonstrated a slower reading rate for vertical text compared to horizontal. Phillips and Edelman [19] further found that the scanning speed of a horizontal row surpassed that of a vertical row, and the visual span row was larger than the vertical row. This discrepancy in visual performance between horizontal and vertical typesetting may be attributed to these findings.

The orthography of several Asian nations, including China and Japan, can be typeset in multiple ways. Kajii and Osaka [14] conducted a comparative study between Japanese horizontal and vertical layouts, concluding that the former is more rapidly readable than the latter. Similarly, Wang [1] *e*xamined the search and comprehension performance of Chinese-English horizontal and vertical layouts. The results indicated that English exhibits superior search and comprehension abilities with horizontal layouts, while Chinese does not demonstrate significant differences between both horizontal and vertical layouts.

Tinker [20] discovered that horizontal reading was quicker than vertical reading, Yet, after six weeks of training, the subjects' vertical reading speed significantly improved. Individuals from Japan and Taiwan area possess extensive experience in aligning the lines of reading horizontally and vertically. This is corroborated by the findings of Oda et al. [21], who discovered that Japanese

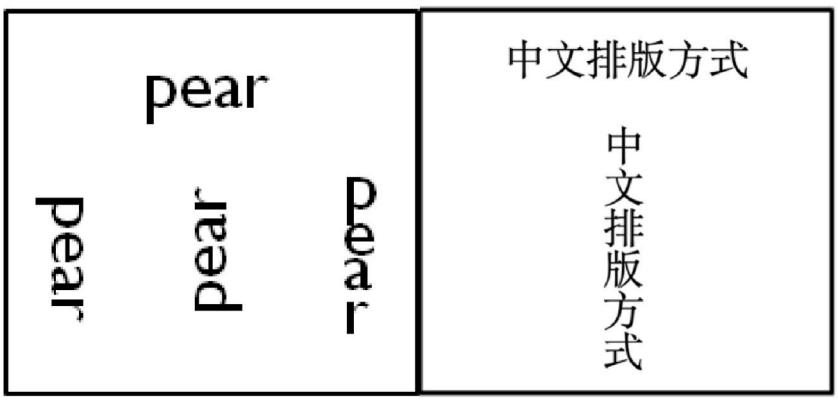

Fig. 1. Left: Four distinct styles of English typesetting; Right: A comparative analysis between horizontal and vertical typography in Chinese.

individuals read at similar speeds in both directions, implying that with sufficient practice, the speed of horizontal and vertical reading can be harmonized. The study's results on logographic characters suggest that the disparity in reading performance between horizontal and vertical text layout methods primarily stems from reading habits rather than any inherent advantage of one layout over the other. Wang [1] noted that while the visual recognition performance of Chinese characters in vertical order was not as effective as that in horizontal order during the initial perceptual stage of cognitive processing, the advantage of road names in vertical order could compensate for this disadvantage during the later stages of cognitive processing, thereby emphasizing its own strengths. This observation underscores the effectiveness and necessity of a well-designed road sign that explores how to arrange the text layout of road names on both sides of signs oriented towards China.

Presently, the majority of countries utilize horizontal typesetting for characters on both sides of road signs. This method, however, inadvertently distorts the understanding of the relationship between road directions and adjacent roads. Specifically, the text layout of road guide texts may influence the spatial representation of road networks. For instance, using lateral typesetting for road names on either side can create an illusion that the road direction is also lateral, thereby leading to an inaccurate spatial depiction of road networks.

Previous studies mainly focused on the font or information amount, lacking research on the layout of the text version of Chinese wayfinding signs, so in order to solve the above problem, considering the unique characteristics of Chinese characters and the long-standing tradition of vertical typesetting, it can be hypothesized that a flexible typesetting approach for Chinese oriented signs might be more suitable.

1.2. The volume of information

The proliferation of traffic sign information (number of roads) can enhance navigational data for drivers. However, this expansion simultaneously demands more time from drivers to observe these signs, potentially compromising safety on the road. For instance, Liu et al. [18] discovered a strong correlation between the distribution of attention points during traffic sign reading and changes in vehicle speed and information volume. As speed and information increase, so too does the driver's focus on the immediate road ahead. Similarly, Wei et al. [22] found that an increased number of directional signs corresponded with a longer visual reaction time. Conversely, insufficient sign information fails to effectively convey road network details, thereby compromising continuity and integrity. Consequently, it is crucial to strike an optimal balance between a driver's information processing capacity and the volume of information provided by road guide sign layouts.

In the realm of guide sign information volume, numerous studies have explored its correlation with recognition time. Lin et al. [23] suggested an optimal quantity of road name data for urban road guide signs, advocating that Chinese character count should be limited to 17 and road name count to 6 in designing layout information. Subsequently, Du et al. [24] employed eye movement tracking technology to analyze the relationship between guide sign information volume and recognition time, based on indoor simulation experiments. They recommended that urban guide signs should not contain more than five road names. Zahabi et al. [25] similarly utilized eye-tracking technology to investigate the link between road sign information volume and target recognition accuracy. Their findings indicated that road signs with six pieces of information exhibited higher recognition accuracy compared to those with nine pieces.

The findings from this section of the research suggest that an optimal volume of information for road signs lies between 5 and 6. However, these studies have only examined the correlation between the volume of information and recognition time, neglecting to explore the spatial relationship between roads. This oversight fails to capture the crucial aspect of "understanding" the layout information of road signs, which is a fundamental element in the role of traffic signs. Consequently, some researchers have delved into the relationship between the volume of information and logo comprehension. Shao et al. [26] conducted an indoor static simulation experiment, finding that the optimal volume of information for road guide signs at intersections was 5 or 6. However, their study focused solely on road signs with a single layout, also overlooking the impact of the typesetting mode of the road signs, hence we have noted these shortcomings and proposed this study.

2. Hypotheses

Prior research has shown that the impact of vertical layout on the recognition performance of Chinese characters is less pronounced than in English. This suggests that Chinese characters exhibit greater flexibility in their layout, thereby providing empirical evidence supporting the potential for a vertical layout of Chinese characters. Based on these findings, we hypothesize that the vertical arrangement of road names in urban guide signs in China may not significantly affect readability. Instead, it may more effectively convey and express the spatial layout information of the road network, thereby facilitating the formation of a comprehensive spatial representation of the citizen's overall road network. Furthermore, the arrangement of information influences both the driver's recognition time and the accuracy of sign interpretation. An optimal layout can enhance the range of information displayed [27,28]. We propose that a longitudinal arrangement of road names on either side of the layout aligns spatially with the actual road, thereby facilitating comprehension. This approach allows for more comprehensive presentation of road name information without adding to the cognitive load experienced by drivers.

To substantiate our hypothesis, we delve deeper into the effects of road guidance signs on the spatial representation of road networks through subsequent experiments. This study broadens the understanding of visual recognition from its initial stages to subsequent phases involving spatial relationship comprehension and representation. The latter stage is particularly crucial for the function of navigational landmarks. Experiment 1 scrutinizes the impact of text layout and information volume on path judgment,

probing whether variations in road layout influence individuals' perception of a path's direction. Experiment 2 investigates the relationship between text layout and information volume on the comprehensive understanding of road networks, with the objective of identifying an optimal layout that facilitates the acquisition of global road network knowledge while observing road signs. Finally, Drawing upon these findings, we offer recommendations for the judicious design of road indicators.

3. EXPERIMENT 1

3.1. Participants

Sixty healthy participants (30 females) with a mean age of 21 years and corrected visual acuity >1.0 were enrolled in this experiment. None of the subjects had participated in similar experiments before. When implemented in practice, the condition of road signs is a matter of concern for not only drivers but also pedestrians and passengers, no restrictions were placed on their ability to drive when subjects were selected.

3.2. Apparatus

The computer screen utilized for the experiment featured a resolution of 1024 × 768 pixels and an average luminance of 147 cd/m2. The experimental program was meticulously crafted using E-Prime 2.0, which autonomously recorded both the correct rate and degree of certainty. The experimental materials utilized in this study consist of two distinct layouts. The primary distinction lies in the orientation of road names on either side of the layout, which are arranged horizontally and vertically, as illustrated in Fig. 2. Given the familiarity effect associated with the road name displayed on the signage, it should be noted that the road name used in the experiment is not an accurate representation of the actual road name.

3.3. Experimental design and procedure

This experiment employs a mixed experimental design, consisting of two text layout modes (horizontal/vertical) and two information volumes (six road names, nine road names). The layout mode represents the variables between subjects, while the volume of information signifies the variables within subjects. The dependent variables are the accuracy and confidence (degree of certainty) in path judgment, which encompasses both path direction judgment task and path relationship judgment task. Subjects had to complete a total of 11 tasks.

As shown in Fig. 3, **the path relationship judgment task** include the following two categories.

1. The relationship between the two sides of the layout and the top of the layout, such as the relationship between 昌丁路 (Changding Road) and 和平路 (Heping Road) ;
2. The relationship between the two sides of the layout and the layout cross, such as the relationship between 昌丁路 (Changding Road) and 百中路 (Baizhong road) .

The path direction judgment task includes the following two categories.

1. The direction of the road above the layout, such as the direction of 和平路 (Heping Road) ;
2. The direction of the road on both sides of the layout, such as the direction of 昌丁路 (Changding Road) .

In both tasks, participants made a response by pressing the key. At each trial of the judgment task, participants were asked to rate their confidence in the task (measured as certainty on a scale from 1 to 5, where higher values indicate greater certainty).

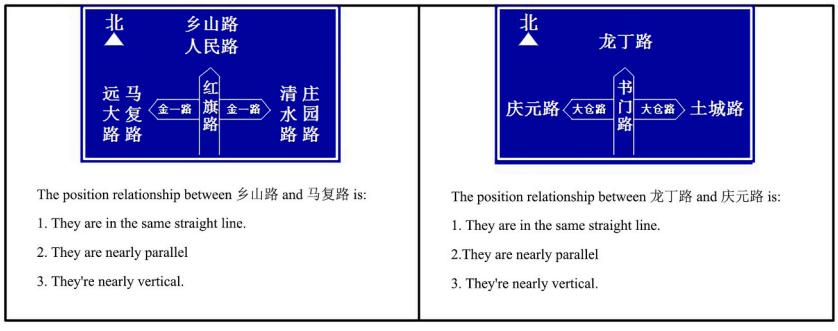

Fig. 2. arranged from left to right, nine road names × vertical, six road names × horizontal.

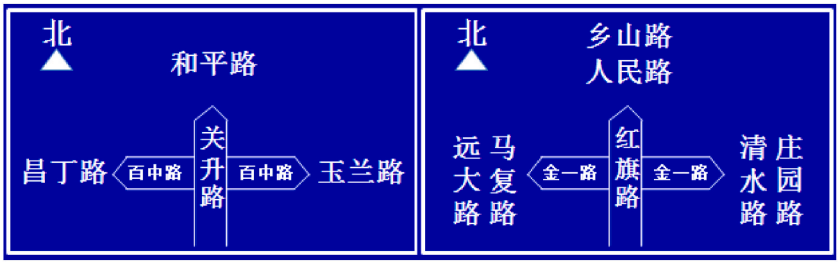

Fig. 3. arranged from left to right, six road names × horizontal, nine road names × vertical. The actual road directions of both sides of the two pictures are north-south, and the actual road directions of the above road names are east-west.

3.4. Results

From Fig. 4 it can be seen that whether it is a path direction judgment task or a path relationship judgment task, the correct rate of vertical layout signage is higher than that of horizontal layout.

The results of the two-factor mixed ANOVA(Analysis of Variance) showed a significant main effect of text layout style in the path direction judgment task. The results of simple effects (Fig. 5) showed that the correct rate of vertical guide signs was significantly higher than that of horizontal rows, whether in the above path ($F(1, 58) = 19.40$, $p < 0.001$, Partial $\eta^2 = 0.251$) or on both sides of the path ($F(1, 58) = 32.72$, $p < 0.001$, Partial $\eta^2 = 0.361$). In the task of judging path relationship, the main effect of text layout is significant. The simple effect results show that the correct rate of path relationship judgment of vertical row guide signs on both sides of the road and above ($F(1, 58) = 16.23$, $p < 0.001$, Partial $\eta^2 = 0.219$) and between the road on both sides and the cross ($F(1, 58) = 44.98$, $p < 0.001$, Partial $\eta^2 = 0.437$) is significantly higher than that of horizontal row.

	layout	df	F	P
path direction judgment task	above	1	19.40	0.001***
	two-sides	1	32.72	0.001***
path relationship judgment	sides × above	1	16.23	0.001***
	sides × cross	1	44.98	0.001***

Fig. 6 shows the confidence of different text layout methods of urban road signs in the judging path direction and path relationship under different number of road names. No significant differences were observed in the certainty of horizontal versus vertical way-finding signs for the tasks. These tasks included determining above-path direction ($t[29] = 0.73$, $p > 0.05$), both sides path direction ($t[29] = 0.79$, $p > 0.05$), the relationship between both sides and above-path ($t[29] = 0.34$, $p > 0.05$), as well as the relationship between both sides and cross paths ($t[29] = 0.68$, $p > 0.05$). This suggests that there is no substantial difference between horizontal and vertical guidance signs in tasks such as judging path direction above, path direction on both sides, path relationship between two sides and above path, and relationship between both sides and cross path.

3.5. Discussion

The findings from Experiment 1 indicate that the accuracy of path direction and path relationship judgment in urban road guide text, specifically vertical typesetting, significantly surpasses that of horizontal layout. This observation holds true for both six and nine

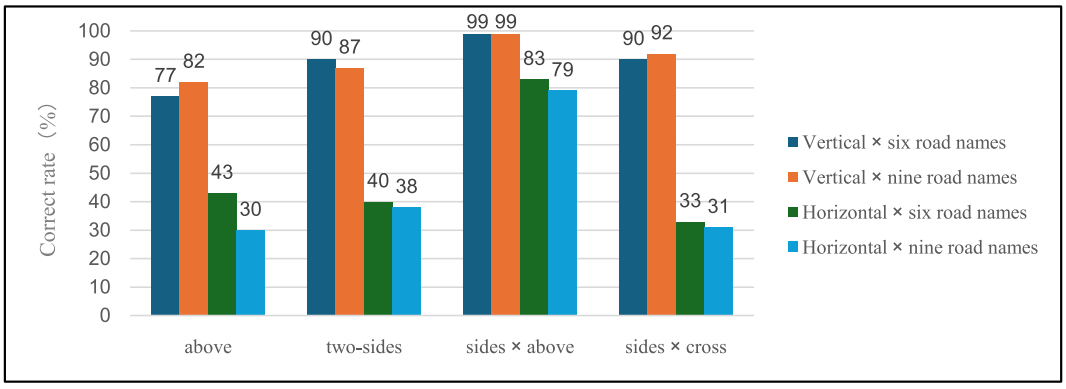

Fig. 4. The correct rate of judgment of different typesetting methods and volume of information.

	layout	df	F	P
path direction	above	1	19.40	0.001***
judgment task	two-sides	1	32.72	0.001***
path relationship	sides × above	1	16.23	0.001***
judgment	sides × cross	1	44.98	0.001***

Fig. 5. The results of simple effects.

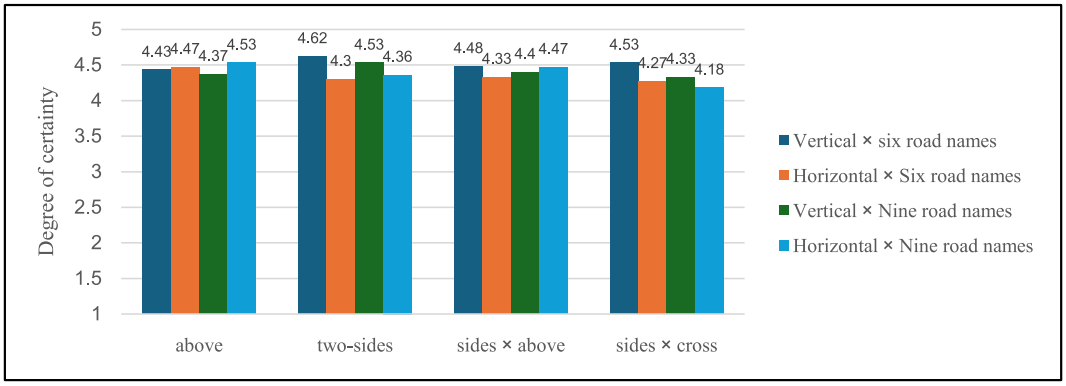

Fig. 6. The degree of certainty of judgment the different typesetting methods and volume of information.

road names.

This suggests that the layout of the text significantly impacts the accurate interpretation of actual road direction. The horizontal positioning of road names on either side is highly likely to induce a false impression in individuals that the road direction is also horizontal, leading to an incorrect spatial representation of the road network. The confidence score further underscores the misleading nature of the horizontal positioning of road names on both sides. This positioning not only leads subjects to make erroneous judgments but also fosters a belief in their own assessments.

Misinterpretations of guide signs in a horizontal layout may arise due to violations of spatial compatibility [29–31]. Spatial compatibility pertains to the congruence between the road display location and direction on the sign, and the actual spatial position within the real environment. In this study, it was observed that the type setting direction of the road names on both sides of the horizontal guide signs did not align with the actual road space direction, thereby violating spatial compatibility. Conversely, the road name layout direction on both sides of the vertical row of the guide signs aligned with the actual road spatial direction, demonstrating compliance with spatial compatibility. In the task of path relationship assessment, under the condition of horizontal road name typesetting on both sides of the guide sign layout, an increase in road name information from six to nine resulted in a decrease in accuracy rate. Although this decline was not statistically significant, all tasks exhibited a consistent downward trend. Conversely, when road names were vertically laid out on both sides of the guide sign layout, an increase in road name information from six to nine did not alter the accuracy rate, and in some task conditions, there was even a slight increase. According to the sign recognition test [32], a successful traffic sign must have at least 85 % of participants accurately interpret its meaning. In this experiment, when road names were horizontally laid out on both sides of the sign layout, the likelihood of subjects correctly interpreting the sign's meaning was significantly below 85 %. However, when road names were vertically laid out, even with an increased number of nine road names, the probability of subjects accurately interpreting the sign's meaning exceeded 85 %. Therefore, when road names were vertically laid out, the volume of information on the road names could be expanded to nine.

Having examined the influence of text layout and information volume on path determination, we will delve deeper into their impact on the global knowledge formation of road networks in Experiment 2.

4. EXPERIMENT 2

4.1. Participants

The study involved a total of 60 healthy participants, comprising 30 females, with an average age of 21 years. All subjects exhibited visual acuity or corrected visual acuity values exceeding 1.0. Importantly, none of the participants had previously participated in similar experiments, and there were no restrictions on their driver status.

4.2. Apparatus

The computer screen utilized for the experiment featured a resolution of 1024 × 768 pixels and an average luminance of 147 cd/m2. The experimental program was meticulously compiled using E-Prime 2.0, which autonomously recorded parameters such as learning frequency, confidence levels and satisfaction.

The experimental visual materials are categorized into four types (six road names × vertical, six road names × horizontal, nine road names × vertical, nine road names × horizontal), with six road names displayed horizontally in Fig. 7. The red triangle within the figure signifies the current position, while the green directional arrow denotes the subsequent turn. The dotted line delineates the previously traversed path, and the urban road guide sign located on the above right provides an indication of the direction sign observed in the red triangle.

4.3. Experimental design and procedure

This experiment is also a two-factor mixed design, with the same independent variables as in Experiment 1, and the dependent variables are learning frequency, confidence (degree of certainty) and satisfaction.

The experimental material initially presented four materials, each accompanied by a global map and urban road guide signs (Fig. 8), with each presentation lasting 20 s. These images emulate the scenario of traversing a section of the path to an intersection. Subsequently, the fifth image (Fig. 9) was displayed as a judgment material. Based on prior memory, subjects were required to identify the name of the red line path depicted in the material and provide the corresponding key response. If the subject's judgment was accurate, the experiment concluded. However, if the judgment was incorrect, the experimental procedure would be repeated until the correct judgment was provided. This iterative process is also referred to as learning frequency. Subjects were asked to rate the degree of certainty of each judgment, how confident they were that the judgment would be successful [1–5]. They were also asked to rate their satisfaction with all types of signs [1–5], which layout was preferred.

4.4. Results

Fig. 10 shows the learning frequency of different text layout methods and the volume of information. The results show that the main effect of text layout of urban road signs is significant ($F(1, 58) = 10.90$, $p < 0.01$, Partial $\eta^2 = 0.158$), which means that the learning frequency of vertical guide signs are significantly less than those of horizontal ones. The main effect of the information content of urban road the guide signs is not significant ($F(1, 58) = 1.50$, $p > 0.05$, Partial $\eta^2 = 0.025$), which means that there was no significant difference in the learning frequency between six road names guide signs and nine road names guide signs. Furthermore, there was no notable interaction between the typesetting mode and the volume of information ($F(1, 58) = 0.01$, $p > 0.05$, Partial $\eta^2 = 0.000$).

The confidence of different text typesetting methods and the volume of information is shown in Fig. 11. The results of the two-factor mixed ANOVA show that the text typesetting mode of urban road signs ($F(1, 58) = 0.23$, $p > 0.05$) and the main effect of the volume of information are not significant ($F(1,58) = 0.05$, $p > 0.05$, Partial $\eta^2 = 0.001$), shows that the typesetting mode and the volume of information of urban road guide signs have no significant effect on the confidence. There was no significant interaction between typesetting mode and the volume of information ($F[1p58] = 0.15$, $p > 0.05$, Partial $\eta^2 = 0.002$).

Fig. 12 shows the satisfaction of different text layout styles and the volume of information. All subjects scored the satisfaction of the four directional signs. The degree of satisfaction is a two-factor ANOVA repeated measurements. The results show that the main effect of text layout of urban road guide signs should be significant ($F(1, 59) = 152.95$, $p < 0.001$, Partial $\eta^2 = 0.722$). The satisfaction of vertical guide signs is significantly higher than of horizontal ones. The main effect of the volume of information is significant ($F(1, 59)$

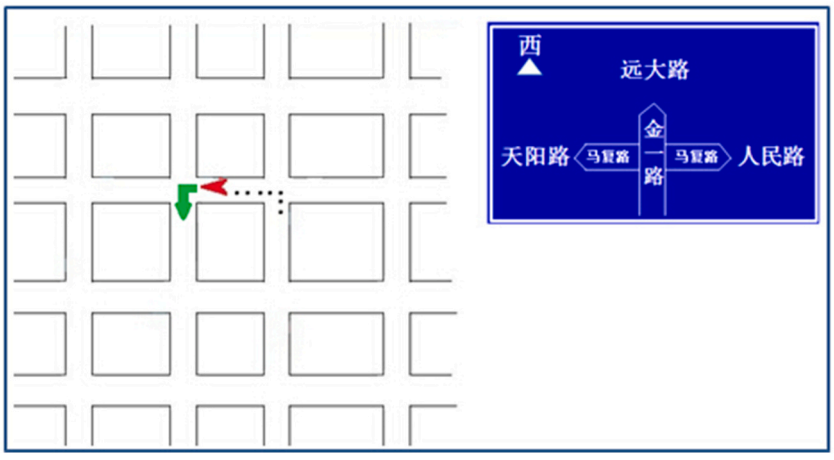

Fig. 7. Material examples of six road names arranged horizontally (Left is the translated version).

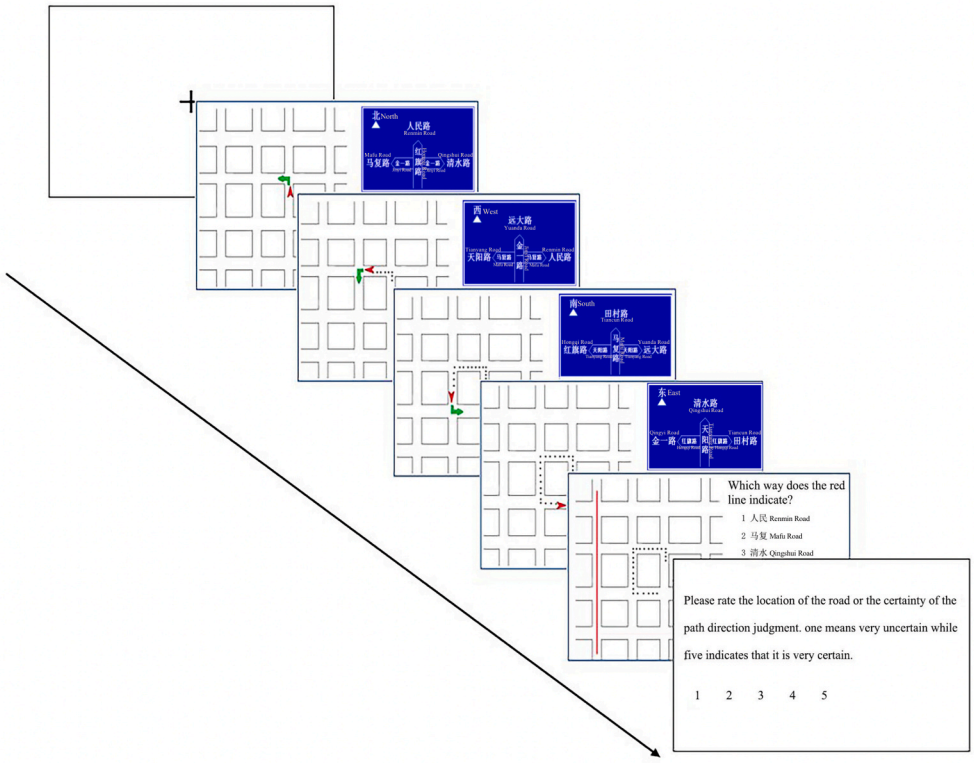

Fig. 8. The flow of Experiment 2.

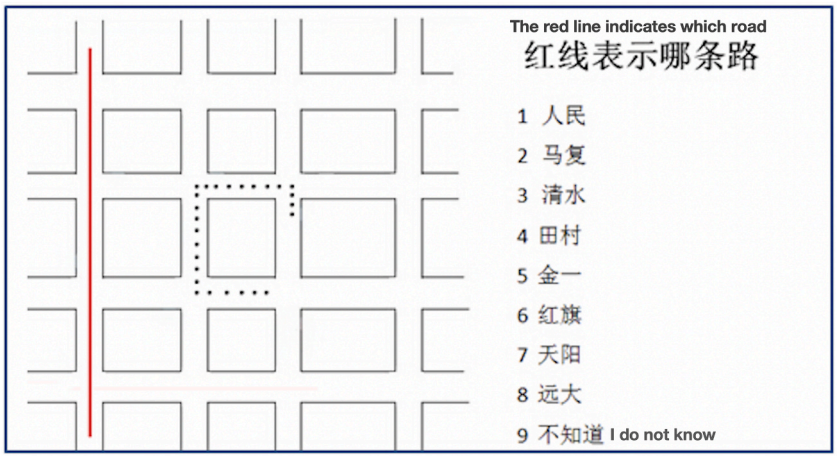

Fig. 9. Judgment material.

$= 47.39$, $p < 0.001$, Partial $\eta^2 = 0.445$), indicating that the volume of information of urban road guide signs has a significant impact on satisfaction, and the satisfaction of six road signs is significantly higher. There was no significant interaction between typesetting mode and the volume of information ($F(1,59) = 3.94$, $p > 0.05$, Partial $\eta^2 = 0.063$).

4.5. Discussion

The findings from Experiment 2 demonstrate that the text layout of urban road guide signs influences individuals' acquisition of global knowledge about road networks. Specifically, the learning frequency for vertical typesetting were significantly shorter than those for horizontal typesetting. This suggests that road signs with a vertical layout of both sides of the road names are more effective in

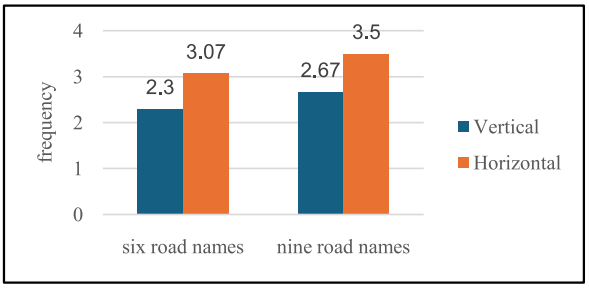

Fig. 10. Learning frequency of different typesetting methods and volume of information.

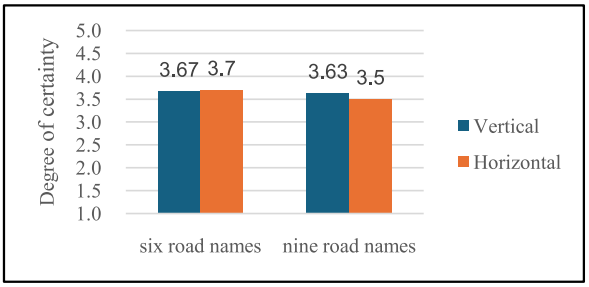

Fig. 11. The degree of certainty of different typesetting methods and volume of information.

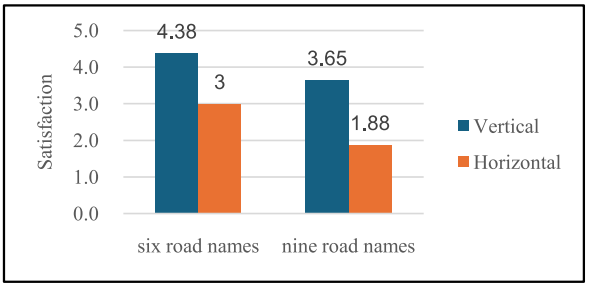

Fig. 12. Satisfaction with different typesetting methods and volume of information.

fostering the formation of global spatial knowledge about road networks. Upon completion of the experiment, we conducted a brief interview with the participants to delve deeper into this phenomenon. The majority of the subjects identified the paths on either side of the guide signs as "horizontal direction" when presented with horizontal guidance signs. For instance, the road names 和平路 (Heping Road) and 昌丁路 (Changding Road) in Fig. 6 were misinterpreted as parallel relationships. This further underscores that road names on both sides of a horizontal layout can inadvertently lead to incorrect path direction judgments, subsequently affecting the assessment of path location relationships and diminishing the efficacy of global spatial knowledge formation. The suboptimal performance of the horizontal directional signs was primarily attributed to a discrepancy between the writing direction of the road names on either side of the layout and the actual road direction. This inconsistency, or violation of spatial compatibility, suggests that the arrangement of road names strongly influences the perceived road direction. Consequently, when two-way road names are arranged horizontally, it can lead to subjects making incorrect judgments about the path direction of both roads. The results corroborate that the spatial compatibility of guide sign layouts plays a pivotal role in shaping the spatial representation of road networks. Notably, vertical guide signs exhibit superior spatial compatibility.

In the process of global knowledge acquisition for road networks, an increase in the volume of road name information from six to nine results in a slight rise in the learning requirements of the subjects. This is irrespective of whether the road names are horizontally or vertically arranged on both sides. However, the increase is more modest under vertical typesetting conditions, even when there are nine road names. As the volume of road name information escalates, the subjective satisfaction of the subjects diminishes. This decrease is significantly less pronounced in the vertical layout condition compared to the horizontal layout. The superiority of the vertical layout is further highlighted by the fact that even with nine road names, the vertical layout indicator exhibits a higher level of satisfaction than the horizontal layout indicator with only six road names. These two indicators also indicate that under the vertical layout condition, the volume of road name information can be increased to nine without significantly impacting its visual

understanding performance.

The findings from Experiment 2 mirrored those of Experiment 1, demonstrating that subjects consistently believed their judgments to be accurate under both horizontal and vertical guide sign conditions. However, the number of learning frequency administered to the subjects exhibited a significant increase under the horizontal layout condition. This suggests that subjects were inadvertently influenced by the horizontal orientation of urban guide signs, remaining unaware of this bias even when they made incorrect judgments, yet still maintaining the belief in their understanding and accuracy.

5. Conclusion

1. The spatial representation of the road network is profoundly affected by the textual layout of urban guide signs. Notably, vertical guide signs exhibit superior performance in comparison to their horizontal counterparts. This suggests that the vertical arrangement of urban road directional sign texts aligns more effectively with ergonomic design principles.
2. Considering that the volume of road name data derived from urban guide signs does not markedly affect the spatial representation of road networks, a vertical layout may provide more detailed information on road names than a horizontal layout. Therefore, by modifying the layout as required, the count of road names can be increased from six to nine.

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Data Accessibility

The data are not publicly available due to privacy or ethical restrictions.

CRediT authorship contribution statement

Jiuxiao Zhu: Writing – review & editing, Writing – original draft, Visualization, Data curation. **Zhenghu Cui:** Investigation, Formal analysis, Data curation, Conceptualization. **Zhen Yang:** Software, Methodology, Investigation. **Qijun Wang:** Investigation, Data curation, Conceptualization. **Yu Tian:** Writing – review & editing, Visualization, Formal analysis. **Duming Wang:** Visualization, Validation, Investigation, Data curation, Conceptualization.

Declaration of Competing interest

The study was approved by the ethics committee of Zhejiang Sci-Tech University (No. 202210E002), and all participants in the experiments signed written informed consent. The authors declare that they have no potential conflicts of interest concerning the research, authorship, or publication of this article.

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