Kurdish Studies
Apr 2023
Volume: 11, No: 02, pp. 2560-2577
ISSN: 2051-4883 (Print) | ISSN 2051-4891 (Online)
www.KurdishStudies.net

Received: May 2023 Accepted: June 2023
DOI: https://doi.org/10.58262/ks.v11i02.186

Emotional Design for Traditional Chinese Wayfinding Symbols: A Quantitative Research Through an Eye-Tracking Experiment for Promoting Wayfinders' Experience

Xiaoye Li[1], Bin Hu[2]*

Abstract

The interpretation of way-finding symbols for comprehensive office buildings has a huge impact on visitors' emotional experience. Due to the modern complexity of comprehensive office buildings, an effective human-centric emotional wayfinding symbol design requires a co-design approach that considers office visitors' cognition and emotional experience. This study adopted a co-design approach, by which twenty-three participants were asked to design Chinese wayfinding symbols for the interior space of the comprehensive building at Macao University. We investigated the impact of these wayfinding symbols on the efficiency and emotional experience of the wayfinders from China and Macao from the perspective of cognition and emotion. Eye-tracking experiments are used to investigate the difference between the wayfinding design elements and design style produced through the co-design workshop and the existing universal standard wayfinding symbols. Wayfinders' attention and directionality are verified using First Fixation Duration, Fixation Count and Time to Fixation Duration. Their emotional experience is indexed based on Average Pupil Size. The results showed that traditional Chinese paper folding wayfinding icons are efficient in providing wayfinding guidance. Meanwhile, they increase wayfinders' pleasure when viewing the icons.

Keywords: *Wayfinding design; symbolic design; emotional experience; co-design; eye-movement metrics.*

Introduction

Wayfinding systems are important to providing people with efficient wayfinding guidance, meanwhile, they also impact people's emotional experience (Hu, 2019). Current navigation systems in China are still based on the universal wayfinding symbols designed by the U.S. Department of Transportation (DOT) for European and American countries and regions (Hashim et al., 2014). Little research has been done on navigation systems that consider the aesthetic sensibilities of Chinese culture, which, however, is an important factor to modulate people's emotional states. This work tends to fill the gap by exploring the approach of wayfinding design in the context of Chinese culture.

We aim to investigate innovative design ideas and design elements in the Chinese context from the perspective of users, in order to improve the efficiency of wayfinding and enhance their emotional experience. We adopted a co-design approach and used eye-movement tracking experiments to produce a solution and design guidance for wayfinding symbolic design under the threshold of Chinese culture. The eye-movement tracking technique allowed us to objectively investigate the impact of wayfinding design elements on Chinese visitors regarding their wayfinding efficiency and emotional experience.

[1]Macao University of Technology and Science in Macao, China. Email: xiaoveli@must.edu.mo
[2]Macao University of Technology and Science in Macao, China. Email: binhu@must.edu.mo (corresponding author)

Literature Review

Research Related to Wayfinding Design

Wayfinding refers to the process of searching for a route to a destination in unfamiliar circumstances (Mollerup, 2013). During wayfinding, people usually use the following approaches: oriented search, following a continuously marked trail, piloting between landmarks, or referring to a cognitive map. These wayfinding systems convey information through words, symbols, and (or) speech (Vilar et al., 2014). It has been found by Hashim et al., 2014 and Tang et al., 2009 that the users' linguistic background and their awareness level have a significant impact on the efficiency of searching for their correct route via textual information. In addition, symbols are more prospective, figurative, and salient. Therefore, users are typically better to understand information conveyed through symbols compared with words (Shieh & Huang, 2003).

It has been suggested that the efficiency of wayfinding symbols also depends on other factors including users' gender, age, education, and cultural background. These factors are usually collected via questionnaires, quizzes, or physiological tests (Devlin, 2014; Hashim et al., 2014; Lee et al., 2014). Specifically, Devlin (2014) considered a hospital as the experimental site, where a master-planned effective wayfinding system was created. To test the effectiveness of wayfinding symbols in directing ways, both young and older people were invited to choose a direction back to the original point from a specified location. The results showed that compared to younger people, elder people relied more on significant wayfinding symbols, which thus provided one possibility for the decreased success in wayfinding with the increased age of users.

Research Related to User Emotional Experience

When focusing on user emotional experience of wayfinding, some scholars have investigated the construction of the requirements framework from different perspectives based on the three-level theory (Gauss et al., 2020; Hou et al., 2021; Lee et al., 2017; Liu et al., 2019). About the requirements framework, Abrahão et al. (2011) proposed an evaluation method that describes the quality of a user according to the perception-based requirements. Kongprasert and Butdee (2017) proposed a method for designing leather products based on affective design and used it to analyze the design factors that attract users to leather products. Wang and Zhao (2017) proposed a method for determining user requirements for intelligent collaborative systems, using a scenario description of the intelligent collaborative system as input and converting that description into a multi-view requirement model.

Despite this, it is worth noting that the requirements framework is influenced by some other subjective factors, which may affect the credibility of the design more or less. In this sense, it is crucial to control the potential influence stemming from subjective factors in the design process to improve the objectivity of design research. Following this point, some scholars have used physiological devices to accurately collect various physiological indicators reflecting the emotional experience of users, which is thought to reflect their attentional bias and preference during the interaction. Moreover, Pentus et al. (2014) conducted the emotion analysis via conjoint analysis and psycho physiological measurements. The benefits of using physiologically intelligent sensors to measure human emotions in a product or the system environment have been pointed out by Balters and Steinert (2017). It could also reduce the subjectivity regarding the emotional experience of users, as well as improve the credibility of findings, using the visualization of physiological indicators. Thus, physiological measurements can advance research on emotion engineering.

Methodology and Experiments

Co-design

Co-design refers to the design process in which designers, researchers, users, and final stakeholders are involved (Sanders & Stappers, 2008). It has been used by researchers to investigate the emotional experience of users (Short et al., 2017, 2019). For example, the complex wayfinding process for navigating users through hospital referrals or departments increases their emotional costs during their consultation process. By using the co-design approach, it was found that the high recognition and coherence of wayfinding symbols in wayfinding systems can reduce the emotional cost for users, therefore, improving their wayfinding experiences (Short et al., 2019). Moreover, in the context of hospitals, it has been indicated that the co-design space contributes to the evolution of healthcare environments' appearance, value, and performance (Reay et al., 2017).

Participants

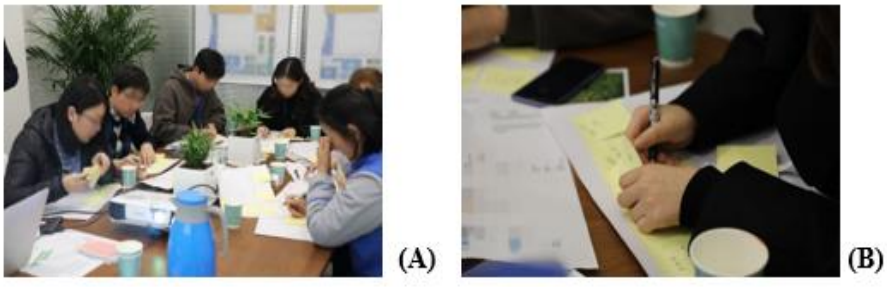
This experiment involves twenty-six participants with age mean and standard deviation equal to 25 and 26, respectively. The permanent residences of the participants were in central, southern, eastern, and northwestern China, including five provinces. All participants met the data collection criteria for this oculomotor experiment and had a normal or corrected-to-normal vision. Before the experiment, all participants signed informed consent, they hanot viewed the experimental materials and none of them had been exposed to the scenes used in the experimental pictures (i.e., building R of MUST). In the end, participants were given a block doll as compensation for their participation.

Co-design Proposal

Twenty-six Chinese participants from five provinces participated in the co-design workshop in early 2021, which is comprised of visual designers, wayfinding researchers, and wayfinding users (see Figure 1A[3].). The co-design workshop was divided into four parts:

1) Participants wrote down the problems (pain points) they encountered in their past wayfinding experiences (see Figure 1B).
2) Participants exchanged their papers and provided their design ideas for problems and solutions put forward by other participants.
3) During the exchange and sharing process, participants were encouraged to try to draw designs that are helpful to solve the problems (i.e., pain points) of wayfinding.
4) The facilitator (author) recorded the various design ideas during the exchange process and collected the papers at the end.

Figure 1: (A) Co-design site and (B) Participants record wayfinding pain points.



Co-design Workshop Results

During the co-design process, most participants indicated that the combination of traditional Chinese paper

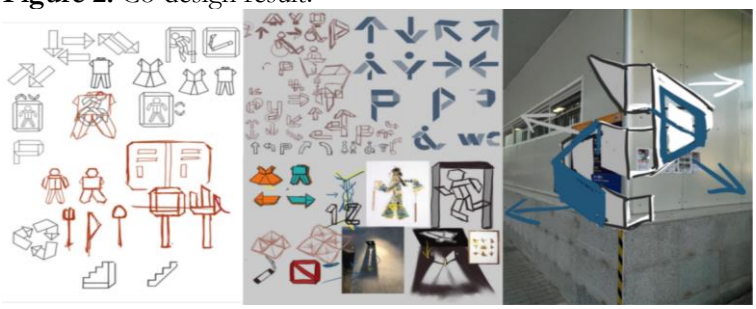
[3] The images were blurred to protect the privacy of the participants

folding culture and wayfinding design can enhance the emotional experience of wayfinding. Based on the design ideas and drafts of the participants in the co-design process, the researcher collected and organized the co-design results of wayfinding symbols (Figure 3.), and proposed design solutions for wayfinding elements.

(1) Wayfinding symbolic design: Chinese users have certain cognitive problems with the existing international wayfinding symbols, and it is difficult to recognize the icons of restrooms, elevator entrances, restaurants and other locations in some scenes. Using the characteristics of planarity and folding in Chinese paper folding culture, the linear pattern in the international common icons can be innovatively designed to fit the aesthetics of Chinese users and highlight the location information conveyed by the wayfinding symbols.

(2) Wayfinding signage board design: the existing flat arrow guide is likely to be misunderstood when going up, going down, or turning a corner. By incorporating the feature of turning stemming from Chinese paper folding culture, the flat arrow previously used in the universal wayfinding sign is replaced by an arrow that can directly point to the destination direction. This change improved the accuracy and efficiency of wayfinding guidance.

Figure 2: Co-design result.



Eye Movement Tracking Experiment

Visual perception is closely related to emotions and the user cannot easily control their physiological responses (Guo et al., 2016; Ho, 2014; Rayner & Pollatsek, 1992; Schifferstein & Desmet, 2007). Also, eye movements are reliable behavioural indicators in the process of visual attention and information acquisition (Horowitz & Wolfe, 1998). Therefore, eye tracking commonly serves as a physiological index to identify the user's raw sensation of the stimulus and studies also have shown that eye-tracing can be used to analyse user behaviours (Gofman Alex et al., 2009). During wayfinding, the user primarily uses vision to obtain the information conveyed by the wayfinding symbols, thus learning the current location and recognizing the direction of their destination. In this process, most behaviours and responses are made automatically and unconsciously by users (Matukin et al., 2016). For example, it has been found that the attention of users is automatically attracted by pleasant or neutral images compared to unpleasant ones (Clement et al., 2013). At the physiological level, viewing positive and neutral pictures led to a larger pupil diameter compared to negative pictures. In addition, looking at pictures of interest typically lead to faster responses, and a greater fixation count within the interest area (Ares et al., 2013; Clement et al., 2013; Hsu et al, 2014; Qu & Guo, 2019; Rudi et al., 2020; Van Loo et al., 2018).

The study regarding wayfinding features involves the wayfinding spatial environment (Veeraswamy et al., 2011; Vilar et al., 2013; Vilar et al., 2014), gaze point (Bianconi et al., 2019), decision-making time (Xie et al., 2012; Xie et al., 2013; Fu et al., 2019), and visual catchment area (VCA) (Filippidis et al., 2006; Xie et al., 2012). The user's interactive behaviour with the wayfinding sign relies mainly on the visual senses during wayfinding. Thus, many studies have used an eye-tracking approach to explore the characteristics

of user interaction with wayfinding systems. They aim to reduce the subjective factors stemming from the users, which then improved the credibility and objectivity of the obtained results (Bae et al., 2020; Bianconi et al., 2019; Vilar et al., 2014).

The current experiment is for detecting the effects of wayfinding symbols on users' preferences, attention, and directionality after adding paper folding cultural elements. Thus, we collected the pupil diameter and first fixation duration of the participants when they are viewing the experimental images (Table 1). Then we analysed the influences of paper folding elements on efficiency and emotional experience of wayfinding.

Table 1: Description of eye movement indicators.

Indicator	Description	Characterization
First Fixation Duration	Attention Span	Refers to the gaze time at the first gaze point in the first passage through an area of interest. The longer the First Fixation Duration, the greater the subject's level of interest in that sample.
Average Pupil Size	Preference	Reflecting the physiological and psychological changes in the subject, the pupils dilate when a strong sense of pleasure is generated, and the pupil diameter size is proportional to the preference.
Time to Fixation Duration	Attractiveness	From the first gaze point of the experimental picture to the time when the gaze point enters the area of interest, the faster the entry time indicates the more significant the attractiveness of the sample.
Fixation Count	Comprehension	The total number of fixation points falling into the region of interest is affected by the difficulty of information processing and the complexity of the material. Too many fixation points mean low efficiency and low comprehension.

Experimental hypothesis

It is found that Chinese wayfinding users have many pain points in their daily wayfinding behaviours. The existing international familiar wayfinding icons and guide signs have much room for improvement regarding users' preferences, attention and understanding. Based on the co-design results, the symbolic icons in wayfinding are redesigned by combining the paper folding elements of Chinese culture with wayfinding symbols. The following hypotheses were verified using eye movement tracking experiments.

1) Combining the wayfinding icons with Chinese paper folding culture to highlight the features of planarity and folding in the icons would improve users' attention to the icons and enhance their pleasant experience compared with the linear pattern in universal international icons.
2) Adding Chinese paper folding cultural elements of turning into the wayfinding sign would reduce the user's demands and time of understanding and thinking of the sign, and would improve the directionality of the sign at the same time compared with the flat arrow in the universal wayfinding sign.

Experimental Design

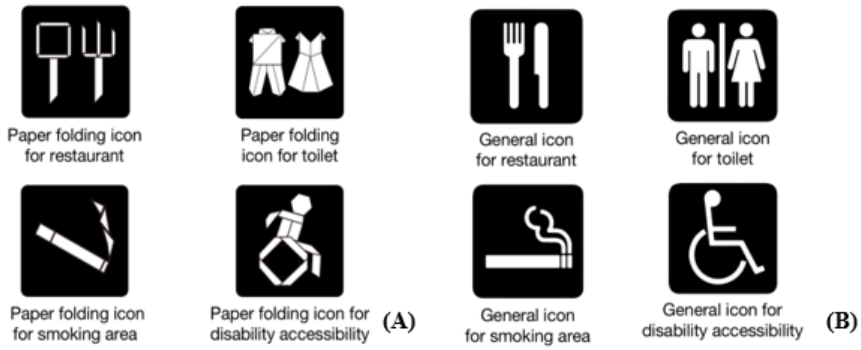
The experiment used Adobe Photoshop 2020 and Adobe Illustrator 2021 software to visualize the Chinese paper folding cultural elements for the wayfinding icon symbols. The sets of experimental material images were produced. The following experimental material design scheme was proposed according to the univariate principle of the eye-movement experiment.

(1) Experiment 1 material - Wayfinding icon design

According to our first hypothesis discussed in Section 3.2.1, we combined the traditional paper folding art in Chinese culture with the wayfinding icon design, highlighting the structure of expressing the planarity and folding in the icons, and redesigning the icons of a restaurant, restroom, smoking area, and handicapped-accessible area (hereinafter referred to as restaurant map, restroom map, smoking map, and

handicapped map) (Figure 3A). The four icons with a Chinese paper folding style were used in the experimental group. In contrast, the four universal wayfinding icons (Hashim et al., 2014), which are commonly used in wayfinding systems in public areas ("Department of Transportation (DOT) Symbols," n.d.), were used in the control group of the current study (Figure 3B). The size of the experimental material images was 628 × 628 px with a resolution of 144 ppi, uniform black background with white patterns, and only a single variable of icon design style existed between the experimental and control groups.

Figure 3: (A) Paper folding icons (B) Universal icons.



In Experiment 1 (a), participants viewed each icon for 4s, and pupil size was measured during this time, the averaged pupil size index was used to analyze the difference in participants' preference for paper folding icons. In Experiment 1(b), the same type of paper folding and universal wayfinding icons were placed in one group (see Figure 4) and divided into four groups of icons according to the restaurant, restroom, smoking and disability pictures. Each group was repeated by flipping the left and correct positions. Eight groups of experimental pictures were displayed in random order, the display time of each group was 4s. The first fixation of the area of interest (AOI) was collected when the participants viewed each group of icons. The AOI index of First Fixation Duration was collected when the participants viewed each group of icons to analyze the difference in attention between paper folding and universal icons.

Figure 4: Left and right placement contrast icons.

(2) Experiment 2 Materials - Wayfinding guide signs design

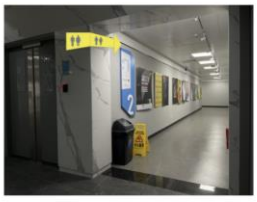
According to our second hypothesis mentioned in Section 3.2.1, we incorporated the twist element of

paper folding art into the arrow of the wayfinding guide. The arrow pointed directly to the destination by way of a paper folding twist.

We found that the interior of Building R of the Macau University of Science and Technology (MUST) is a square structure design. There are more complicated route-finding routes in its interior environment such as intersections, upper and lower floors, and left and right turning angles. They look like the Chinese character "回". They meet the requirement of road-finding scene simulation in this experiment. Therefore, the researchers went to the interior of Block R of the MUST and photographed indoor areas such as elevator entrances, up and down floors, left corners, right corners, and restroom corners as the wayfinding scenes. Then, they simulated a continuous indoor wayfinding scene from entering the building to reaching the restroom which was set as the destination. The produced wayfinding guide was combined with the scene map and set as the experimental group (Figure 4).

Figure 5: Paper folding signs.


Paper folding guide sign 1


Paper folding guide sign 2


Paper folding guide sign 3


Paper folding guide sign 4

The existing wayfinding guide in Block R of the MUST is shown in Figure 8. Based on the experimental comparison of the single variable method, the characteristics of its flat arrow guide were retained. Its icon shape, guide colour, placement and area were modified to create a set of universal wayfinding guides. These universal wayfinding guides were used as the control group and were placed in the same position as the paper folding wayfinding guide in the same scene (see Figure 9).

Figure 8: Wayfinding guide sign in Block R of the MUST.

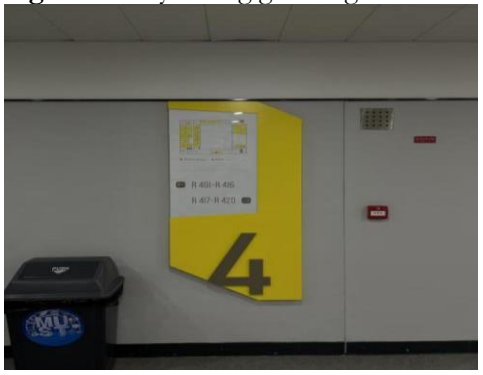


Figure 9: Universal signs.

The size of the experimental material was 943 × 707 px with 144 ppi resolution. The material that has a yellow background and grey icons was used to design the guide signs. In Experiment 2 (a), the participants were asked to find the guide sign used in the experimental group within 10s. During the process, the AOI of the guide sign was collected and used to compare the user's understanding of the information conveyed by different types of signs (the paper folding vs. the universal guide sign). In Experiment 2(b), participants were asked to look at the destination guided by the sign as fast as possible. The time to fixation duration index of the AOI was collected to examine the time used by participants to find and look at the intersection under the guidance and explore the difference in directionality between paper folding and universal signs (Figure 10).

Figure 10: AOI partition of experimental pictures.

Results

Experiment 1 (a): Paper Folding Icon Cannot Enhance Positive Emotion

In Experiment 1 (a), we performed a paired t-test on the averaged pupil size, when participants viewed the paper folding and universal icons (restaurant, restroom, smoking, and disability). The results suggest that the pupil diameter difference between the two groups is significant, t = xx, p = xx. This indicates that paper folding elements in wayfinding icons has a huge impact on the average pupil size (Table 2 &Table 3).

Table 2: Experiment 1 (a) Average Pupil Size data.

	Mean	Std. Deviation
Paper folding restaurant icon	3.65565	0.502764
Universal restaurant icon	3.78696	0.522028
Paper folding restroom icon	3.75217	0.501787
Universal restroom icon	3.56826	0.494117
Paper folding smoking icon	3.79652	0.500651
Universal smoking icon	3.63652	0.491034
Paper folding disability icon	3.82478	0.545851
Universal disability icon	3.63609	0.528942

Table 3: Experiment 1 (a) Average Pupil Size difference data.

	Mean	Std. Deviation	t	Two-Sided p
Paper folding restaurant icon - Universal restaurant icon	-0.131304	0.125673	-5.011	<.001
Paper folding restroom icon - Universal restroom icon	0.183913	0.112199	7.861	<.001
Paper folding smoking icon - Universal smoking icon	0.16	0.125915	6.094	<.001
Paper folding disability icon - Universal disability icon	0.188696	0.221181	4.091	<.001

In the experiments which involved the restroom symbol, smoking symbol, and disability symbol, we found that the pupil diameters were more extensive for the paper folding icons compared with the universal icons. It has been indicated that the pupils dilate when a strong sense of pleasure is generated, and the pupil diameter size is proportional to the preference. Thus, this finding demonstrated that adding paper folding elements to the wayfinding icons in the restroom, smoking area, and disability accessibility area increased users' pleasure when viewing the icons.

In the experiment that involved the restaurant diagram, the pupil diameter was smaller when considering the paper folding icon compared with the universal icon. This indicates that the restaurant paper folding icon cannot enhance pleasure and even results in negative emotions. According to the pose-experiment interview, this is because most participants felt puzzled and uncomfortable when viewing the paper folding restaurant icon. So, why do paper folding restaurant icons bring negative emotions?

(1) By comparing the paper folding restaurant icon with other paper folding icons, we found that the percentage of figure area in the paper folding restaurant icon was much less than in other paper folding icons. This may be due to the poor visual visualization of paper folding cultural elements that do not clearly show well the folding effect of planarity in the icon, which induced negative emotions.

(2) In the post-experiment interview, most of the participants expressed confusion about the paper folding restaurant icon. After comparing them with other paper folding icons, it was found that the visual effect of the paper folding restaurant icon was not good. Therefore, the participants were not able to quickly interpret the information conveyed by the icon when viewing it. This resulted in an increased thinking time and negative emotions.

The above results suggested that to reduce the thinking time for the users to interpret the icon, we should highlight the characteristics of planarity and folding, increase the proportion of planarity, strengthen the folding effect of planarity, and realize the design according to the symbolic symbols of the location of the directions. These changes can further improve users' positive emotions.

Experiment 1 (b): Paper Folding Icon Better Suits Chinese Users' Aesthetic Preferences

In Experiment 1 (b), we performed a two-way repeated-measures ANOVA on participants' first fixation duration when participants viewed left-right placed paper folding and universal wayfinding icons. The results showed that the change in left-right position did not have a statistically significant effect on the First Fixation Duration data for both types of icons ($F = xx$, $p = xx$). However, the First Fixation Duration difference between the two different icon styles (paper folding vs. universal) was statistically significant ($F = xx$, $p = xx$). This indicated that the addition of paper folding elements to the icons affect participants' First Fixation Duration when viewing the icons. (see Table 4 & Table 5).

Table 4: Experiment 1 (b) First Fixation Duration data.

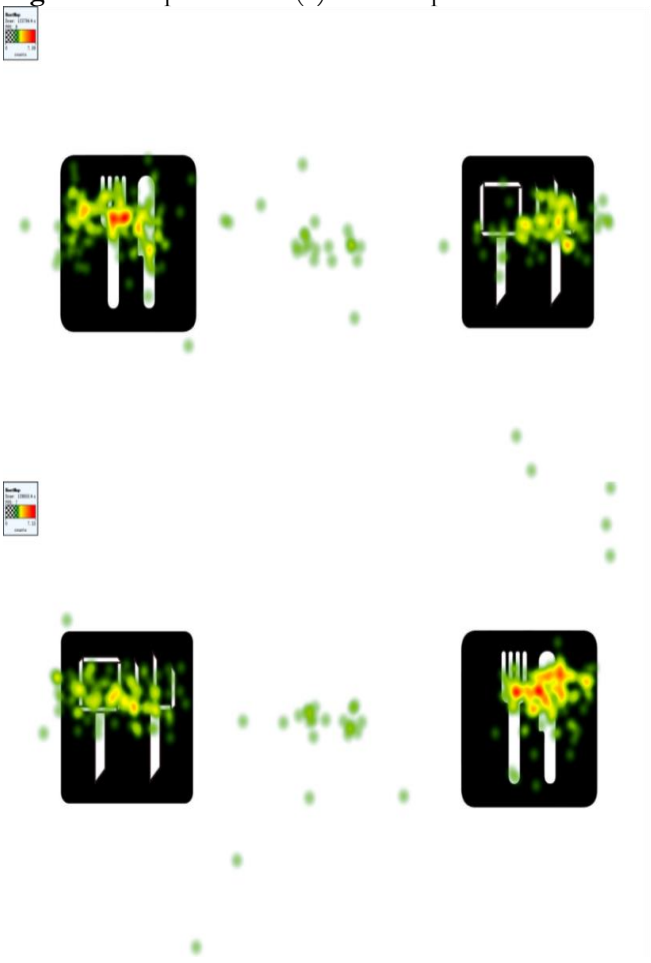
	Mean	Std. Deviation
Left universal restaurant icon	0.13458	0.078161
Right universal restaurant icon	0.22928	0.135203
Left paper folding restaurant icon	0.23431	0.15423
Right paper folding restaurant icon	0.28083	0.172956
Left universal restroom icon	0.15002	0.066051
Left paper folding restroom icon	0.31459	0.171357
Right universal restroom icon	0.16466	0.071182
Right paper folding restroom icon	0.28755	0.153906
Left universal disability icon	0.13053	0.059464
Right universal disability icon	0.14158	0.07123
Left paper folding disability icon	0.37182	0.225827
Right paper folding disability icon	0.26138	0.140691
Left universal smoking icon	0.13551	0.061217
Right universal smoking icon	0.15596	0.102335
Left paper folding smoking icon	0.25547	0.154001
Right paper folding smoking icon	0.28757	0.225993

Table 5: Experiment 1 (b) First Fixation Duration difference data.

Style	Mean Difference	Std. Error	F	Sig.
Paper folding restaurant icon - Universal restaurant icon	0.076	0.032	5.542	0.028
Paper folding restroom icon - Universal restroom icon	0.144	0.019	58.623	<.001
Paper folding disability icon - Universal disability icon	0.241	0.043	44.565	<.001
Paper folding smoking icon - Universal smoking icon	0.126	0.027	21.465	<.001

Based on Figure 4, the paper folding icons are associated with greater First Fixation Durations compared with universal icons. Based on the previous studies, this indicated that paper folding icons elicit greater attention than universal icons and users are more interested in paper folding icons. Moreover, the analysis of the eye heat map revealed that participants paid more attention to the paper folding icon in the experiments of the restroom map, smoking map, and disability map. In contrast, in the experiment that involves the restaurant map (Figure 11.), the eye heat map revealed that the universal restaurant icon received more attention than the paper folding restaurant icon both before and after the change of the left and right positions of the icon. This was different from the results of the two-factor repeated analysis of the First Fixation Duration.

Figure 11: Experiment 1 (b) Heat map of restaurant icon.



The above results showed that when both types of icons appear at the same time, the design style of the paper folding icon is more suitable for Chinese users' aesthetic preferences. Users are more interested in the paper folding icon, thus paying more attention to them. In the process of wayfinding in the Chinese environment, paper folding icons can attract users' attention faster, which improves the efficiency of wayfinding. However, when there are fewer figure areas and the paper folding elements are visually visualized, the folding effect is not prominent and the pictographic effect does not make a difference. It may be due to the users being confused, which results in negative emotions.

Experiment 2 (a): Paper Folding Icon Can Be Recognized More Efficiently

In Experiment 2(a), we performed a paired t-test on the Fixation Count within the area of interest for the paper folding and universal guide signs. The results showed that the difference in the Fixation Count between the paper folding and universal guide signs was statistically significant (t = xx, p = xx). This indicates that the change of the guide method affected the Fixation Count on the guide signs. In the experiment, the participants were asked to find the guide sign in the scene picture and to look at the intersection they were guided to. Thus, the Fixation Count of the guide is correlated with the participants' understanding of the guide sign, indicating that the more gaze points, the greater needs of participants for the guide sign before they find the intersection, whereas the slower they can get the guide information and the worse understanding of the guide sign. On the contrary, the fewer gaze points suggest a better utilization of the guide signs (Table 6, Table 7).

Table 6: Experiment 2 (a) Fixation Count data.

	Mean	Std. Deviation
Paper folding guide sign 1	4.95652	1.77042
Universal guide sign 1	6.86957	1.914166
Paper folding guide sign 2	4.47826	2.428422
Universal guide sign 2	6.30435	3.390291
Paper folding guide sign 3	4.13043	1.961084
Universal guide sign 3	5.47826	2.777664
Paper folding guide sign 4	3.56522	2.659906
Universal guide sign 4	5.17391	3.651303

Table 7: Experiment 2 (a) Fixation Count difference data.

	Mean	Std. Deviation	t	Two-Sided p
Paper folding guide sign 1 –Universal guide sign 1	-1.913043	2.728853	-3.362	0.003
Paper folding guide sign 2 –Universal guide sign 2	-1.826087	3.498729	-2.503	0.02
Paper folding guide sign 3 –Universal guide sign 3	-1.347826	2.673246	-2.418	0.024
Paper folding guide sign 4 –Universal guide sign 4	-1.608696	3.564205	-2.165	0.042

In the comparison experiment, the number of observation points of the paper folding guideposts was less than that of the universal guideposts. This indicates that participants paid less attention to the paper folding guideposts. However, the understanding of the paper folding guideposts was better than that of the universal guideposts after adding the paper folding twist elements to the arrow of the wayfinding guideposts. The difference in the number of viewing points between the elevator entrance and the upper and lower floors was the largest (1.91±2.73). Moreover, the results based on the trajectory map show that the visual trajectory in the paper folding guide 1 scene map was mostly focused on the guide sign and the elevator entrance. In contrast, the visual trajectory in the universal guide 1 scene map was more diffused (Figure 12.). This difference indicated that the advantage of the paper folding in the wayfinding guidance was mostly reflected on the upper and lower floors. When focusing on the intersection scene, the comparative analysis of the trajectory diagram showed that the visual trajectory of the paper folding guidance 2 scene diagram is focused on the guidance signs and the target intersection; whereas the visual trajectory of the universal guidance 1 scene diagram is more diffused (Figure 13.). It suggests that the paper folding guidance has the advantage of wayfinding guidance in the intersection scene.

Figure 12: Track chart of Guide 1 scene.

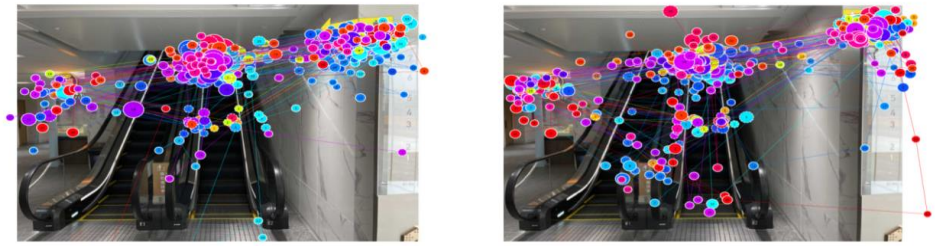
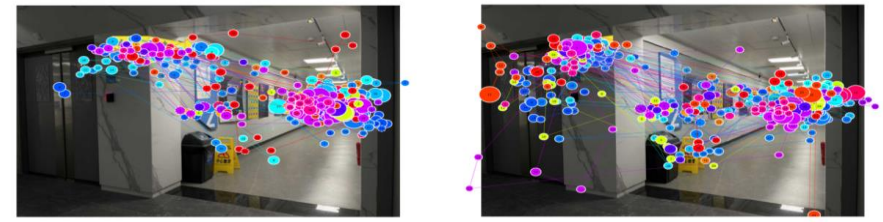


Figure 13: Track chart of Guide 2 scene.



Universal guide signs indicate the directions using two-dimensional arrow directions. For the up and down floors, the universal flat guide signs guide the direction using up and down arrows, which are also used for front and back. So, for example, when looking at an up arrow, users may be confused. In complex wayfinding scenarios (i.e., up and down floors, intersections) or some situations that are combined with various guidance (i.e., forward and then left, right and then forward), users need to invest more thinking time to interpret the universal flat arrow guidance. This reduces wayfinding efficiency and impairs users' emotional experience. However, the limitation of the flat surface can be addressed by turning the three-dimensional arrow.

Experiment 2 (b): Paper Folding Icons Have Stronger Pointing Ability

In Experiment 2(b), the participants were asked to find the guidance sign in the scene map and to look at the intersection point. We performed a paired t-test on the Time to the Fixation Duration of the target intersections' interest areas in the eight scene maps. The result suggests a significantly different between paper folding and universal guidance scene maps (Table 8, Table 9). For the eight scene maps, the Time to Fixation Duration of the target intersection interest area in all four-paper folding guided scene maps was smaller than the target intersection in the universal-guided scene map. This indicates that in the paper folding-guided scenario maps, the participants can find the pointed target intersection faster with the paper folding guidance, suggesting an obvious gain of the pointing ability guided by the paper folding compared to the universal sign.

Table 8: Experiment 2 (b) Time to Fixation Duration data.

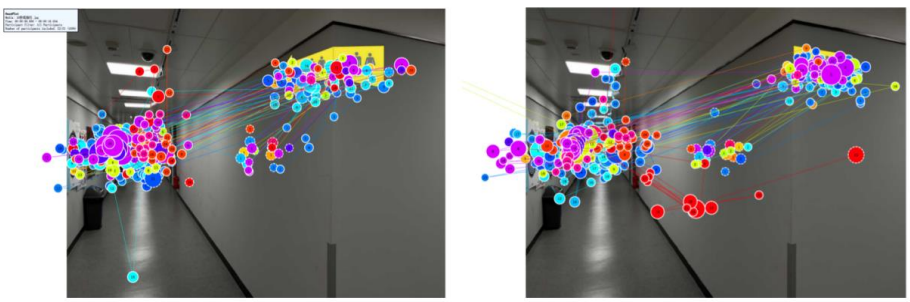
	Mean	Std. Deviation
Paper folding intersection 1	2.65717	0.903919
Universal intersection 1	3.76094	1.271839
Paper folding intersection 2	1.77921	0.622009
Universal intersection 2	3.50455	1.721038
Paper folding intersection 3	1.36546	0.497776
Universal intersection 3	1.86516	0.623915
Paper folding intersection 4	2.24023	1.097523
Universal intersection 4	2.80542	1.246604

Table 9: Experiment 2 (b) Time to Fixation Duration difference data.

	Mean	Std. Deviation	t	Two-Sided p
Paper folding intersection 1 - Universal intersection 1	-1.103774	1.131044	-4.68	<.001
Paper folding intersection 2 - Universal intersection 2	-1.725343	1.807975	-4.577	<.001
Paper folding intersection 3 - Universal intersection 3	-0.499704	0.434582	-5.514	<.001
Paper folding intersection 4 - Universal intersection 4	-0.565187	0.806777	-3.36	0.003

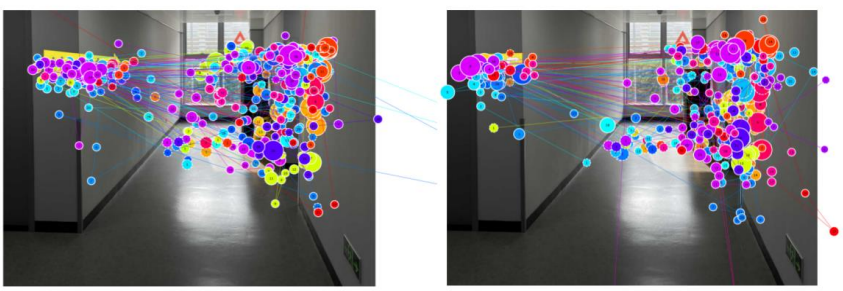
Moreover, the difference in the Time to Fixation Duration to the target intersection was more prominent for the Guide signs 1 and 2 scene maps (Guide signs 1: 1.10 ± 1.13 s, Guide signs 2: 1.73 ± 1.81 s). The results based on the trajectory maps analysis showed that for the two maps, the visual trajectories of the paper folding Guide signs scene map were mostly focused on the Guide signs and the target intersection, while the trajectory diagram of the universal guiding scene map is relatively diffused (Figure 12. and Figure 13.). This indicates that the advantage of the paper folding guide is preferred when wayfinding scenarios are complex, for example, up and down floors, and intersections. However, the difference between Guide sign 3 and Guide sign 4 is smaller regarding the Time to Fixation Duration of the target intersection (Guide sign 3: 0.50±0.43 s, Guide sign 4: 0.57±0.81 s). However, the results of the trajectory maps (Figure 14. and Figure 15.) suggest that the visual trajectories of the paper folding and universal guide signs are similar between guide sign 3 and guide sign 4. This indicates that although the directionality of the paper folding guide is more vital than that of the universal guide, the advantage is not that obvious in simple indoor wayfinding scenarios.

Figure 14: Track chart of Guide 3 scene.



Paper folding guide sign 3 track chart General guide sign 3 track chart

Figure 15: Track chart of Guide 4 scene.



Paper folding guide sign 4 track chart General guide sign 4 track chart

Universal guide signs use two-dimensional arrows to guide the direction of a location in three-dimensional space, therefore, has weak directionality. In contrast, paper folding guidance provides arrows with the possibility to guide any three-dimensional direction by turning, which greatly improves the directionality of guidance signs. Its advantage is more prominent in the scenes of up and down floors, as well as the multiple intersections. During the wayfinding process, the explicit directional signs enable users to quickly find the direction to their destinations, at the same time, they can reduce their thinking time and improve the efficiency and emotional experience of wayfinding.

Limitations

This study explored the affective experience of the users during the interactive wayfinding. We simply collected and analyzed their visual behaviour and did not take into account the impact from other perceptions (i.e., tactile and/or auditory). In this sense, it is necessary to consider the influences of efficacy and emotional experience of users by various perceptions in wayfinding interactions. Additionally, due to the limitation of the eye-movement tracking device used in this study, the user's wayfinding process in the natural environment cannot be fully restored. Therefore, shortcomings remain in the control of variables and the restoration of real situations. In future research, mobile eye-movement tracking devices could be used to analyze the user's visual behaviour in the natural wayfinding environment and further explore the user's emotional experience of wayfinding. Moreover, the sample size of the current study was small due to COVID-19. Although we have obtained some significant findings, more participants are needed to can make the research results more convincing.

Conclusions

This study has proposed innovative design ideas and design elements in the Chinese context from the perspective of users. The results showed that the paper folding style enhance the pleasure of Chinese users when viewing the icon and attracted more attention to the structural features of the planarity and fold. Thus, the design is realistic according to the symbols of the location, in the sense that it can lead to a better visual effect, improve the understanding rate of the icons, and reduce the time and cost of the users to interpret the icons. Moreover, adding Chinese paper folding cultural elements of turning into the sign reduces the users' understanding costs and improves the users' positive experience during the wayfinding.

Acknowledgements

We would like to thank all the participants in our study for their time and efforts. This study is partially supported '中國文化元素視閾下的交互式尋路系統研究', a project from Macau University of Science and Technology FRG, grant number FRG-22-037-FA.

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