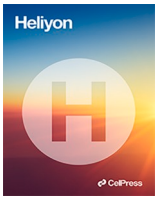
Heliyon 10 (2024) e25003

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon



Research article

Elderly users' perceptions of signage systems from tertiary hospitals in Guangzhou

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ARTICLE INFO

Keywords:
Elderly people
User perception
Hospital
Signage system design
Wayfinding

ABSTRACT

Wayfinding in hospitals today is a significant challenge for urban residents, especially for the elderly. This study investigated the perceptions and attitudes of the elderly toward existing hospital signage systems to identify the wayfinding needs in the healthcare environment. This study collected 762 elderly participants' perceptions and personal preferences regarding 12 features of the existing signage systems in three hospitals in the Yuexiu, Haizhu, and Liwan districts of Guangzhou using a questionnaire methodology. The study further explored the differences in perceptions and preferences for signage based on the gender, age, and educational level of the elderly participants. The findings indicate that most of the elderly participants experienced becoming lost in the hospital; they typically chose to ask others for directions first, followed by using the signage system. Most of the elderly participants had positive attitudes toward the current hospital signage system. Furthermore, they emphasized the importance of the signage system's graphics, texts, colors, and updates, which directly affects the readability and comprehensibility of signs. We found gender differences in perceptions and attitudes toward signage; male participants had more positive attitudes toward the hospital signage systems than female participants. Additionally, consistent with previous findings, the older the age of participants, the less comprehension they had regarding signage graphic symbols. We also found that the more educated elderly participants were, the more understanding of signage they had. At the same time, however, they were less satisfied, which is possibly because the more educated they were, the more aware they were of signage issues.

1. Introduction

Chinese society has entered the status of an aging population. In 2020, the population aged 60 and above in three Guangzhou districts: Yuexiu, Haizhu, and Liwan, exceeded 20 % of the registered population [1]. With an expanding urban population and the use of increasingly large, complex building spaces, such as hospitals and shopping malls, wayfinding is essential for elderly citizens to live and travel [2–6].

As the elderly population grows, the number of older people visiting hospital outpatient clinics increases, especially in large general hospitals [7,8]. Tertiary hospitals are large general public hospitals that provide medical and health services across regions, provinces,

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https://doi.org/10.1016/j.heliyon.2024.e25003
Received 23 July 2023; Received in revised form 16 January 2024; Accepted 18 January 2024
Available online 23 January 2024

and cities as well as to the entire country; they have comprehensive medical, teaching, and research capabilities, and usually have 500 or more inpatient beds [9]. According to the Guangzhou Municipal Health Commission, there are 42 tertiary hospitals in Guangzhou, which totaled 144,251,100 consultations in 2021 [10]. As such, these hospitals' colossal traffic and high utilization rates pose a challenge to the service and management of Guangzhou's healthcare facilities [10].

In addition, wayfinding in hospitals is a challenge that the elderly must face due to the decline of their physical and cognitive abilities [11–13]. As a wayfinding aid, an effective hospital signage system can assist elderly people's navigation process [14,15]. This can reduce their stress and their chances of becoming lost on the premises. When hospital signage is not designed to meet the perceptions of the elderly, it is challenging for them to recognize or familiarize themselves with a building, making it difficult for them to find their way [16–19]. Studies indicate that elderly people are often less efficient at wayfinding and require more time to reach their destination, and more crucially, they are more likely to become lost [20–22].Moreover, disorientation can harm a patient's physiological health by increasing delirium, depression, and the need for painkillers, and, in certain situations, it is time consuming and can cause economic loss [23]. Research suggests that a hospitals lost almost 4500 h and USD 202,000 annually in USA, due to disoriented people asking for directions [24].

While a large number of studies have recommended preliminary suggestions for enhancing user wayfinding efficiency by improving the legibility and comprehensibility of signage systems [15,17,22,25] [–] [31], there are few specific hospital signage design recommendations for the elderly groups [32]. In addition, perceptions and preferences for signage systems are culturally diverse [15,33–38], and no research has been found on the perceptions of hospital signage systems by elderly users in China. Therefore, it is necessary to explore hospital signage systems that meet the needs of the elderly in the Chinese cultural context.

This study aimed to investigate the elderly user's perceptions and usage needs of the signage systems in three tertiary hospitals in Guangzhou and to make suggestions for improving the design of the signage systems. The main results of this study can help to determine the actual situation of the signage systems in these three hospitals in Guangzhou, especially the real perceptions of the signage systems by the elderly users, and we identified the differences in the perceptions of the signage by age, gender, and educational level, which can be used as a basis for similar studies on other healthcare organizations in China. In addition, this study proposed recommendations to improve and optimize the hospital signage systems from the perspective of the usage needs of elderly users, so that a wider group of users can benefit and thus the healthcare service experience can be improved.

2. Literature review

Generally, a signage system is a method of providing wayfinding information. According to the American Institute of Graphic Arts (AIGA) [39], the definition of signage system design is a visual design that provides identification, guidance, explanation, warning, and other functions through a combination of words, patterns, and colors. Studies indicate that signage has a considerable impact on wayfinding behavior; both software (words, graphics, arrows, or color combinations) and hardware (material, form, or size) elements are used to render precise, concrete explanations during wayfinding [19,39–42].

Hospital signage systems are regarded as critical information for wayfinding success. The signage design of hospital outpatient clinics helps guide attendees to their destinations to receive medical services [43,44]. Previous studies have emphasized the importance of a hospital's signage system, particularly in hospital outpatient areas with the highest concentration of hospital traffic [21,39,43,45–48]. Additionally, the outpatient environment is unfamiliar and complex to patients, which often causes wayfinding challenges, which reflects the quality of the "wayfinding design" of an outpatient space [21,49]. While analyzing hospital wayfinding, Carpman found that wayfinding issues can cause confusion, annoyance, rage, stress, high blood pressure, headaches, and exhaustion [2,22]. Therefore, hospital signage system design is critical for visitors to receive essential services swiftly and without experiencing obstacles within hospital settings [15,50,51].

As the population of elderly people increases, it becomes even more vital to consider their requirements when designing signage systems. Typically, hospital spatial features are identical and challenging to distinguish, especially for elderly people [52]. Therefore, it is crucial to help the elderly navigate hospitals through an effective signage system [21,47,53,54]. Moreover, due to visual impairments, cognitive declination, and reduced physical mobility, wayfinding concerns pose significant challenges for the elderly [3–5,55]. According to the literature, aging is linked to reduced cognitive function, which may lead to increased navigational errors; older adults gain lesser spatial information while navigating [2,56,57] and perform slower spatial tasks [6].

For elderly people, however, visual decline may be a barrier to reading signage, which can be avoided by following effective design techniques [11,38,58]. However, losses in visual performance among older persons can also be linked to cognition. Research suggests that visual decline in elderly people is caused by decreased selective attention, focusing on specific information while overlooking others [2,59–61]. When searching for items described by a single feature, older people perform comparably to younger people but exhibit a disproportionate decrease in performance when searching for objects defined by a combination of several elements [2,62,63]. Therefore, due to the decline of all physical functions, older people are more likely to be disoriented than younger people; their wayfinding performance is typically poorer, particularly in hospitals, subways, airports, and other large complex public spaces. In addition to age differences, studies indicate that other basic demographic information, such as gender and educational background, will also affect people's perception and understanding of signage [33,64–66]. Furthermore, cultural differences have also received more attention as they involve the user's processing of wayfinding information [37,38,67].

However, due to complicated structures, consultation flow, and huge crowds, the difficulty of wayfinding in hospitals cannot be overstated. An effective hospital signage system should be easy to perceive and recognize. It is essential to enhance visual perception when visual signals are used in such spaces as a result. Previous research has identified the characteristics and performance of wayfinding for the elderly [11,15,17,18,26,37,53,68], and provided preliminary recommendations and methods for hospital signage

system design. Mollerup argued that the standard approach to solving the problem of wayfinding in hospitals is to improve signage, and proposed the use of an inclusive approach to create signage systems that meet the needs of all populations because helping the less fortunate approach will ultimately help everyone [15]. Jianfeng Wu et al. constructed a methodological framework for hospital wayfinding signage design based on situational cognitive commonalities in terms of signage familiarity and concreteness to enhance the comprehensibility of signage symbols for elderly users [32]. However, the above studies paid little attention to the influence of user factors on cognitive commonality because different age groups and characteristics of elderly people may have different cognitive patterns. In contrast, Ido Morag et al. emphasized the centrality and uniqueness of the user by creating an inclusive questionnaire for hospital settings to assess the wayfinding problems faced by hospital users [69]. This study focused on exploring users' experiences and perceptions of wayfinding in hospitals, summarizing users' use and perceptions of signage and wayfinding information during the wayfinding process. Laura Bezerra Martins and Ann Sloan Devlin, also emphasized user factors [36,51]. However, Laura Bezerra Martins et al. argued that to effectively operate a hospital wayfinding information system, in addition to considering user characteristics, it is important to go beyond the graphic system and work with other disciplines beyond the scope of signage, such as the

Categories	Characteristics	Sources
Basic visual elements	The graphic or symbol design of the signage is moderate in size The graphic or symbol design of the signage is easy to understand The text design of the signage is clear and moderate in size The text design of the sigange is recognizable The color design of the signage is appropriate and eye-catching	Elbardawil (2022); Rodrigues et al. (2019; Hassan Iftikhar et al.; Zineddin et al.); Sakai and Inui (2001); Ng and Chan (2007);Vigolo et al. (2020); Zhang et al. (2022)
Installation and Maintenance	The number of signage is sufficient The installation position of the signage is suitable The material used for the signage is suitable The signage can be regularly maintained and updated	Rodrigues et al. (2019); Martins and Melo (2014); Calori and Vanden-Eynden (2015b)
Layout and design style	The signage design style is uniform Signage can be easily seen in the environment The space layout on the signage is clear	Zhang et al. (2022); Calori and Vanden-Eynden (2015b); Rodrigues et al. (2019) Dubey et al. (2021)
Personal preferences	Tilting my head to read hanging signs or signs on the wall is easy for me The less colorful the signage, the better it helps me find my way The cooler color signage makes me feel more comfortable When graphics and text are together in the signage, I will look at the graphics first Image-based signage helps me a lot in wayfinding The existing signage design can meet my needs	Hsieh(2017)

Fig. 1. 12 Design features of the signage systems.

physical characteristics of the environment as well as the circulatory system [51]. Ann Sloan Devlin similarly emphasizes the healthcare environment from the perspective of environmental psychology, including program configuration and inventory cues, and the role of technology [36].

In general, signage design is an integrated system that encompasses multiple aspects, and differences in graphic systems, architectural spaces, and user cultures can lead to differences in comprehension. Therefore, research related to wayfinding signage should include subjects from different ages, genders, educational levels, and cultural backgrounds with different characteristics to explore age-inclusive signage design guidelines and recommendations, which can improve the ease of use and comprehensibility of signage. As Mollerup states professional wayfinding designers will research the problem before designing a solution, a thorough analysis of the current signage system is a natural starting point for any improvements [15].

Based on the existing literature, the present study defines three types of design elements for signage systems: (1) basic visual elements, (2) installation and maintenance, and (3) layout and design style. These elements have 12 corresponding design features and six indicators corresponding to personal preferences for hospital signage systems, as shown in Fig. 1.

This study used a questionnaire to perform the following three objectives: (1) To assess the perceptions and personal preferences of the elderly participants on the existing signage systems in three hospitals in Guangzhou; (2) To determine whether differences based on age, gender, and educational level affect perceptions and personal preferences of hospital signage systems; (3) To recommend a hospital signage system design that meets the needs of the elderly.

3. Method

This study collected the perceptions of the elderly regarding the signage systems in three tertiary hospitals in Guangzhou using a questionnaire. Questionnaires were administered from October to December 2022. Each respondent received 20 RMB. Three administrative districts of Guangzhou (Yuexiu, Haizhu, and Liwan) were selected to distribute the questionnaire, and one tertiary hospital was selected in each administrative district. The three hospital sample locations were named Sample A, B, and C, respectively.

3.1. Participants

The questionnaire was randomly distributed to the patients, family members, companions, and general visitors over 65 years old in the hospital outpatient lobby. According to the rough estimation method proposed by Bentler and Chou [70], the sample size should be determined by the number of variables used, which is 5–10 times the number of questionnaire scale entries; the sample size can be expanded by 20 % by considering the number of invalid samples. The study questionnaire included 18 scale entries. Considering that the sampling error becomes smaller with a larger sample size, a total of 1200 questionnaires were distributed in the three hospitals, and 762 valid samples were obtained. The final valid sample sizes for this study met the statistical sample size requirements of McQuitty [71].

Informed consent was obtained from participants before questionnaire distribution to ensure confidentiality and voluntary participation prior to participation. For privacy reasons, the questionnaire did not collect personally identifiable data, such as name, address, or date of birth. Additionally, all participants were informed that they may withdraw from the study without any queries or negative consequences. All participants' identities and personal details were kept confidential. Only the researcher and supervisor could access the original data and recorded information.

3.2. The hospitals

Yuexiu District, Haizhu District, and Liwan District, which comprise the older urban areas of Guangzhou, all have a resident elderly population of more than 20 %. Therefore, this study's questionnaire was conducted in three randomly selected tertiary hospitals in these three districts. By reviewing the official websites and statistics of the three hospitals, we selected large general hospitals with long histories and high levels of expertise and quality regarding medical services. Among them, Hospital C was the earliest established hospital, which had the most significant number of departments and beds and the largest potential elderly population in the region, followed by Hospital A and Hospital B. Table 1 shows the details of the three hospitals and the elderly population obtained from official statistics [1].

Table 1
The details of the three tertiary hospitals.

Code	Name of Hospital	District	Year of Establishment	No. of Departments	No. of Beds	No. of elderly people served
A	The Third Affiliated Hospital of Guangzhou University of Chinese Medicine	Li wan District	1985	26	1506	223,100
B	The Second Affiliated Hospital of Guangzhou Medical University	Hai zhu District	1982	59	2500	284,500
C	Guangdong Province Traditional Chinese Medical Hospital	Yue xiu District	1933	73	3524	314,300

3.3. Measures

The questionnaire comprised three parts: (1) demographic characteristics, (2) the participants' perceptions of the hospital signage system categories, including "basic visual elements," "installation and maintenance," "layout and design style," and (3) participants' personal preferences for the hospital signage systems. The literature on related topics was consulted to develop the questionnaire content [72–75], as shown in Fig. 1. The questionnaire was scored using a 5-point Likert scale ("1 = strongly disagree," "2 = disagree," "3 = neither agree nor disagree," "4 = agree," "5 = strongly agree,"). A pretest with 30 elderly visitors was conducted in Hospital A to optimize the questionnaire before formal distribution. Hospital A received 350 questionnaires and 283 valid questionnaires were returned, with a recovery rate of 70.8 %. Hospital B received 340 questionnaires, and 247 valid questionnaires were returned, with a recovery rate of 61.8 %. Hospital C received 310 questionnaires, and 232 valid questionnaires were returned, with a recovery rate of 58 %. Across all three hospitals, a total of 762 valid questionnaires were obtained, with a total recovery rate of 63.5 %.

3.4. Statistical analysis

Data collected for this study were analyzed using SPSS 25, with a statistical significance level of $P < .05$. We used three different analyses to examine the data gathered for this investigation. First, reliability and validity analyses were used to examine the internal consistency of the factors and the validity of the questionnaire structure. Second, descriptive statistical analysis was used to examine the frequency of hospital visits, ways of finding their way around the hospital, becoming lost in the hospital, perceptions and opinions of the existing hospital signage system, personal preferences, and overall satisfaction with the hospital signage system among older participants of different genders (female, male), ages (65–70, 71–74, 75 and above), and educational levels (primary school, junior school, senior high school, college, undergraduate, graduate and above). A third analysis involved a series of t-tests to assess how participants' perceptions of the hospital signage system and other performance elements changed with age. Finally, data from the three hospitals were pooled to comprehensively assess whether there was a correlation between participants' age and educational level and their perceptions of different attributes of the hospital signage system. We used Pearson correlation analysis to examine the relationship between hospital signage system characteristics and participant performance.

3.5. Reliability and validity testing

This study tested the reliability and validity of the questionnaire for elderly users' perceptions of the three hospital signage systems using SPSS 25 software. The details are presented in Table 2. Specifically, Hospital A had a Cronbach's alpha value of 0.762 and a KMO value of 0.841, with Bartlett's spherical test reaching significant levels ($p < .001$). Hospital B had a Cronbach's alpha value of 0.817 and a KMO value of 0.875, with Bartlett's spherical test reaching significant levels ($p < .001$). Hospital C had a Cronbach's α value of 0.838 and a KMO value of 0.847, with Bartlett's spherical test reaching significant levels ($p < .001$). The mean value of Cronbach's α value for the three hospitals was 0.806, and the mean value of KMO was 0.854, with KMO values greater than 0.8. This indicates that the questionnaire data had good reliability and validity and were suitable for subsequent analysis.

4. Results

4.1. Participant demographic characteristics

Table 3 shows the demographic characteristics of the respondents, including gender, age, and educational level. The statistical results indicate that most respondents were male, including 139 males and 93 females in Hospital A. There were 151 males and 96 females in Hospital B and 170 males and 113 females in Hospital C. Additionally, the age of the respondents in the three hospitals was between 65 and 70, and 70–75 years old. The educational level of the respondents was primarily junior high and high school. However,

Table 2
The reliability and validity of the questionnaire.

Item			Value
Hospital A	Cronbach's α value		.762
Hospital B			.817
Hospital C			.838
All hospitals			.806
Hospital A	KMO sampling suitability measure		.841
	Bartlett sphere test	Approximate chi-square	2062.916
		Sig.	.000
Hospital B	KMO sampling suitability measure		.875
	Bartlett sphere test	Approximate chi-square	1617.289
		Sig.	.000
Hospital C	KMO sampling suitability measure		.847
	Bartlett sphere test	Approximate chi-square	2387.061
		Sig.	.000
All hospitals	KMO sampling suitability measure		.854

Table 3
Demographic characteristics of the participants.

Type		Hospital A		Hospital B		Hospital C	
		N	%	N	%	N	%
Gender	Male	139	59.9	151	61.1	170	60.1
	Female	93	40.1	96	38.9	113	39.9
Age	65–70	131	56.5	99	40.1	153	54.1
	71–75	86	37.1	29	48.2	96	33.9
	>75	15	6.5	119	11.7	34	12.0
Educational level	Primary school	11	4.7	6	2.4	30	10.6
	Junior school	42	18.1	87	35.2	50	17.7
	Senior high school	102	44.0	75	30.4	131	46.3
	College	57	24.6	63	25.5	40	14.1
	Undergraduate	15	6.5	12	4.9	25	8.8
	Graduate and above	5	2.2	4	1.6	7	2.5
Total		232	100	247	100	283	100

there was also a significant number of people with a college education in Hospitals A and B, accounting for 24.6 % and 25.5 % of the total respondents, respectively. Most respondents were not visiting the hospital for the first time. Specifically, 143 from Hospital A were not first-time visitors, and 89 were first-time visitors. In Hospital B, 179 respondents were not first-time visitors, and 68 were first-time visitors. In Hospital C, 155 were not first-time visitors and 128 were. Most respondents had the experience of becoming lost in the particular study hospital. Particularly, 128 respondents (55.2 %) became lost in Hospital A; 190 respondents (76.9 %) in Hospital B, and 220 respondents (77.7 %) in Hospital C had become lost.

Table 4 shows the results of the respondents' ranking of the reasons for becoming lost in the three study hospitals. The reasons for becoming lost were primarily focused on the following: "Consultation process is complicated," "Hospital environment structure is too complex," and "The signage is difficult to identify." In Hospital A, the top reason for becoming lost was cited as "Hospital environment structure is too complex," with a mean score of 3.22, which was followed by "The signage is difficult to identify," with a mean score of 3.10. Regarding Hospital B, the top reason for becoming lost was cited as "Consultation process is complicated," with a mean score of 2.80, which was followed by "The signage is difficult to identify," with a mean score of 2.11. Similar to Hospital B, in Hospital C, the top reason for becoming lost was "Consultation process is complicated," with a mean score of 3.59. The second reason was "The signage is difficult to identify," with a mean score of 2.88.

Table 5 shows the ranking results of the wayfinding methods used by the respondents in the three hospitals. Most respondents adopted the wayfinding method of "Asking others for directions." In Hospital A, "Asking others for directions" ranked first, with a mean score of 2.95, which was followed by "Paper Maps," with a mean score of 2.45. In Hospital B, the top method respondents used to find directions was "Asking others for directions," with a mean score of 3.28, which was followed by "Signage system," with a mean score of 2.79. In Hospital C, the top method to find directions was the "Signage system," with a mean score of 3.04, which was followed by "Asking others for directions," with a mean score of 3.03.

4.2. Elderly people's perceptions of existing hospital signage systems

Table 6 and Fig. 2 shows the percentage and number of participants rating each hospital on the 12 indicators and the total score, mean, and standard deviation of the 12 indicators. Table 6 and Fig. 2 demonstrates the highest overall ratings of the three hospitals were Hospital B, then followed by Hospital C and Hospital A. The mean scores of all 12 indicators for the three hospitals were above 3.5, which indicates that respondents rated these indicators more positively, as shown in Table 6. Specifically, Hospital A's mean range was 3.50–3.98. The indicators with the highest mean scores were "The number of signage updated sufficiently(3.98)," "The graphic or symbol design of the signage is moderate in size(3.88)," and "Signage can be easily seen in the environment(3.79)." Indicators with the lowest scores were "The signage can be regularly maintained and updated(3.50)," "The installation position of the signage is suitable (3.54)," and "The graphic or symbol design of the signage is easy to understand(3.58)." Hospital B's mean range was 3.15–3.96, and the indicators with the highest mean scores were "The space layout on the signage is clear(3.96)," "The number of signage is sufficient (3.96)," and "Signage can be easily seen in the environment(3.84)." The lowest scoring indicators were "The graphic or symbol design of the signage is moderate in size(3.15)," "The graphic or symbol design of the signage is easy to understand(3.32)," and "The

Table 4
Participants ranked the reasons for becoming lost in the hospital.

Item	Hospital A			Hospital B			Hospital C		
	Total	M	SD	Total	M	SD	Total	M	SD
The consultation process is complicated.	554	2.38	.840	693	2.80	.593	1017	3.59	.871
The signage is difficult to identify.	720	3.10	.594	523	2.11	.673	816	2.88	.633
The hospital environment structure is too complex.	748	3.22	1.053	328	1.32	.827	591	2.08	.649
Too many people in the hospital.	298	1.28	.681	309	1.25	.585	406	1.43	.882

Table 5
Participant hospital wayfinding ranking results.

Item	Hospital A			Hospital B			Hospital C		
	Total	M	SD	Total	M	SD	Total	M	SD
Asking others for directions	686	2.95	1.208	812	3.28	1176	859	3.03	1.211
Signage system	525	2.26	.973	690	2.79	.705	863	3.04	.783
Mobile App navigation	539	2.32	.990	545	2.20	.797	657	2.32	.713
Paper Maps	570	2.45	1.153	423	1.71	1.041	450	1.59	.997

Table 6
Mean and standard deviation of different characteristics of the three hospital signage systems.

Characteristics	Hospital A			Hospital B			Hospital C		
	Total	M	SD	Total	M	SD	Total	M	SD
The graphic or symbol design of the signage is moderate in size.	900	**3.88**	.990	777	3.15	1.153	1031	3.64	1.153
The graphic or symbol design of the signage is easy to understand.	831	3.58	.972	819	3.32	.918	1027	3.63	.986
The text design of the signage is clear and moderate in size.	874	3.77	.688	930	3.77	.728	1016	3.59	.777
The text design of the signage is recognizable.	880	3.78	.703	932	3.77	.719	1004	3.55	.982
The color design of the signage is appropriate and eye-catching.	848	3.66	.908	940	3.81	.756	1017	3.59	.979
The number of signage is sufficient.	924	**3.98**	.727	977	**3.96**	.750	1116	**3.94**	.770
The installation position of the signage is suitable.	822	3.54	.925	923	3.74	.686	1066	3.77	.675
The material used for the signage is suitable.	874	3.77	.713	932	3.77	.696	1021	3.61	.820
The signage can be regularly maintained and updated.	813	3.50	.958	937	3.79	.688	988	3.49	.965
The signage design style is uniform.	840	3.62	.834	937	3.79	.723	1087	**3.84**	.694
Signage can be easily seen in the environment.	880	**3.79**	.715	949	**3.84**	.724	1083	3.83	.740
The space layout on the signage is clear.	930	3.52	.738	978	**3.96**	.742	1124	**3.97**	.757

installation position of the signage is suitable(3.74).” Hospital C’s mean range was 3.49–3.97, and the indicators with the highest mean scores were “The space layout on the signage is clear(3.97),” “The number of signage is sufficient(3.94),” and “The signage design style is uniform(3.84).” The lowest scoring indicators were “The signage can be regularly maintained and updated(3.49),” “The text design of the signage is recognizable(3.32),” “The text design of the signage is clear and moderate in size(3.49),” and “The color design of the signage is appropriate and eye-catching(3.59).”

4.3. Personal preferences for hospital signage systems among the elderly

Table 7 shows the personal preferences of the elderly respondents regarding the hospital signage systems. The highest mean scores for both Hospitals A and C were “Image-based signage helps me a lot in wayfinding,” with 3.25 and 3.42, respectively. Hospital B had the highest mean score of “The less colorful the signage, the better it helps me find my way” (3.36). Based on the mean scores, “Tilting my head to read hanging signs or signs on the wall is easy for me” received the lowest score among the three hospital participants, with the three hospitals scoring (Hospitals A 2.93, Hospitals B 2.94, and Hospitals C 2.90). These findings suggest that the elderly respondents attached more importance to the graphic symbols and color elements of the signage system. Furthermore, it was challenging for elderly users to look up at the hanging signs, so their physical and mental preferences were low in this regard. Concerning satisfaction with existing signage, the average value of all three hospitals was around 3, which is considered the middle level.

Table 6 and Fig. 2 indicate that the highest overall score was in Hospital B. Hospital A was rated between 1 and 3(Likert 5-point scale)more frequently than Hospitals B and C. These negative ratings may be due to the fact that although Hospital A was established later (1985) than Hospitals B (1982) and C (1933), its signage system has not been updated promptly, and in particular, it occupies more low scores in terms of the signage location, the level of standardization, the legibility and the layout design compared to that of Hospital B and Hospital C. Therefore, it is not able to satisfy the user’s needs for wayfinding in this hospital.

4.4. Age differences in perceived signage system and personal preferences

To further examine the correlation between the 12 indicators and age, we conducted a Pearson correlation analysis to explore whether the perceptions and physical and mental preferences of participants from different age groups toward the existing hospital signage system were significantly correlated. Tables 9 and 10 show the results of the Pearson correlation analysis. Specifically, regarding the participants’ perceptions of the existing hospital signage system: “The graphic or symbol design of the signage is moderate in size” ($r = -0.399$, $p < .001$); “The graphic or symbol design of the signage is easy to understand” ($r = -0.427$, $p < .001$); and “The color design of the signage is appropriate and eye-catching” ($r = -0.192$, $p < .001$). These three variables showed a significant negative correlation with age, while the rest of the variables indicated no significant correlation with age. Regarding the participants’ personal preference for hospital signage systems: “The cooler colors signage makes me feel more comfortable” ($r = -0.255$, $p < .001$) and “When graphics and text are together in the signage, I will look at the graphics first” ($r = -0.405$, $p < .001$) showed a significant negative correlation with age. The remaining variables were not significantly correlated.

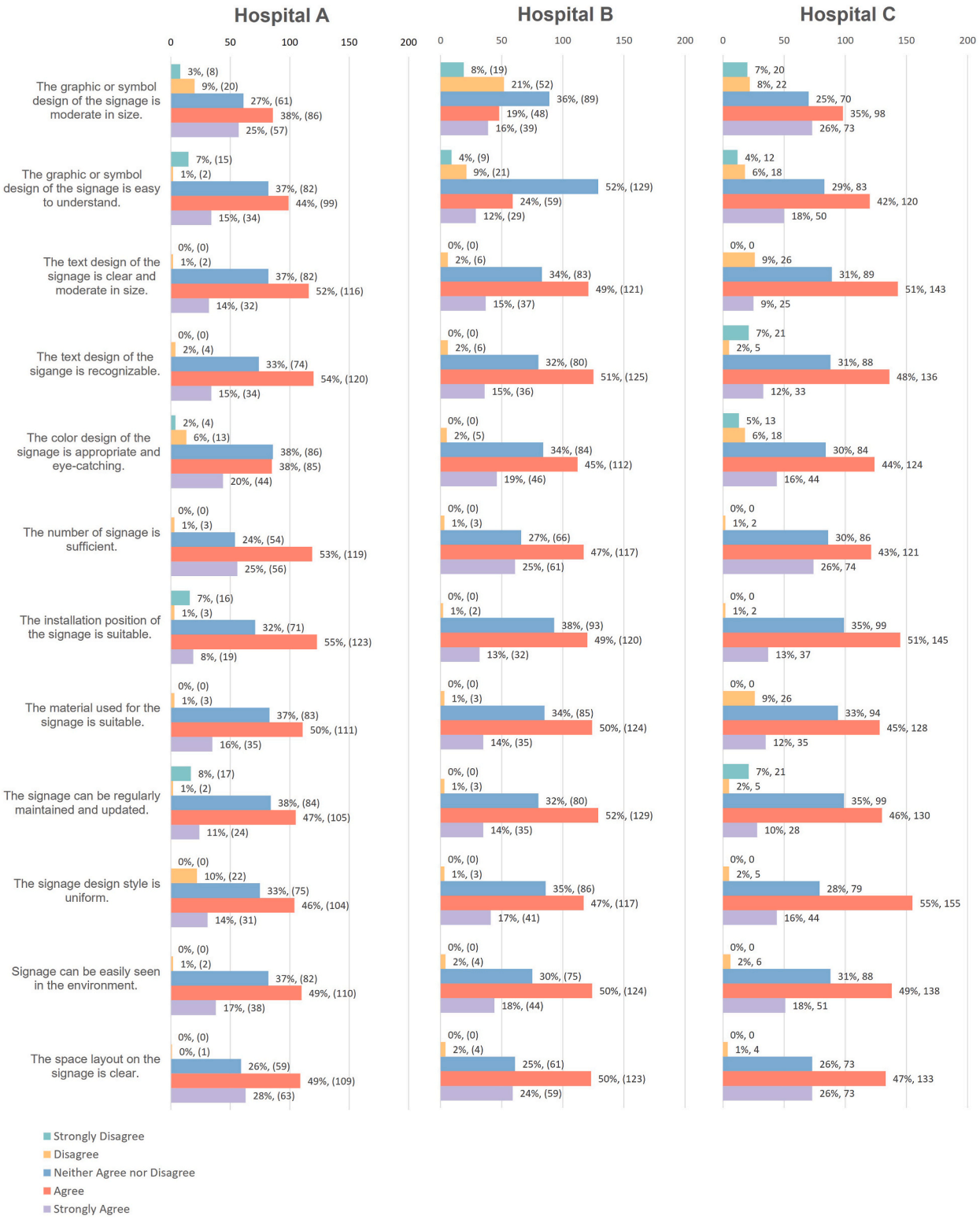

Fig. 2. Evaluations of the 12 signage characteristics made by the respondents of each hospital under study.

Table 7
Means and standard deviations of personal preferences for hospital signage systems among the elderly.

Characteristics	Hospital A			Hospital B			Hospital C		
	Total	M	SD	Total	M	SD	Total	M	SD
Tilting my head to read hanging signs or signs on the wall is easy for me.	680	**2.93**	.951	725	**2.94**	.943	822	**2.90**	.965
The less colorful the signage, the better it helps me find my way.	713	**3.07**	.832	829	**3.36**	.808	856	**3.02**	.920
The cooler color signage makes me feel more comfortable.	743	**3.20**	.851	753	**3.05**	.795	861	**3.14**	.866
When graphics and text are together in the signage, I will look at the graphics first.	714	**3.08**	.864	640	**2.99**	.987	857	**3.03**	.850
Image-based signage helps me a lot in wayfinding.	755	**3.25**	.702	795	**3.22**	.716	912	**3.42**	.774
The existing signage design can meet my needs.	689	**2.97**	.813	749	**3.03**	.932	836	**2.95**	.888

Table 8
Gender differences in perceived signage characteristics and personal preferences.

	Levene's Test for Equality of Variances			*t*-test for Equality of Means					95 % Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
The graphic or symbol design of the signage is easy to understand.	Equal variances assumed	1.962	0.162	2.892	761	0.004	0.206	0.071	0.066	0.346
	Equal variances not assumed			2.921	668.250	0.004	0.206	0.071	0.068	0.345
The text design of the signage is clear and moderate in size.	Equal variances assumed	0.005	0.941	2.012	761	0.045	0.110	0.055	0.003	0.217
	Equal variances not assumed			2.029	664.515	0.043	0.110	0.054	0.004	0.216
The text design of the signage is recognizable.	Equal variances assumed	0.006	0.940	2.496	761	0.013	0.153	0.061	0.033	0.273
	Equal variances not assumed			2.516	663.719	0.012	0.153	0.061	0.034	0.272
The color design of the signage is appropriate and eye-catching.	Equal variances assumed	4.110	0.043	3.379	761	0.001	0.222	0.066	0.093	0.351
	Equal variances not assumed			3.332	615.652	0.001	0.222	0.067	0.091	0.352
The signage design style is uniform.	Equal variances assumed	1.953	0.163	3.921	761	0.000	0.216	0.055	0.108	0.325
	Equal variances not assumed			3.958	666.881	0.000	0.216	0.055	0.109	0.324
Signage can be easily seen in the environment.	Equal variances assumed	0.193	0.660	3.281	761	0.001	0.175	0.053	0.070	0.280
	Equal variances not assumed			3.308	664.476	0.001	0.175	0.053	0.071	0.279
When graphics and text are together in the signage, I will look at the graphics first.	Equal variances assumed	0.120	0.729	−2.018	761	0.044	−0.138	0.068	−0.272	−0.004
	Equal variances not assumed			−2.005	632.695	0.045	−0.138	0.069	−0.273	−0.003
Tilting my head to read hanging signs or signs on the wall is easy for me.	Equal variances assumed	0.604	0.437	−2.274	761	0.023	−0.123	0.054	−0.230	−0.017
	Equal variances not assumed			−2.318	687.068	0.021	−0.123	0.053	−0.228	−0.019

Table 9
Correlation between age and perception of the hospital signage system.

	Age	1	2	3	4	5	6	7	8	9	10	11	12
Age	1	**−.399****	**−.427****	0.015	0.024	**−.192****	0.033	0.064	0.002	0.029	0.042	0.002	−0.034
1. The graphic or symbol design of the signage is moderate in size.	−.399**	1											
2. The graphic or symbol design of the signage is easy to understand.	−.427**	.553**	1										
3. The text design of the signage is clear and moderate in size.	0.015	.182**	.236**	1									
4. The text design of the signage is recognizable.	0.024	.141**	.167**	.590**	1								
5. The color design of the signage is appropriate and eye-catching.	−.192**	.428**	.517**	.302**	.241**	1							
6. The number of signage is sufficient.	0.033	.189**	.262**	.286**	.261**	.247**	1						
7. The installation position of the signage is suitable.	0.064	.103**	.159**	.225**	.193**	.192**	.231**	1					
8. The material used for the signage is suitable.	0.002	.173**	.215**	.533**	.591**	.300**	.303**	.186**	1				
9. The signage can be regularly maintained and updated.	0.029	−0.010	0.070	.462**	.520**	.108**	.154**	.428**	.433**	1			
10. The signage design style is uniform.	0.042	.196**	.211**	.341**	.260**	.293**	.303**	.579**	.307**	.416**	1		
11. Signage can be easily seen in the environment.	0.002	.336**	.395**	.387**	.274**	.430**	.368**	.300**	.388**	.176**	.394**	1	
12. The space layout on the signage is clear.	−0.034	.285**	.272**	.302**	.284**	.261**	.529**	.217**	.306**	.124**	.317**	.399**	1

Table 10
Correlation between age and personal preferences of the hospital signage system.

	Age	1	2	3	4	5	6
Age	1	0.035	−0.032	**−.255****	**−.405****	0.045	0.045
1. Tilting my head to read hanging signs or signs on the wall is easy for me.	0.035	1					
2. The less colorful the signage, the better it helps me find my way.	−0.032	.548**	1				
3. The cooler colors signage makes me feel more comfortable.	−.255**	.548**	.453**	1			
4. When graphics and text are together in the signage, I will look at the graphics first.	−.405**	.423**	.349**	.501**	1		
5. Image-based signage helps me a lot in wayfinding.	0.045	.634**	.467**	.425**	.321**	1	
6. The existing signage design can meet my needs.	0.045	.409**	.272**	.317**	.258**	.369**	1
**. Correlation is significant at the 0.01 level (2-tailed).							

4.5. Gender differences in perceiving the signage system and personal preferences

This study conducted an independent samples *t*-test to explore differences in perceptions of the hospital signage system between elderly male and female respondents. There were 762 elderly participants, males ($n = 460$) and females ($n = 302$) from the three hospitals. Table 8 presents the statistical results of the independent samples *t*-test. The results indicate significant differences between male and female elderly participants regarding six indicators of the perceptions of the hospital signage systems: "The graphic or symbol design of the signage is easy to understand" (male: $M = 3.60$ $SD = 0.982$; female: $M = 3.39$ $SD = 0.935$), $t(761) = 2.892$, $p < .05$, 95 % CI [0.066 ; 0.346]. This indicates that the male respondents found hospital signage easier to understand compared to females. "The text design of the signage is clear and moderate in size" (male: $M = 3.60$ $SD = 0.982$; female: $M = 3.39$ $SD = 0.935$), $t(761) = 2.892$, $p < .05$, 95 % CI [0.003 ; 0.217]. This indicates that the male respondents found the size and clarity of hospital signage text appropriate compared to females. "The text design of the signage is recognizable" (male: $M = 3.76$ $SD = 0.839$; female: $M = 3.60$ $SD = 0.807$), $t(761) = 2.496$, $p < .05$, 95 % CI [0.033 ; 0.273]; "The color design of the signage is appropriate and eye-catching" (male: $M = 3.77$ $SD = 0.863$; female: $M = 3.55$ $SD = 0.922$), $t(761) = 3.379$, $p < .05$, 95 % CI [0.093 ; 0.351]; "Signage can be easily seen in the environment" (male: $M = 3.89$ $SD = 0.733$; female: $M = 3.72$ $SD = 0.704$), $t(761) = 3.281$, $p < .05$, 95 % CI [0.070 ; 0.280]; "The signage design style is uniform" (male: $M = 3.84$ $SD = 0.759$; female: $M = 3.63$ $SD = 0.725$), $t(761) = 3.921$, $p < .05$, 95 % CI [0.108 ; 0.325]; and "When graphics and text are together in the signage, I will look at the graphics first" (male: $M = 2.85$ $SD = 0.912$; female: $M = 2.98$ $SD = 0.940$), $t(761) = -2.018$, $p < .05$, 95 % CI [0.272; 0.004]. These findings indicate that female seniors were more likely to look at the graphics of the signage rather than the textual information compared to male seniors. There were no significant gender differences in the remaining indicators.

4.6. Educational level differences in perceived signage system and personal preferences

We conducted a Pearson correlation analysis to explore whether the perceptions of participants with differing levels of education on the existing hospital signage system and their physical and mental preferences for the signage system were significantly correlated. Tables 11 and 12 present the Pearson correlation analysis results. Specifically, in terms of participants' perceptions of the existing hospital signage system: "The text design of the signage is clear and moderate in size" ($r = -0.072$, $p < .005$); "The color design of the signage is appropriate and eye-catching" ($r = -0.110$, $p < .001$); and "The signage can be regularly maintained and updated" ($r = -0.203$, $p < .001$) showed a significant negative correlation with the participants' educational level. "The number of signage is sufficient" ($r = 0.364$, $p < .001$) and "The space layout on the signage is clear" ($r = 0.301$, $p < .001$) were significantly positively correlated with the participant's educational level and the remaining indicators were significantly correlated with the participant's educational level. The rest of the indicators were not significantly correlated with educational level.

Regarding participants' personal preference for the hospital signage systems, "The existing signage design can meet my needs" ($r = -0.327$, $p < .001$) showed a significant negative correlation with participants' educational level. The remaining indicators were not significantly correlated with educational level.

5. Discussion

The main objective of this study was to investigate the perceptions and attitudes of the elderly toward existing hospital signage systems and to further clarify the perceptions and needs of the elderly in the healthcare environment. Results based on perceptions and personal preferences of the elderly on 12 indicators of hospital signage systems indicated that the elderly had positive attitudes towards the three existing hospital signage systems.

5.1. Reasons for elderly people getting lost in hospital

This study's results indicate that most of the elderly patients who participated had experienced becoming lost (unable to find their destination) in the hospital. The main reasons for becoming lost were cited as: "Consultation process is complicated," "Hospital environment structure is too complex," and "The signage is difficult to identify." This result may be attributed to the fact that these three large general hospitals were established earlier and have been expanded as the number of people served is increasing due to the

Table 11
Correlation between educational level and perception of the hospital signage system.

	Educational level	1	2	3	4	5	6	7	8	9	10	11	12
Educational level	1	0.070	0.059	**−.072***	**−.110****	−0.034	**.364****	−0.061	−0.067	**−.203****	−0.020	0.059	**.301****
1. The graphic or symbol design of the signage is moderate in size.	0.070	1											
2. The graphic or symbol design of the signage is easy to understand.	0.059	.553**	1										
3. The text design of the signage is clear and moderate in size.	−.072*	.182**	.236**	1									
4. The text design of the signage is recognizable.	−.110**	.141**	.167**	.590**	1								
5. The color design of the signage is appropriate and eye-catching.	−0.034	.428**	.517**	.302**	.241**	1							
6. The number of signage is sufficient.	.364**	.189**	.262**	.286**	.261**	.247**	1						
7. The installation position of the signage is suitable.	−0.061	.103**	.159**	.225**	.193**	.192**	.231**	1					
8. The material used for the signage is suitable.	−0.067	.173**	.215**	.533**	.591**	.300**	.303**	.186**	1				
9. The signage can be regularly maintained and updated.	−.203**	−0.010	0.070	.462**	.520**	.108**	.154**	.428**	.433**	1			
10. The signage design style is uniform.	−0.020	.196**	.211**	.341**	.260**	.293**	.303**	.579**	.307**	.416**	1		
11. Signage can be easily seen in the environment.	0.059	.336**	.395**	.387**	.274**	.430**	.368**	.300**	.388**	.176**	.394**	1	
12. The space layout on the signage is clear.	.301**	.285**	.272**	.302**	.284**	.261**	.529**	.217**	.306**	.124**	.317**	.399**	1

*. Correlation is significant at the 0.05 level (2-tailed).**. Correlation is significant at the 0.01 level (2-tailed).

Table 12
Correlation between educational level and personal preferences of the hospital signage system.

	Educational level	1	2	3	4	5	6
Educational level	1	0.027	−0.010	−0.007	−0.009	−0.012	−.327**
1. Tilting my head to read hanging signs or signs on the wall is easy for me.	0.027	1					
2. The less colorful the signage, the better it helps me find my way.	−0.010	.548**	1				
3. The cooler colors signage makes me feel more comfortable.	−0.007	.548**	.453**	1			
4. When graphics and text are together in the signage, I will look at the graphics first.	−0.009	.423**	.349**	.501**	1		
5. Image-based signage helps me a lot in wayfinding.	−0.012	.634**	.467**	.425**	.321**	1	
6. The existing signage design can meet my needs.	−.327**	.409**	.272**	.317**	.258**	.369**	1

**. Correlation is significant at the 0.01 level (2-tailed).

urban population explosion [12,44,76]. Existing hospitals therefore possess characteristics such as larger spaces, more complex building structures, and untimely updating of signage systems [77].

5.2. Wayfinding methods for the elderly in hospitals

The most used method of wayfinding among the respondents in Hospital A and Hospital B was "asking others for directions", however, in Hospital C, it was "signage system" followed by "asking others for directions". The main reason for this result may be that the existing signage system in Hospital C is more satisfying in terms of quantity, installation location, degree of standardization, ease of visibility, and layout design, and therefore more people choose the signage system for wayfinding. Of course, this difference in preference could also be caused by the internal environment of the hospital, the flow of the visit, and differences in the sampling of older participants, so a larger sample and more rational sampling techniques are needed to provide more insights in future studies [38].

In general, the results of this study showed that most of the older adults found their way by asking for directions and signage systems, which is consistent with previous findings [20,75,78]. This finding suggests that asking others for leadership is not unique to China but is a universal method of wayfinding. However, while it is often considered to be more efficient and faster, it has a hidden cost to hospitals [78]. Therefore, on the one hand, the utilization rate of the signage can be increased by improving its recognizability and comprehensibility, and on the other hand, the frequency of users asking for directions verbally can be reduced, which in turn reduces the economic costs for both users and hospitals.

5.3. Signage design features that are easily perceived by the elderly

Elderly users in all three hospitals rated the text, graphic symbols, and color design elements of the signage poorly, especially in Hospital C. Comparing the results of older users' perception of the signage design features of the three hospitals, we found some commonalities. The first is the age-related difference in perception. The present study's findings indicated that the older the participants were, the more worse they perceived the signage's text size, graphic symbols and the color, which may be related to vision loss and physiological memory deterioration common in senior populations [79]. Furthermore, the older participants were more inclined to find their way by preferentially looking at the textual information of the signage rather than the graphics. However, previous findings indicate that icons with graphic symbols as design elements are easier to recognize and understand than single textual messages since images are more universally recognizable than text because graphics contain fewer barriers than verbal text [80,81]. This can help avoid problems associated with inadequate reading skills or language unfamiliarity [82–84]. However, for the elderly, comprehension of signage graphic symbols can worsen with age [17,19,60], and the satisfaction with the signage is reduced [19]. This may be due to age-related changes in selective attention, inhibition efficiency, and the ability to form new associations [17,25]. Moreover, familiarity with graphic symbols affects users' comprehension [28], and signage medical symbols are typically composed of graphic symbols that lack familiarity [37], which will be more challenging to remember and understand for elderly people. Regarding signage color, older participants preferred a high-saturation, warm, and eye-catching signage color scheme, possibly due to weakened color perception caused by declining visual perception [85].

Table 6 and Fig. 2 demonstrated the users' satisfaction with the signage of the three hospitals, with the lowest ratings were "The graphic or symbol design of the signage is easy to understand," "The graphic or symbol design of the signage is moderate in size," "The color design of the signage is appropriate and eye-catching," and "The signage can be regularly maintained and updated." Of course, in addition to these common characteristics, there are also variations from hospital to hospital. For example, the scores for "The installation position of the signage is suitable," and "The space layout on the signage is clear," were also very low in Hospital A, while the opposite was true for Hospital C. It is also worth noting that in Hospital C, "The text design of the signage is clear and moderate in size," and "The text design of the signage is recognizable," also scored relatively low. These findings suggest that respondents placed the highest importance on the graphics, colors, texts, layout design, installation position and updates of the signage system. These indicators directly affect the legibility and comprehensibility of the signage. Therefore, these areas must be improved in the existing hospitals.

5.4. Gender differences in perceptions of signage systems

Regarding the variability in the perceived aspects of the hospital signage systems between the elderly male and female participants, there were significant differences in the following: the comprehensibility of the signage's graphics, the clarity of the text, whether the signage's colors were eye-catching, the effectiveness of the English text messages, the overall design and whether it was in harmony with its surroundings. There were no significant differences in the remaining indicators. Overall, the male respondents had more positive attitudes and overall satisfaction than females. Regarding personal preference for signage systems, female seniors preferred to view the signage graphics over textual information, with no significant gender differences in the remaining indicators. These gender differences may be due to other factors, such as participant differences in other factors, such as visual knowledge, experience levels, and cultural backgrounds in understanding signage and, therefore, differing levels of comprehension [37,38,86]. However, previous studies indicate that males and females differed in visual perception and visual preference and that females may be more sensitive to color than males; thus, females may outperform males in color perception in visual tasks, and females also tend to have the ability to perceive speed, i.e., the ability to compare pictures quickly and accurately [87,88]. This may explain the lower ratings of text, graphics, and color of hospital signage by female users in this study. Given this gender difference, further research is needed to investigate the effects of participants' knowledge, experience level, and cultural background on visual perception and preference.

5.5. Differences in perceptions of signage systems by educational level

Regarding the perceptions and personal preferences of participants with different levels of education regarding the existing hospital signage systems, as expected, the higher educated participants perceived the signage to help them easily find their way compared to the less educated participants. The higher educated participants understood the graphic symbolic information of the signage more accurately [37]. However, at the same time, the higher educated participants were less satisfied with the existing signage than the less educated participants. For example, participants generally felt that the textual information on the current signs was not clear enough, the colors of the signs were not eye-catching, and the maintenance and updating of the signs were lacking. This does not mean that less educated people encountered fewer challenges, but perhaps more highly educated people are more aware of the problems with signage, and therefore they demand higher quality [78].

5.6. Recommendations for hospital signage system design

As mentioned above, the color, text format, symbols or pictograms, layout design, installation location, and maintenance and updating of hospital signage are the most important design factors to the users. Numerous studies have shown that text, graphic symbols, and color factors directly affect the readability and comprehensibility of signage [15,17,25–28]. However, differences in perceptions of and preferences for signage are not only age-dependent but also include gender and level of education. Some studies have shown that cultural factors are the key to the differences in users' perceptions of signage [15,33–38]. Therefore, how to meet the needs and habits of different groups of older persons of different genders and educational backgrounds within the same signage system is an important issue that needs attention. Based on the results of this study, improvement strategies are proposed from the needs of the target group through several aspects of signage, including text, graphics, and color to enhance and improve the signage system in the context of Chinese culture.

In the case of signage text, studies have shown that the recognizability of different fonts of the same size at different distances is significantly different, with non-serifed fonts being more suitable for long-distance viewing than serifed fonts [75,78]. Text alignment, font type, font size, layout, and grouping all affect the way users interpret information [16,75,89]. In the hospital space, a large amount of signage needs to be viewed from a distance. Therefore, for elderly people, it is necessary to use larger, bold, non-serifed fonts (e.g., Arial, Helvetica, and Frutiger in English) for the main message of the signage, and for Chinese fonts we recommend FZHeiTi and Microsoft Yahei, while serifed fonts represented by SimSun and KaiTi are not recommended. In the context of this study, improving the accuracy and comprehensibility of medical terminology on signage is a key to improving the accuracy and comprehensibility of medical terminology on signage, especially when signage graphics are difficult to comprehend, as less educated and female populations are less inclined to use signage text for wayfinding. Therefore, we recommend using text alongside graphics as well as enhancing the layout and consistency of signage messages to help improve visual attention [15,16,90].

The results of this study indicated that older, less educated, and female elderly users perceived and understood the graphic symbols to a lesser extent. Therefore, upgrading hospital signage systems requires the development of generic graphic symbols that are easily recognizable. Studies have shown that familiar, figurative graphic symbols are more accurate and easier to recognize and understand than unfamiliar, abstract graphic symbols because more details that users recognize and perceive are included in familiar, concrete symbols [26,32,84,91,92]. Several studies have emphasized that anthropomorphic symbols or pictogram symbols are more likely to increase familiarity as well as ease of recognition especially for older and less educated populations, because these symbols have the shape and appearance of real-world objects [32,93–95]. Secondly, the design of universal healthcare symbols is the future direction of signage design [35,36,96–98]. The design of universal healthcare symbols is particularly important as hospitals are places that serve all people, including different cultures, ages, genders, and education levels. We recommend that hospital management and designers conduct symbol comprehensibility testing and training among a broader population when developing signage systems to improve user comprehension and future utilization [99,100].

Another design factor that must be enhanced is the color of the signage. Due to visual degradation, the contrast of signage colors is critical to attract attention and differentiate messages. This study showed that the green signage in Hospitals B and C was preferred by

the elderly, and the brown color in Hospital A was not considered to be eye-catching enough. Based on the results of this study, we recommend that signage be made in highly saturated, eye-catching colors that are preferred by the elderly [74,95] [–] [97]. In the context of Chinese culture, black, white, grey, or bright red are often rarely used in public space signage systems; from a color psychology perspective black, white, and grey are high in contrast but lack affinity, while bright red is mostly used in celebratory scenes to highlight a warm atmosphere [101,102]. In terms of the overall color scheme, the colors of all signage should be uniform to identify sectors and industries and to emphasize information through color [85,103,104].

Overall, the above design elements are used throughout the design and implementation of a signage system, whether creating a new signage system or updating an existing one. Good pre-planning for signage will save maintenance costs for an organization in the long run [75]. To better understand the needs of target users, methods such as user testing and participatory design during the pre-planning phase can also help reduce wayfinding issues after a signage system is implemented [29,73,105]. In addition, hospital management and designers can improve the standardization, comprehensibility, and cultural characteristics of the signage system through signage text, graphics, colors, and layout design during the design and implementation phases. In particular, signage should be maintained and updated after installation. The results of the study showed that the common problem of signage in the three hospitals was the low evaluation of the maintenance and updating of the signage by the users. It is more cost-effective to maintain a signage system than for hospitals to have to replace an entire system due to outdated or degraded existing signage [48,75,78]. Therefore, when hospital administration creating an age-inclusive signage system should consider and analyze the environmental characteristics, cultural factors, and user population, and this should be included from the pre-planning, design and implementation, and post-maintenance and updating of the signage system.

6. Conclusions

This study investigated the perceptions and personal preferences of seniors regarding several features of existing signage systems in three hospitals in Guangzhou using a questionnaire. It further explored the differences in perceptions and preferences for signage based on gender, age, and educational level. To our knowledge, this is the first article published in China to explore the perceptions and attitudes of senior citizens toward existing hospital signage systems. The results of this study can provide reference and insight into the aging-friendly hospital signage system design. These findings may serve as a basis for research on hospital signage systems in other countries or regions.

However, due to time constraints and the questionnaire sample, this study's limitations are as follows. One of the main limitations of this study is the research methodology, which tends to favor traditional empirical research. Empirical research emphasizes that things are measurable and quantifiable [106], but not all issues in wayfinding research can be precise. This can easily lead to the study being formal and not in-depth [106,107]; for example, it is difficult to quantify the data to reveal elderly users' disorientation point in hospital and why they get lost. Additionlly, this study was limited to 762 elderly respondents. This is mainly because older people are less efficient in completing the questionnaire or lack patience when there are too many questions, which may abandon the questionnaire in the middle of the process and reduce the number of valid questionnaires. Some potential respondents were unwilling to complete the questionnaire or to share their experience of finding their way in the hospital due to time constraints or anxiety. In addition, due to time and budget constraints, this study could not include every tertiary hospital in Guangzhou. Therefore, the study results only represent certain elderly people in Guangzhou and some large public general hospitals in Guangzhou, which cannot represent hospitals in other regions and countries. Moreover, although this study provides recommendations for improving the common problems of the signage systems in the three hospitals, there are also individual problems in each hospital, which may be related to the variability of the hospital's environment, building structure, consultation process, and the characteristics of the users themselves. Therefore, we were not able to provide perfect improvement recommendations for each hospital.

The following are suggestions for follow-up of future related studies. To address the limitations of traditional empirical research, more cutting-edge experimental research methods can be considered to improve the precision and interpretability of the research, such as eye-tracking [108–110] and electroencephalography (EEG) analysis tools [104,111,112], the route-tracking experiments, and action research can help to obtain precise and specific feedback from users [99,113]. And considering the study subjects were senior citizens over 65, they were more likely to suffer from visual deterioration and cognitive decline. The comprehensibility of healthcare symbols in signage systems can be tested to further explore differences in comprehension among the elderly due to physiological deterioration [27]. Additionally, the study sample size was limited. More research is required to further validate the results presented in this study. Therefore, the sample size of the elderly population in different regions across more hospitals could be appropriately increased as the study population. In particular, perceptual differences based on users' age, gender, education level, cultural differences, and experiences should be explored in depth in one healthcare setting and targeted recommendations for the improvement of signage in that hospital should be provided. Moreover, future studies can add health literacy and visual acuity tests before the formal questionnaire [37]. However, educational attainment was associated with health literacy, and this relationship is not always reliable [114]. Statistical inaccuracies due to health literacy and vision problems were avoided by assessing the study participants' health literacy and the presence of vision problems.

Data availability statement

The data are not publicly available due to their containing information that could compromise the privacy of research participants. The data that support the findings of this study are available on request from the corresponding author.

Ethics statement

Ethic Review and approval were not needed for this study because according to the regulations on ethical review of Universiti Sains Malaysia, studies involving education, training tests, questionnaires (perceptions, judgments, attitudes, effectiveness), interview surveys, or observation of public behavior may be eligible for exemption from review. In addition, written informed consent was obtained from the participants for the experimental protocol, which did not involve disclosure of participants' privacy, and the data were free from commercial interests and intellectual property rights. Therefore, this study followed the exemption from ethical approval by the Ethics Review Committee of Universiti Sains Malaysia.

CRediT authorship contribution statement

Lujie Deng: Writing – original draft, Visualization, Investigation. **Bolun Zhang:** Project administration, Funding acquisition. **Guangyuan Shi:** Writing – review & editing. **Cheng Zhang:** Investigation, Data curation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e25003.

References

[1] Guangzhou Municipal Bureau of Statistics. Guangzhou Aging Project Development Report and Elderly Population Data Book for 2020, Guangzhou, 2021. Available online: http://wjw.gz.gov.cn/xxgk/shgysyjs/content/post_7987101.html, 2021.
[2] S.J. Bosch, A. Gharaveis, Flying solo: a review of the literature on wayfinding for older adults experiencing visual or cognitive decline, Appl. Ergon. 58 (2017) 327–333, https://doi.org/10.1016/j.apergo.2016.07.010.
[3] L.S. Webber, J.L. Charlton, Wayfinding in older adults, Clin. Gerontol. 23 (2001) 168–172, https://doi.org/10.1300/J018v23n01_16.
[4] L.E.M. Grierson, J. Zelek, H. Carnahan, The application of a tactile way-finding belt to facilitate navigation in older persons, Ageing Int. 34 (2009) 203–215, https://doi.org/10.1007/s12126-009-9039-2.
[5] L. Seunghae, Wayfinding aids for older adults, undefined (2013).
[6] S.M. Wilkniss, M.G. Jones, D.L. Korol, P.E. Gold, C.A. Manning, Age-related differences in an ecologically based study of route learning, Psychol. Aging 12 (1997) 372–375, https://doi.org/10.1037/0882-7974.12.2.372.
[7] S. Barnes, J.M. Torrington, K.P. Lindquist, Does the design of hospitals meet the needs of older people? An evaluation of three acute-care settings, J. Architect. Plann. Res. 33 (2016) 91–104.
[8] P. Ford, J. Fisher, L. Paxman-Clarke, M. Minichiello, Effective wayfinding adaptation in an older National Health Service hospital in the United Kingdom: insights from mobile eye-tracking, Design for Health 4 (2020) 105–121, https://doi.org/10.1080/24735132.2020.1729000.
[9] National Health Commission of the People's Republic of China, Graded Management Standards for General Hospitals (Draft for Trial Implementation), 1989.
[10] Guangzhou Municipal Health Commission. 2020 Guangzhou Health Resources and Medical Services Briefing, 2021. Available online: http://wjw.gz.gov.cn/xxgk/sjtj/content/post_7216921.html.
[11] C. En-I, M.P.b. Bebit, Analysis of the Existing Healthcare Signages for the Elderly in KOTA KINABALU: for Effective Healthcare Signages. GA 11 (2021) 1–20, https://doi.org/10.51200/ga.v11i2.3571.
[12] M. Yang, Research on Wayfinding in Outpatient Department Based on Elderly Going to the Hospital Alone – Taking Typical Policlinic in Dalian as an Example. Master Degree, Dalian University of Technology, Dalian,China, 2019.
[13] Y.b. Zeng, Z.p. Yuan, Y. Fang, A Study on Medical Consultation Behavior of Chinese Elderly and its Influencing Factors, China Health Statistics, 2020, pp. 199–205.
[14] L. Deng, N.H. Romainoor, B. Zhang, Evaluation of the usage requirements of hospital signage systems based on the kano model, Sustainability 15 (2023) 4972, https://doi.org/10.3390/su15064972.
[15] P. Mollerup, Wayshowing in hospital, Australas. Mark. J. (2008) 112, https://doi.org/10.4066/amj.2009.85. –114.
[16] J.B. Rousek, M.S. Hallbeck, Improving and analyzing signage within a healthcare setting, Appl. Ergon. 42 (2011) 771–784, https://doi.org/10.1016/j.apergo.2010.12.004.
[17] P. Schulz, K. Labudda, V. Bertke, S. Bellgardt, S. Boedeker, S. Spannhorst, S.H. Kreisel, M. Driessen, T. Beblo, M. Toepper, Age effects on traffic sign comprehension, IATSS Res. 44 (2020) 103–110, https://doi.org/10.1016/j.iatssr.2019.10.001.
[18] I.J.M. van der Ham, M.H.G. Claessen, How age relates to spatial navigation performance: functional and methodological considerations, Ageing Res. Rev. 58 (2020) 101020, https://doi.org/10.1016/j.arr.2020.101020.
[19] V. Vigolo, A. Bonfanti, R. Sallaku, J. Douglas, The effect of signage and emotions on satisfaction with the servicescape: an empirical investigation in a healthcare service setting, Psychol. Market. 37 (2020) 408–417, https://doi.org/10.1002/mar.21307.
[20] M.S. Chen, Y.T. Ko, W.C. Hsieh, Exploring the planning and configuration of the hospital wayfinding system by space syntax: a case study of cheng ching hospital, chung kang branch in taiwan, IJGI 10 (2021) 570, https://doi.org/10.3390/ijgi10080570.
[21] S.-Y. Tzeng, J.-S. Huang, Spatial forms and signage in wayfinding decision points for hospital outpatient services, J. Asian Architect. Build Eng. 8 (2009) 453–460, https://doi.org/10.3130/jaabe.8.453.
[22] J.R. Carpman, M.A. Grant, D.A. Simmons, Hospital Design and Wayfinding. Environment and Behavior 17 (1985) 296–314, https://doi.org/10.1177/0013916585173002.
[23] A.-B. Nadine, R. Shaher, A.-R. Rama, The psychological supportive design features in hospitals: case of a public Jordanian hospital in amman, undefined (2021).
[24] R. Mora, A. Oats, P. Marziano, Percepción de la señalización y orientación espacial de los usuarios de tres complejos hospitalarios de Santiago, Chile, Rev. Med. Chile 142 (2014) 1291–1296, https://doi.org/10.4067/S0034-98872014001000009.

[25] M.F. Lesch, W.J. Horrey, M.S. Wogalter, W.R. Powell, Age-related differences in warning symbol comprehension and training effectiveness: effects of familiarity, complexity, and comprehensibility, Ergonomics 54 (2011) 879–890, https://doi.org/10.1080/00140139.2011.606924.
[26] Y. Liu, C. Ho, The effects of age on symbol comprehension in central rail hubs in Taiwan, Appl. Ergon. 43 (2012) 1016–1025, https://doi.org/10.1016/j.apergo.2012.02.004.
[27] C.Y. Zou, X.F. Long, Y.Q. Chen, Analysis of Comprehensibility and Influencing Factors of Healthcare Symbols, first ed., Springer, 2019.
[28] T. Ben-Bassat, D. Shinar, J.K. Caird, R.E. Dewar, E. Lehtonen, M. Sinclair, L. Zakowska, S. Simmons, G. Liberman, M. Pronin, Ergonomic design improves cross-cultural road sign comprehension, Transport. Res. F Traffic Psychol. Behav. 78 (2021) 267–279, https://doi.org/10.1016/j.trf.2021.01.015.
[29] B. Hu, Wayfinding for modern healthcare: a participatory approach to designing a wayfinding system in a Chinese Hospital Setting, Des. J. (2023) 1, https://doi.org/10.1080/14606925.2023.2216877. –11.
[30] T. Mustikawati, Y.A. Yatmo, P. Atmodiwirjo, Understanding wayfinding experience of hospital visitor through tours and maps analysis, E-BPJ 2 (2017) 149, https://doi.org/10.21834/e-bpj.v2i6.992.
[31] G. Patel, P. Mukhopadhyay, Ergonomic analysis and design intervention in symbols used in hospitals in central India, Appl. Ergon. 94 (2021) 103410, https://doi.org/10.1016/j.apergo.2021.103410.
[32] J. Wu, X. Liu, C. Lu, S. Yu, D. Jiao, X. Ye, Y. Zhu, A design framework of medical wayfinding signs for the elderly: based on the situational cognitive commonness, Int. J. Environ. Res. Publ. Health 19 (2022) 13885, https://doi.org/10.3390/ijerph192113885.
[33] H. Iftikhar, P. Shah, Y. Luximon, Human wayfinding behaviour and metrics in complex environments: a systematic literature review, Architect. Sci. Rev. 64 (2020) 1–12, https://doi.org/10.1080/00038628.2020.1777386.
[34] J. Liu, H. Wen, D. Zhu, W. Kumfer, Investigation of the contributory factors to the guessability of traffic signs, Int. J. Environ. Res. Publ. Health 16 (2019) 162, https://doi.org/10.3390/ijerph16010162.
[35] C.-W. Joy Lo, H.-W. Yien, I.-P. Chen, How universal are universal symbols? An estimation of cross-cultural adoption of universal healthcare symbols, HERD 9 (2016) 116–134, https://doi.org/10.1177/1937586715616360.
[36] A.S. Devlin, Wayfinding in healthcare facilities: contributions from environmental psychology, Behav. Sci. 4 (2014) 423–436, https://doi.org/10.3390/bs4040423.
[37] M.J. Hashim, M.S.K.M. Alkaabi, S. Bharwani, Interpretation of way-finding healthcare symbols by a multicultural population: navigation signage design for global health, Appl. Ergon. 45 (2014) 503–509, https://doi.org/10.1016/j.apergo.2013.07.002.
[38] Iftikhar Hassan, Salman Asghar, Luximon Yan, A cross-cultural investigation of design and visual preference of signage information from Hong Kong and Pakistan, J. Navig. 74 (2021) 360–378, https://doi.org/10.1017/S0373463320000521.
[39] C. Calori, D. Vanden-Eynden, Signage and Wayfinding Design: A Complete Guide to Creating Environmental Graphic Design Systems, second ed., John Wiley & Sons, Inc, Hoboken, NJ, USA, 2015. ISBN 1119085837.
[40] T. Gärling, A. Böök, E. Lindberg, Spatial orientation and wayfinding in the designed environment: a conceptual analysis and some suggestions for postoccupancy evaluation, J. Architect. Plann. Res. 3 (1986) 55–64.
[41] C.-H. Tang, W.-T. Wu, C.-Y. Lin, Using virtual reality to determine how emergency signs facilitate way-finding, Appl. Ergon. 40 (2009) 722–730, https://doi.org/10.1016/j.apergo.2008.06.009.
[42] R.K. Dubey, T. Thrash, M. Kapadia, C. Hoelscher, V.R. Schinazi, Information theoretic model to simulate agent-signage interaction for wayfinding, Cogn Comput 13 (2021) 189–206, https://doi.org/10.1007/s12559-019-09689-1.
[43] F. Qi, Y. Chen, A pilot study of satisfaction with outpatient spatial environment in a general hospital, in: Proceedings of the 2020 *Annual* Academic Conference of the Architectural Society of China, 2020, p. 133, https://doi.org/10.26914/c.cnkihy.2020.027234. –137.
[44] N.y. Wu, A preliminary study on improving outpatient experience, China Rural Health Care Management 39 (2019) 656–658.
[45] p. Arthur, R. Passini, Wayfinding: People, Signs, and Architecture, 1992.
[46] C. Miller, D. Lewis, Wayfinding in complex healthcare environments, Inf. Des. J. 9 (1998) 129–160, https://doi.org/10.1075/idj.9.2-3.04mil.
[47] J.R. Carpman, M.A. Grant, Design that Cares: Planning Health Facilities for Patients and Visitors, Wiley, 2016. ISBN 9781118221631.
[48] P. Wright, A.J. Hull, A. Lickorish, Navigating in a hospital outpatients' department: the merits of maps and wall signs, J. Architect. Plann. Res. 10 (1993) 76–89.
[49] L. Deng, N.H. Romainoor, Research on evaluation method of wayfinding signs in medical institutions based on mobile network intelligent navigation, Sci. Program. 2022 (2022) 1–8, https://doi.org/10.1155/2022/1089406.
[50] C. Suess, M. Mody, The influence of hospitable design and service on patient responses, Serv. Ind. J. 38 (2018) 127–147, https://doi.org/10.1080/02642069.2017.1385773.
[51] L.B. Martins, H.F.V. de Melo, Wayfinding in hospital: a case study, in: A. Marcus (Ed.), *Design, User Experience, and Usability*, User Experience Design for Everyday Life Applications and Services : Third International Conference, DUXU 2014, Held as Part of HCI International 2014, Heraklion, Crete, Greece, June 22-27, 2014 : Proceedings/Aaron Marcus, Cham, 2014, vols. 72–82, Springer, Cham, 2014. ISBN 978-3-319-07635-5.
[52] R. Wayfinding Passini, A conceptual framework, Urban Ecol. 5 (1981) 17–31, https://doi.org/10.1016/0304-4009(81)90018-8.
[53] D. Head, M. Isom, Age effects on wayfinding and route learning skills, Behav. Brain Res. 209 (2010) 49–58, https://doi.org/10.1016/j.bbr.2010.01.012.
[54] L. Deng, N.H. Romainoor, A bibliometric analysis of published literature on healthcare facilities' wayfinding research from 1974 to 2020, Heliyon 8 (2022) e10723, https://doi.org/10.1016/j.heliyon.2022.e10723.
[55] D. Wolstenholme, Design-led service improvement for older people, Australas. Mark. J. 3 (2010) 465–470, https://doi.org/10.4066/AMJ.2010.377.
[56] R. Cm, F. Aa, R. S, K. Mk, H. A, I. S, Non-intrusive, visual-less wearable haptic stimuli navigational assistance for elderly with dementia 20 (2020) 128–137, https://doi.org/10.37268/mjphm/vol.20/no.Special1/art.699, 1.
[57] D.X. Marquez, R.H. Hunter, M.H. Griffith, L.L. Bryant, S.J. Janicek, A.J. Atherly, Older adult strategies for community wayfinding, J. Appl. Gerontol. : the official journal of the Southern Gerontological Society 36 (2017) 213–233, https://doi.org/10.1177/0733464815581481.
[58] C. Calori, D. Vanden-Eynden, Signage and Wayfinding Design: A Complete Guide to Creating Environmental Graphic Design Systems, second ed., Wiley, Hoboken, NJ, 2015. ISBN 9781118692998.
[59] P.A. Allen, T.A. Weber, D.J. Madden, Adult age differences in attention: filtering or selection? J. Gerontol. 49 (1994) P213–P222, https://doi.org/10.1093/geronj/49.5.p213.
[60] J. Barrash, Age-related decline in route learning ability, Dev. Neuropsychol. 10 (1994) 189–201, https://doi.org/10.1080/87565649409540578.
[61] P.S. Foster, D.G. Webster, Emotional memories: the relationship between age of memory and the corresponding psychophysiological responses, Int. J. Psychophysiol. 41 (2001) 11–18, https://doi.org/10.1016/s0167-8760(00)00163-x.
[62] D.G. Humphrey, A.F. Kramer, Age differences in visual search for feature, conjunction, and triple-conjunction targets, Psychol. Aging 12 (1997) 704–717, https://doi.org/10.1037//0882-7974.12.4.704.
[63] R. Camicioli, M.M. Moore, G. Sexton, D.B. Howieson, J.A. Kaye, Age-related brain changes associated with motor function in healthy older people, J. Am. Geriatr. Soc. 47 (1999) 330–334, https://doi.org/10.1111/j.1532-5415.1999.tb02997.x.
[64] A. Bonfanti, V. Vigolo, J. Douglas, C. Baccarani, Servicescape navigation, TQM 29 (2017) 546–563, https://doi.org/10.1108/TQM-01-2017-0003.
[65] A. Kinnison, R.R. Cottrell, K.A. King, Proper hand-washing techniques in public restrooms: differences in gender, race, signage, and time of day, Am. J. Health Educ. 35 (2004) 86–89, https://doi.org/10.1080/19325037.2004.10603614.
[66] Elisângela Vilar, Francisco Rebelo, Paulo Noriega, Indoor human wayfinding performance using vertical and horizontal signage in virtual reality, Human Factors and Ergonomics in Manufacturing & Service Industries 24 (2014) 601–615, https://doi.org/10.1002/hfm.20503.
[67] B.K. Soh, T.L. Smith-Jackson, Influence of map design, individual differences, and environmental cues on wayfinding performance, Spatial Cognit. Comput. 4 (2004) 137–165, https://doi.org/10.1207/s15427633scc0402_2.
[68] G. Iaria, L. Palermo, G. Committeri, J.J.S. Barton, Age differences in the formation and use of cognitive maps, Behav. Brain Res. 196 (2009) 187–191, https://doi.org/10.1016/j.bbr.2008.08.040.

[69] I. Morag, A. Heylighen, L. Pintelon, Evaluating the inclusivity of hospital wayfinding systems for people with diverse needs and abilities, J. Health Serv. Res. Policy 21 (2016) 243–248.
[70] P.M. Bentler, C.-P. Chou, Practical issues in structural modeling, Socio. Methods Res. 16 (1987) 78–117, https://doi.org/10.1177/0049124187016001004.
[71] S. McQuitty, Statistical power and structural equation models in business research, J. Bus. Res. 57 (2004) 175–183, https://doi.org/10.1016/S0148-2963(01)00301-0.
[72] S. Alrawahi, S.F. Sellgren, S. Altouby, N. Alwahaibi, M. Brommels, The application of Herzberg's two-factor theory of motivation to job satisfaction in clinical laboratories in Omani hospitals, Heliyon 6 (2020) e04829, https://doi.org/10.1016/j.heliyon.2020.e04829.
[73] G. Sandra, T. Anna-Lena, B. Daniella, Faustino, T. Bruce, A Framework for Evaluating Wayfinding Systems, Communication and Place, 2018.
[74] E. Bosman, C. Rusinek, Creating the user-friendly library by evaluating patron perception of signage, RSR: Ref. Serv. Rev. 25 (1997) 71–82.
[75] R. Rodrigues, R. Coelho, J.M.R.S. Tavares, Healthcare signage design: a review on recommendations for effective signing systems, HERD 12 (2019) 45–65, https://doi.org/10.1177/1937586718814822.
[76] W.F. Zhang, Research on the Design of Public Space of Large General Hospital from the Perspective of Wayfinding. Master's Thesis, Beijing University of Architecture, Beijing, 2019.
[77] Y. Zhang, Research on the Design of Graphic Symbols for Medical Public Information. Master Degree, Nanjing Normal University, Nanjing, China, 2019.
[78] R. Rodrigues, R. Coelho, J.M.R.S. Tavares, Users' perceptions of signage systems at three Portuguese hospitals, HERD 13 (2020) 36–53, https://doi.org/10.1177/1937586720924761.
[79] A.C. McLaughlin, C.B. Mayhorn, Designing effective risk communications for older adults, Saf. Sci. 61 (2014) 59–65, https://doi.org/10.1016/j.ssci.2012.05.002.
[80] D.W. Christopher, H. Justin G, B. Simon, P. Raja, Engineering Psychology and Human Performance, fourth ed., Psychology Press, New York, 2013. ISBN 9781315665177.
[81] S. Blankenberger, K. Hahn, Effects of icon design on human-computer interaction, Int. J. Man Mach. Stud. 35 (1991) 363–377, https://doi.org/10.1016/S0020-7373(05)80133-6.
[82] M.S. Wogalter, R.J. Sojourner, J.W. Brelsford, Comprehension and retention of safety pictorials, Ergonomics 40 (1997) 531–542, https://doi.org/10.1080/001401397188017.
[83] S. Wiedenbeck, The use of icons and labels in an end user application program: an empirical study of learning and retention, Behav. Inf. Technol. 18 (1999) 68–82, https://doi.org/10.1080/014492999119129.
[84] C.-F. Chi, R.S. Dewi, Matching performance of vehicle icons in graphical and textual formats, Appl. Ergon. 45 (2014) 904–916, https://doi.org/10.1016/j.apergo.2013.11.009.
[85] M. Kinateder, W.H. Warren, K.B. Schloss, What color are emergency exit signs? Egress behavior differs from verbal report, Appl. Ergon. 75 (2019) 155–160, https://doi.org/10.1016/j.apergo.2018.08.010.
[86] D.R. Boyd, Creating signs for multicultural patrons, Acquisit. Libr. 5 (1993) 61–66, https://doi.org/10.1300/J101v05n09_07.
[87] S. Trisnawati, A.B. Sriwarno, Visual perception of the depiction of human figures in pictorial signage of public toilets, Cogent Arts & Humanities 5 (2018) 1553325, https://doi.org/10.1080/23311983.2018.1553325.
[88] B. Hultén, Sensory Marketing: Theoretical and Empirical Grounds, Routledge, London, 2017. ISBN 9781317427858.
[89] Ministry of Health, NSW. *Wayfinding For Healthcare Facilities*, Guidelines for wayfinding, 2014. Standard No. GL2014018.
[90] A.Z. Zineddin, P.M. Garvey, R.A. Carlson, M.T. Pietrucha, Effects of practice on font legibility, Proc. Hum. Factors Ergon. Soc. Annu. Meet. 47 (2003) 1717–1720, https://doi.org/10.1177/154193120304701326.
[91] Y.T. Prasetyo, R.S. Dewi, N.M. Balatbat, M.L.B. Antonio, T. Chuenyindee, Perwira Redi, Anak Agung Ngurah, M.N. Young, J.F.T. Diaz, Y.B. Kurata, The evaluation of preference and perceived quality of health communication icons associated with COVID-19 prevention measures, Healthcare 9 (2021) 1115, https://doi.org/10.3390/healthcare9091115.
[92] S.J. McDougall, M.B. Curry, O. de Bruijn, Measuring symbol and icon characteristics: norms for concreteness, complexity, meaningfulness, familiarity, and semantic distance for 239 symbols, Behav. Res. Methods Instrum. Comput. 31 (1999) 487–519, https://doi.org/10.3758/BF03200730.
[93] A. Daryanto, N. Alexander, G. Kartika, The anthropomorphic brand logo and its effect on perceived functional performance, J. Brand Manag. 29 (2022) 287–300, https://doi.org/10.1057/s41262-022-00271-z.
[94] Y. Cao, Y. Zhang, Y. Ding, V.G. Duffy, X. Zhang, Is an anthropomorphic app icon more attractive? Evidence from neuroergonomomics, Appl. Ergon. 97 (2021) 103545, https://doi.org/10.1016/j.apergo.2021.103545.
[95] A.W.Y. Ng, A.H.S. Chan, V.W.S. Ho, Comprehension by older people of medication information with or without supplementary pharmaceutical pictograms, Appl. Ergon. 58 (2017) 167–175, https://doi.org/10.1016/j.apergo.2016.06.005.
[96] S. Lee, S.S. Dazkir, H.S. Paik, A. Coskun, Comprehensibility of universal healthcare symbols for wayfinding in healthcare facilities, Appl. Ergon. 45 (2014) 878–885, https://doi.org/10.1016/j.apergo.2013.11.003.
[97] E.I. Mosca, E. Steinfeld, S. Capolongo, Universal Design assessment tool to promote well-being and inclusion in healthcare environment, Eur. J. Publ. Health 30 (2020), https://doi.org/10.1093/eurpub/ckaa165.589.
[98] R.L. Mace, Universal design in housing, Assist. Technol. 10 (1998) 21–28, https://doi.org/10.1080/10400435.1998.10131957.
[99] Y.-K. Ou, Y.-C. Liu, Effects of sign design features and training on comprehension of traffic signs in Taiwanese and Vietnamese user groups, Int. J. Ind. Ergon. 42 (2012) 1–7, https://doi.org/10.1016/j.ergon.2011.08.009.
[100] Z. Shen, L. Zhang, X. Xiao, R. Li, R. Liang, Icon familiarity affects the performance of complex cognitive tasks, i-Perception 11 (2020) 2041669520910167, https://doi.org/10.1177/2041669520910167.
[101] M. Saito, A comparative study of color preferences in Japan, China and Indonesia, with emphasis on the preference for white, Percept. Mot. Skills 83 (1996) 115–128, https://doi.org/10.2466/pms.1996.83.1.115.
[102] Amitava Chattopadhyay, Gerald J. Gorn, Darke Peter, Differences and Similarities in Hue Preferences between Chinese and Caucasians. Sensory Marketing, Routledge, 2011, pp. 219–239.
[103] F. McLachlan, X. Leng, Colour here, there, and in-between—placemaking and wayfinding in mental health environments, Color Res. Appl. 46 (2021) 125–139, https://doi.org/10.1002/col.22570.
[104] S. Kalantari, V. Tripathi, J. Kan, J.D. Rounds, A. Mostafavi, R. Snell, J.G. Cruz-Garza, Evaluating the impacts of color, graphics, and architectural features on wayfinding in healthcare settings using EEG data and virtual response testing, J. Environ. Psychol. 79 (2022) 101744, https://doi.org/10.1016/j.jenvp.2021.101744.
[105] S. Elbardawil, Legibility research of highway signage typefaces: a critical review and a potential design-centred approach, Des. J. 25 (2022) 86–103, https://doi.org/10.1080/14606925.2021.2004716.
[106] P. Velte, M. Stawinoga, Integrated reporting: the current state of empirical research, limitations and future research implications, J Manag Control 28 (2017) 275–320, https://doi.org/10.1007/s00187-016-0235-4.
[107] P. Hallinger, Leadership for learning: lessons from 40 years of empirical research, J. Educ. Adm. 49 (2011) 125–142, https://doi.org/10.1108/09578231111116699.
[108] M. Fu, R. Liu, Q. Liu, How individuals sense environments during indoor emergency wayfinding: an eye-tracking investigation, J. Build. Eng. 79 (2023) 107854, https://doi.org/10.1016/j.jobe.2023.107854.
[109] P. Ford, J. Fisher, L. Paxman-Clarke, M. Minichiello, Effective wayfinding adaptation in an older National Health Service hospital in the United Kingdom: insights from mobile eye-tracking, Design for Health 4 (2020) 105–121, https://doi.org/10.1080/24735132.2020.1729000.
[110] R. Davis, A. Sikorskii, Eye tracking analysis of visual cues during wayfinding in early stage alzheimer's disease, Dement. Geriatr. Cogn. Disord 49 (2020) 91–97, https://doi.org/10.1159/000506859.

[111] B. Zhu, J.G. Cruz-Garza, Q. Yang, M. Shoaran, S. Kalantari, Identifying uncertainty states during wayfinding in indoor environments: an EEG classification study, Adv. Eng. Inf. 54 (2022) 101718, https://doi.org/10.1016/j.aei.2022.101718.
[112] S. Kalantari, V. Tripathi, J.D. Rounds, A. Mostafavi, R. Snell, J.G. Cruz-Garza, Evaluating wayfinding designs in healthcare settings through EEG data and virtual response testing, bioRxiv (2021), https://doi.org/10.1101/2021.02.10.430638, 2021.02.10.430638.
[113] E. Koletsis, C.P.J.M. van Elzakker, M.-J. Kraak, W. Cartwright, C. Arrowsmith, K. Field, An investigation into challenges experienced when route planning, navigating and wayfinding, International Journal of Cartography 3 (2017) 4–18, https://doi.org/10.1080/23729333.2017.1300996.
[114] K. Sørensen, S. van den Broucke, J. Fullam, G. Doyle, J. Pelikan, Z. Slonska, H. Brand, Health literacy and public health: a systematic review and integration of definitions and models, BMC Publ. Health 12 (2012) 80, https://doi.org/10.1186/1471-2458-12-80.