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Colour configuration of residential interior spaces preferred by the older people in Jinan City

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Abstract: ‘Ageing in place’ has emerged as the predominant form of ageing in Jinan. The colour configuration of residential spaces is often considered the most crucial determinant affecting the psychological well-being of older people. This paper takes the city of Jinan in China as an example. Data about the preference for colour configuration of the older people were collected by image simulation method and questionnaire survey. Statistical methods were used to analyse the data. Findings reveal the following. The brightness of both the side interface and primary colour was significantly positively correlated with the preference of older people. The warm hue dominated the hue preference of the primary colour, and the background colour was under the influence of the primary colour. These study findings supplement the theoretical discourse surrounding the colour configuration of age-friendly spaces and establish a practical benchmark for the design of colour configurations in ageing-friendly spaces.

Keywords: colour configuration; emotional preference; ageing-friendly; residential space.

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Feng Wang is a scholar specialising in design. He earned his PhD in Design from Silpakorn University in Thailand, with a focus on spatial design. Before that, he obtained his Master’s in Architecture from Shandong Jianzhu University, providing a strong foundation for his academic and professional development. He has achieved significant success in academic research, publishing numerous articles in international journals indexed by SCI, EI, and Scopus. Many of these articles have been included in renowned databases and have received considerable citations. His primary research interests include age-friendly spatial design and regional spatial design.

Xiangyun Wang holds a Master’s degree in Art Design from Krirk University and is currently pursuing his PhD at University of Technology MARA. His research focuses on age-friendly public space design, aiming to create accessible and functional environments for elderly populations. He is currently a faculty member at Shandong Youth University of Political Science, where he applies his expertise to educate and inspire future designers.

Yichen Qi holds a PhD from Silpakorn University and Master’s degree from Shandong University of Art and Design. She specialises in visual communication design, focusing on innovative design strategies and their role in effective communication. She has published several papers in her field, contributing to design theory and practice. She is currently a faculty member at Shandong Youth University of Political Science, where she shares her expertise to inspire and educate future designers.

Fankai Nie holds a PhD in Design from Silpakorn University and is currently a faculty member at City College of Huizhou. His primary research focus is regional design, and he has carried out numerous design practices in this area, receiving positive social feedback for his work. His contributions have been well-received in the field, reflecting the practical impact and relevance of his research.

1 Introduction

Colour is called the first ‘vision’ of humans (Cheng and Tan, 2018). Colour possesses the ability to elicit emotional responses and psychological states, as well as create an emotional environment (Güneş and Olguntürk, 2020). In the field of environmental psychology, the impact of colour configurations on individuals’ emotions and behaviours has long been a significant research topic (Fernández-Portero et al., 2017; Lawton, 1985). The colour configuration of a spatial environment is closely related to the psychological

needs of its users, particularly in the elderly population, where this relationship is even more pronounced (Peace, 2022). By optimising environmental factors, it is possible to stimulate individuals' intrinsic psychological drives, thus meeting their emotional needs (Windley and Scheidt, 2015). Particularly when the environment aligns with an individual's emotional needs, it can generate positive psychological effects, thereby enhancing quality of life (Zhou et al., 2021). Within this theoretical framework, Environmental Gerontology research suggests that elderly individuals, due to physiological and psychological changes, often face unique spatial needs (Wang et al., 2024). Professor Laura L. Carstensen (2021), a psychologist and proponent of the socioemotional selectivity theory, observes that older adults do not follow a simple decline as they age. Instead, their emotional needs tend to remain stable or even increase over time (Carstensen, 2007; Jacobsen, 2019), a phenomenon often referred to as the 'paradox of ageing' (Carstensen, 2007). Therefore, older individuals are more likely to seek environmental factors that provide emotional fulfilment, making colour configuration in spatial design a key element influencing their emotional and psychological well-being.

The study of colour configuration has been a long and complicated process. Grassmann's seminal work, the Law of Colour, identified three fundamental characteristics of colour, namely, brightness, chroma, and hue (Grassmann, 1,854). In 1,898, A. Munsell introduced the Munsell colour system, a quantitative method for calibrating colours founded upon and defined digitally by these three attributes: brightness (abbreviated as V), hue (abbreviated as H), and chroma (abbreviated as C) (Munsell and Nickerson, 1915). The three variables labelled by this system are evenly distributed, which is in line with image thinking and visual laws, and scholars have begun conducting a broader range of colour configuration studies using this system (Tang, 2021). Currently, the colour configuration research has mainly focused on colour harmony (Chevreul, 2023) and colour preference (Wilms and Oberfeld, 2018). In particular, colour harmony relates to people's satisfaction with two or more juxtaposed colours, whereas colour preference focuses on the study of colour tendency of specific groups of people with similar backgrounds. From the perspective of socioemotional selectivity theory, colour configurations often serve as stimuli that trigger individuals' emotional responses (Carstensen, 2021). In interactions, individuals seek to gain rewards. When the applied colour configuration aligns with the user's psychological needs, the user experiences positive psychological effects during this interaction (Wang et al., 2024; Zhang et al., 2024). Regarding the research on colour harmony, scholars found that the number of colours and their average saturation value are some of the critical factors affecting the colour harmony of an image (Sagawa and Shimizu, 1996). A high negative correlation exists between the mean value of chromaticity on the image and the visual comfort of the observer (Sagawa, 1999). Meanwhile, several scholars have studied colour preference. For example, Jean-Philippe Lenclos, a famous French colourist, first proposed the concept of colour geography based on many practical investigations. He pointed out that distinct geographical environments all significantly influence human races, nationalities, customs, cultures, and emotional preferences (Lenclos, 2019). Subsequent studies have further illustrated that age (Beke et al., 2008; Dittmar, 2001), sex (Hurlbert and Ling, 2007), cognition (Kato et al., 2006), and geographic environment (Jeon et al., 2020) often lead to similar colour preferences across human individuals.

1.1 Research on the colour configuration of space

A well-designed colour configuration can enhance the user's emotional comfort, thereby positively influencing their mental health (Zhou et al., 2021). The formation of this psychological effect can be explained through the 'environment-behaviour relationship' model in environmental psychology, which suggests that visual elements in the spatial environment directly impact an individual's emotional responses and behavioural performance (Nakhodaezadeh et al., 2017). A large number of inclusions in a space result in a considerable number and variety of colours. Scholars usually categorised each colour composition element within a space and study it holistically (Portillo, 2009). The most common classification is to divide the elements of the colour composition of the space into primary, background, and accent colours. Among them, the primary colour of a given space is commonly denoted by the dominant skin colour of the furniture within that space. The background colour is typically indicated by the colours of the top, side, and bottom interfaces of the space. Meanwhile, the accent colour refers to the skin colour of the decorative furnishings in the space that occupies a smaller area. Academic research has indicated that a wider perception of width is associated with a decrease in the intensity of the chroma at the bottom interfaces of a room (Divers, 2021). Most Chinese older houses are mostly collective houses; the indoor space of such type is comparatively small, and the older group finds a sense of spaciousness more appealing. Other scholars have found that attaining colour harmony in a spatial environment is facilitated by lower average chromaticity and higher brightness of individual colour components (Shen et al., 1996). They found that the older people's eyes are often accompanied by pupil shrinkage, increased corneal thickness, the crystal losing its luster, gradual weakening of the retina's light perception, and gradual hardening of the crystal body with pigmentation and other distinctive characteristics. This results in a notable decline in the visual acuity of the older people in dimly lit environments when compared to younger individuals. Simultaneously, their sensitivity is insufficient to observe objects with low contrast, particularly smaller ones, and their field of view is also somewhat restricted (Rooth, 2017). Hence, in colour configuration of age-friendly spaces, one must consider the expressive, more extensive area of the space background colour and the primary colour of these two types of colour composition elements. Typically, older individuals cannot perceive the background of the top interface (ceiling), which has a negligible impact on the spatial colour environment. This region exhibits the most intense brightness of white. This colour scheme can indirectly improve the environment's brightness by maximising the diffuse reflection effect at the space's apex. Simultaneously, one must try to improve the contrast between the primary and background colours; the primary colour of the space should be a medium to medium-high, whereas the background colour should be of a lower hue. Such an indoor colour setting makes the whole indoor space subject prominent, while also reducing chromatic contrast and creating a relatively subdued atmosphere. This is further consistent with the hypothesis of Sagawa (1999, 2000; Sagawa and Shimizu, 1996), who posited a highly negative correlation between the mean value of chroma and visual comfort.

Concerning the age-friendly residential void, the aforementioned research results focus primarily on the chromaticity characteristics of the body and background colours of the colour configuration space. A low chroma is suggested for the background, whereas medium and medium-high chroma values are suggested for the body. Therefore, this study conducts a colour configuration study of age-friendly spaces concerning the

remaining brightness and hue attributes of the background and body colours of age-friendly spaces. Both of these colour characteristics can have an equally substantial impact on the level of satisfaction that older individuals have with the colour scheme of a given space. Among the three attributes of colour, brightness serves as the foundation for every colour application (Žurek et al., 2023). Harmony of brightness is more likely to elicit a pleasant emotional response from the observer (Malik-Moraleda et al., 2022). The psychological preferences of users are affected by numerous factors, including the brightness of a single interface, the brightness contrast between multiple interfaces, and the overall brightness of the space. However, to what extent and which interfaces influence preference requires additional research via experimentation and observation (Malik-Moraleda et al., 2022). Meanwhile, the hue is the most significant characteristic of colour, and current research on the colour preference mainly refers to the study of hue preference (Beke et al., 2008; Dittmar, 2001; Saito, 1996). The older people living in Jinan City probably have similar hue preferences.

In summary, a quantitative analysis of spatial colours according to the Munsell colour system is presented in this paper. This was combined with prior research conducted by specific authors on the chromaticity properties of spatial colours. Finally, this study explores the factors influencing the luminance modulation of age-friendly spaces in Jinan City and the preference for colour hues of older people for each interior component.

2 Method

2.1 Materials and procedures

Test samples were produced for a colour configuration study. The experiment was conducted in a completely dark laboratory with a standard monitor (DELL SP2208WFP) to ensure colour consistency. For this study, the living room space was selected as the test sample, as it represents a traditional Chinese house and encompasses a variety of functions and constituent elements. As shown in Figure 1, preliminary household research and interviews were conducted, and images of the living room were collected. These images were then used to construct a database of original images of various interior components of the older residents' living rooms. The original images in the database were subsequently analysed and preprocessed to categorise. We focus on generalising and categorising the two components of body colour and background colour in the living room of a family of older people's homes.

This study consists of four distinct stages. The initial stage entails examining the brightness harmony of age-friendly spaces in Jinan. Subsequently, the second stage investigates the hue preference of older individuals in Jinan for the primary colour. In the final two stages, hue preference of Jinan older people for background interfaces will be investigated further, with the third and fourth stages, focusing on the bottom and partial side interfaces, respectively. Participants evaluate the test samples sequentially according to the test requirements. The experimenters took the results of the assessment. The assessment data were finally analysed using SPSS software.

Figure 1 Field research (partial) (see online version for colours)



2.1.1 Stage 1: Experiment with the lightness harmony

2.1.1.1 Participants

Five hundred older participants from Jinan City participated in this study. The average age of all participants was 71.3 years, with 246 (49.2%) men and 254 (50.8%) women. Stratified sampling was based on age groups, with 113 (22.6%) participants aged 60–65 years, 114 (22.8%) aged 66–70 years, 113 (22.6%) aged 71–75 years; 107 (21.4%) aged 76–80 years; and 53 (10.6%) aged 80 years or older. Visual acuity of all participants was adequate for daily living, and all participants have normal colour vision. The experimental procedure was thoroughly explained, and participants could choose whether to participate in the survey after understanding the purpose and procedures of the study.

2.1.1.2 Experimental materials

As shown in Figure 2, the brightness values of the specimens were determined according to the brightness criteria of the Munsell colour system. It is composed of 11 levels that span the gamut from minimum brightness ($V = 0$, black) to maximum brightness ($V = 10$, white) (Munsell and Nickerson, 1915). Within this spectrum are three distinct brightness classifications (low, medium, and high): 0–3 is commonly regarded as low brightness, 4–6 as medium brightness, and 7–10 as high brightness. Additionally, there are three levels of brightness contrast (weak, medium, and strong): a disparity in colour brightness between three levels signifies a weak contrast of brightness, a brightness difference within three to five levels of difference constitutes a moderate contrast of brightness, and a brightness difference exceeding five levels of difference constitutes a strong contrast of brightness (Chevreul, 2023; Li, 2021).

According to the aforementioned criteria, the original image database was analysed. In addition to the existing brightness of the decorative materials prevalent in Jinan City, the brightness ranges for the three interior components were established as follows: side interface: 4–10, primary colour brightness; bottom interface: 2–8. To guarantee that the test samples encompassed a representative subset of each of the three brightness levels (low, medium, and high) and contrast levels (weak, moderate, and strong), this study established that the luminance of the side interface would have values of $V = 4, 7$, and 10 , respectively. To maximise the brightness of the test samples across the three categories (low, medium, and high) and contrast categories (weak, moderate, and strong), we observed the side interface brightness at $V = 4, 7$, and 10 , respectively (low V colours are not frequently used on the side interface of traditional Chinese houses over large areas, and excessively low brightness could cause visual discomfort for the age individuals (Yuki et al., 2021). Thus, the fourth level of brightness, which is closest to low brightness, was selected as the lowest brightness for this component); the brightness of the primary colour and bottom interface samples were both $V = 2, 5$ and 8 .

The images were stripped of their chromaticity to eliminate the impact of colour hue and chroma on evaluation. The examination display was kept at its original composition, surface area, and viewpoint to ensure consistency. Additionally, the three selected brightness gradients of the three components were incorporated into the examination display to form the final collection of examination samples. As shown in Figure 3, this collection of test samples includes all the constituent elements with different brightness gradients and contrast intensities between the three different elements. In total, 27 test samples were generated.

Figure 2 Diagram of the Munsell colour system (see online version for colours)

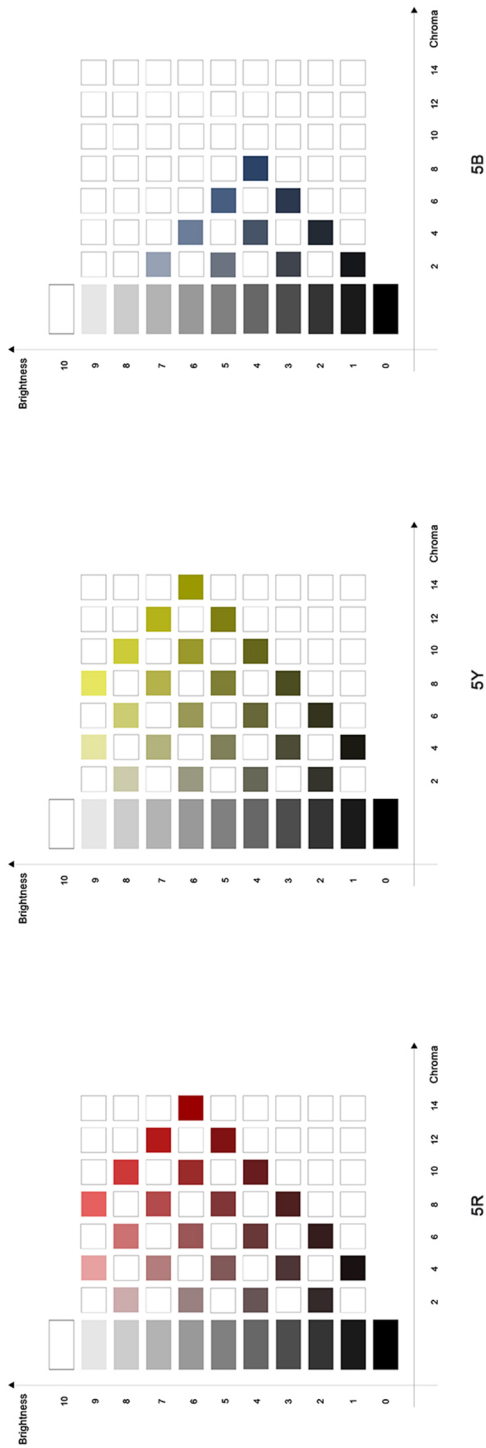
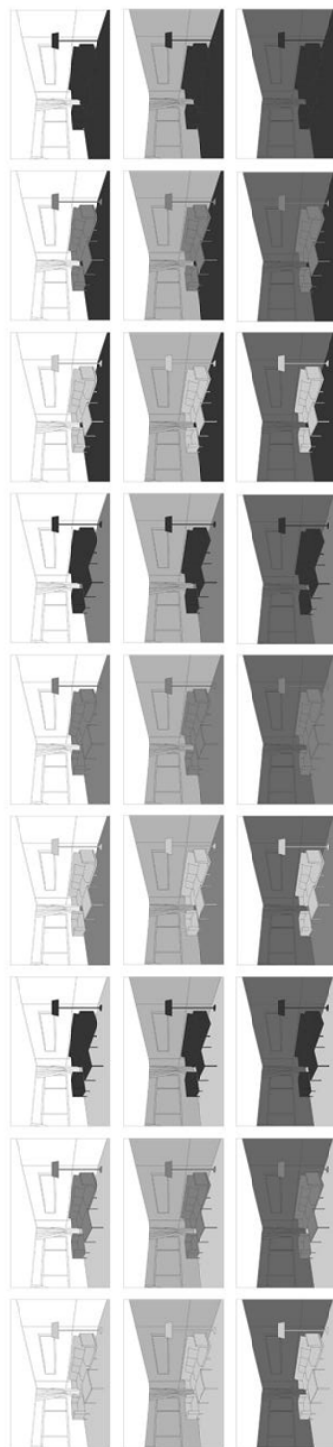


Figure 3 Test samples for brightness harmony



2.1.1.3 Procedure

Utilising a visual simulation display device, we displayed the required colour configuration of the indoor space to simulate the visual appearance of the space. The images of indoor space samples were presented visually to each older adult participating in the test.

The display device randomly presented the sample images from the test sample repository, with each examination image being displayed for 10 seconds. Using a seven-point Likert psychometric scale, the participants evaluated their preference level with the 27 samples in the repository (Anjaria, 2022).

After tabulating the data, the evaluators calculated the average preference scores for each sample. This study subsequently examined the data for correlations between preference and potential influencing factors using a multiple linear regression model. The dependent variable is 'Brightness harmony', and the predictors are 'the brightness of the side interface', 'the brightness of the primary colour', 'brightness of the bottom interface', 'difference in brightness between the side interface and the primary colour', 'difference in brightness between the side interface and the bottom interface', and 'difference in brightness between the primary colour and bottom interface'. SPSS 26 software was used to analyse all the data.

2.1.2 Stage 2: Experiments on hue preferences for primary colour

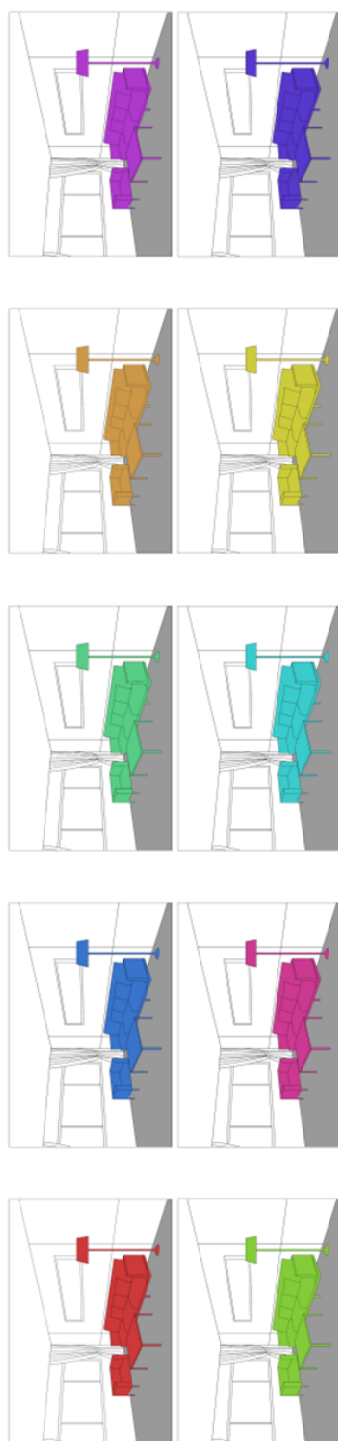
2.1.2.1 Participants

Five hundred older participants from Jinan City participated in this study. The average age of all participants was 70.4 years, with 249 (49.8%) men and 251 (50.2%) women. Stratified sampling was based on age groups, with 130 (26.0%) participants aged 60–65 years, 115 (23.0%) aged 66–70 years, 112 (22.4%) aged 71–75 years; 98 (19.6%) aged 76–80 years; and 45 (9.0%) aged 80 years or older. Similar to Stage 1, visual acuity of all participants was adequate for daily living, and all participants have normal colour vision. The experimental procedure was thoroughly explained.

2.1.2.2 Experimental materials

As determined by the results of the brightness harmony analysis in stage 1, the indoor side interface of age-friendly houses in Jinan should feature the highest possible brightness ($V = 10$). The brightness of the primary colour should be as close as possible to the brightness of the side interface. However, due to a decline in vision, the ability of older people to distinguish objects is diminished. Thus, it is advisable to select a primary colour with a brightness of 7 ($V = 7$, the brightness difference between primary colour and side interface 3, and the contrast of brightness is moderate) (Li, 2021). To highlight the primary colour more, we recommend that the brightness of the bottom interface further opens the brightness gap with the brightness of the primary colour (brightness difference of 3, moderate contrast), and the brightness of the bottom interface must be 4 ($V = 4$, brightness difference with the primary colour is 3, moderate contrast; brightness difference with the background wall is 6, strong contrast).

Figure 4 Test samples for hue preferences of primary colour (see online version for colours)



Production of test samples

With the brightness of the top ($V = 10$), side ($V = 10$), and bottom ($V = 4$) interfaces, and the brightness of the primary colour ($V = 7$), the image remains unchanged in terms of aspect ratio and perspective; the sole modification is made to the hue of the primary colour.

The primary colour is an important component of the visual display, and a vast array of colour options are available. To provide a more comprehensive coverage of the fundamental tonal range, the test employs primary colour masking colours from the 'Munsell colour system'. These colours are labelled as follows: 5R, 5B, 5G, 5YR, 5P, 5GY, 5RP, 5BG, 5Y, and 5PB. A total of ten test samples were produced. Included were the intermediate hues of the five primary colours – red (R), yellow (Y), green (G), blue (B), and purple (P) – along with them. Concurrently, colours with medium to medium-high chroma are advised for use as the primary colour, following the results of previous studies and taking into account the visual adaptability of the older people. Therefore, the primary colour of the test image is selected to ensure high brightness ($V = 7$) with medium-high chroma ($C = 10$). Such a primary colour not only can reflect the sense of colour but also has a high degree of visual acceptability. A total of 10 test samples were produced (Figure 4).

2.1.2.3 Procedure

A simulation display device was employed to visually represent the colour configuration of the indoor space that was mandatory for the experiment. Each older adult participating in the study examined a sample of the virtual image depicting the indoor space. The display device randomly presented sample images from the test sample library for 10 seconds each. The participant selected the colour sample from ten sample images that he or she preferred the most. The results were recorded individually by the evaluator. The documented results were summarised and inputted into the SPSS statistical software to conduct a chi-square superiority analysis. SPSS 26 software was used to analyse all data and the primary colour hue preferences of older people in Jinan City.

2.1.3 Stage 3: Experiments on hue preferences for bottom interface.

2.1.3.1 Participants

Five hundred older participants based in Jinan City, with an average age of 72.05 years, 237 (47.4%) men and 263 (52.6%) women participated in this study. Participants were divided into two groups based on their preference for primary colours: 256 in Group I (preference for warm primary colours) and 244 in Group II (preference for cold primary). The two cohorts were divided into strata according to age: Group I is composed of the following: 60–65 years = 56 (21.9%), 66–70 years = 56 (21.9%), 71–75 years = 50 (19.5%), 76–80 years = 59 (23.1%), and 80 years or above = 35 (13.7%). Meanwhile, Group II is composed of the following: 60–65 years = 54 (22.1%), 66–70 years = 54 (22.1%), 71–75 years = 60 (24.6%), 76–80 years = 51 (20.9%), and 80 years or above = 25 (10.3%). Visual acuity of all participants was adequate for daily living, and all participants have normal colour vision. The experimental procedure was thoroughly explained, and participants could choose whether to participate in the survey after understanding the purpose and procedures of the study.

2.1.3.2 Experimental materials

Through research on the ground pavement market in Jinan City, the colour of ground pavement is divided into two types: coloured and uncoloured. The common bottom interface pavement with colour has two colour tendencies, namely, red (close to the colour of 5R) and orange (close to the colour of 5YR), and the uncoloured colour is grey. At the same time, according to previous scholars' research results, the bottom interface should choose a colour with low chromaticity. Therefore, the chroma value of the bottom interface is established at 4, whereas the chromaticity value of the primary colour is 10. By utilising this chromatic contrast, the primary colour can be effortlessly emphasised, whereas the original colour scheme of the residential bottom interface pavement is preserved.

Producing test samples

The theory of colour harmony posits that variations in the primary colour can affect the inclination toward a particular background colour. The test samples are categorised into two groups according to the primary colour's warm and cold tendencies, as illustrated in Figure 5. The warm colour 5YR7/10 and the cold colour 5B7/10, which were found to be the most preferred by older individuals in Jinan based on the results of the third stage of the experiment, were selected as the hue references for the primary colour. The hue preference tests for the bottom interface were conducted in the following manner: sample 1 was coloured 5R4/4, sample 2 was coloured 5YR4/4, and sample 3 was left uncoloured N6/. Two distinct types of test samples were generated, with three of each type produced for a grand total of six.

Figure 5 Test samples for hue preferences for the bottom interface (see online version for colours)



2.1.3.3 Procedure

The colour scheme of the indoor environment necessary for the experiment was visually represented through the use of a visual simulation display device. For the bottom interface hue preference test, each participant was divided into a separate group based on his or her personal inclination toward warm or cold colours in the primary colour.

Three test samples featuring a primary colour of 5YR/10 will be utilised to evaluate testers who prefer warm colours. Meanwhile, three test samples with a primary colour of 5B/10 will be utilised to evaluate testers with a cold colour preference. Samples of virtual images of indoor spaces are presented through visual presentation. The experimental procedure is the same as that of stage 2.

2.1.4 Stage 4: Tests on hue preferences for the partial side interface

2.1.4.1 Participants

The same set of participants in Stage 3 participated in Stage 4.

2.1.4.2 Experimental materials

The results of the previous colour brightness harmony reveal that choosing white for the large-area side interface is preferable, but using all the colourless white tends to make the space monotonous and uninteresting (Mahnke, 1996). Concurrently, the partial side interface will require colour for certain decorative or functional components of the side interface. Due to the narrowing of older people's range of vision and the limitations of the size of the residence, the daily visual environment of older people will usually only observe the primary and side interface colours. Therefore, this experiment will be the bottom interface for the colourless treatment. According to the former brightness harmony results, the colour brightness of the bottom interface $V = 4$.

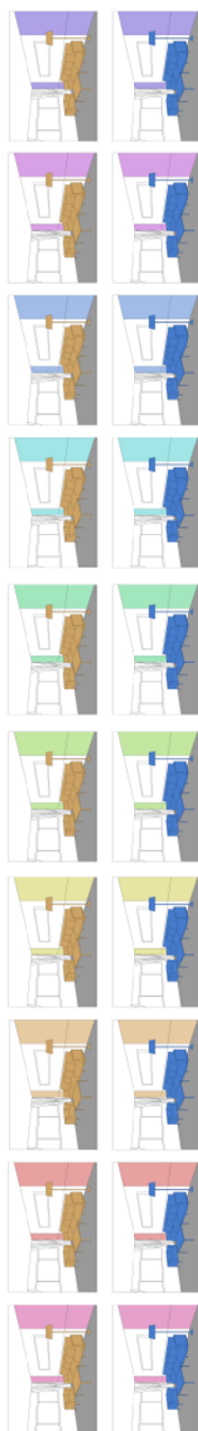
The theory of colour harmony posits that the different primary colours may affect the colour choice of the background colour. According to the results of the preferences of the indoor brightness environment of older people residence and the results of the hue preference of the primary colour, the warm colour (5YR, $V = 7$, $C = 10$) and the cold colour (5B, $V = 7$, $C = 10$), which older people in Jinan City preferred the most, were chosen as the primary colour references, respectively. Ten reference hues were still chosen for the partial side interface colours: 5R, 5B, 5G, 5YR, 5P, 5GY, 5RP, 5BG, 5Y, and 5PB. According to the results of the previous brightness harmony and the colour recommendations of previous scholars, the partial side interface brightness is selected to be of high brightness $V = 8$, and the chroma is selected as of low scale, with the value of the colour scale $C = 4$. Two types of test samples are produced: 10 test samples for each of the two types of test samples and a total of 20 test samples (Figure 6).

2.1.4.3 Procedure

The colour scheme of the indoor space required for the experiment was visually represented through the use of a visual simulation display device. To conduct the partial side interface hue preference test, each participant was divided into a separate group based on his or her personal inclination toward warm or cold colours in the primary colour.

Ten test samples with a primary colour of 5YR/10 will be administered to the testers whose primary colour preference is warm. Testers with a cold primary colour preference will be tested on 10 test samples with a primary colour of 5B/10. Visual representations are used to exhibit samples of virtual images of indoor spaces. The experimental procedure is the same as that of stage 1.

Figure 6 Test samples for hue preferences for the partial side interface (see online version for colours)



3 Results and discussion

3.1 Brightness harmony experiment

The samples were ranked in accordance with the degree of brightness harmony, as illustrated in Figure 7. The samples with the highest ratings were positioned at the top of the list. The results suggest that the ambiance of the top five samples in the ranking is generally bright, as are the side interface brightness images of the top five samples, both of which have a value of 10 for high brightness ($V = 10$). The top 3 side interface brightness and primary colours all fall within the medium and high brightness range. Conversely, all the lowest-ranking samples feature low overall brightness.

Figure 7 Results of the bipolar brightness harmony statistics

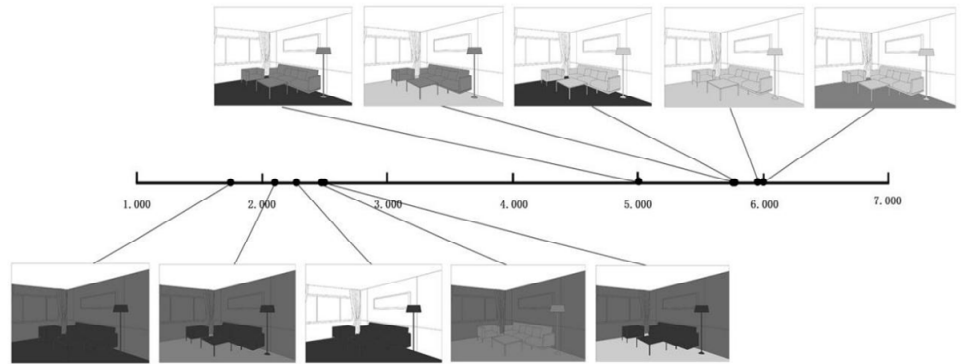
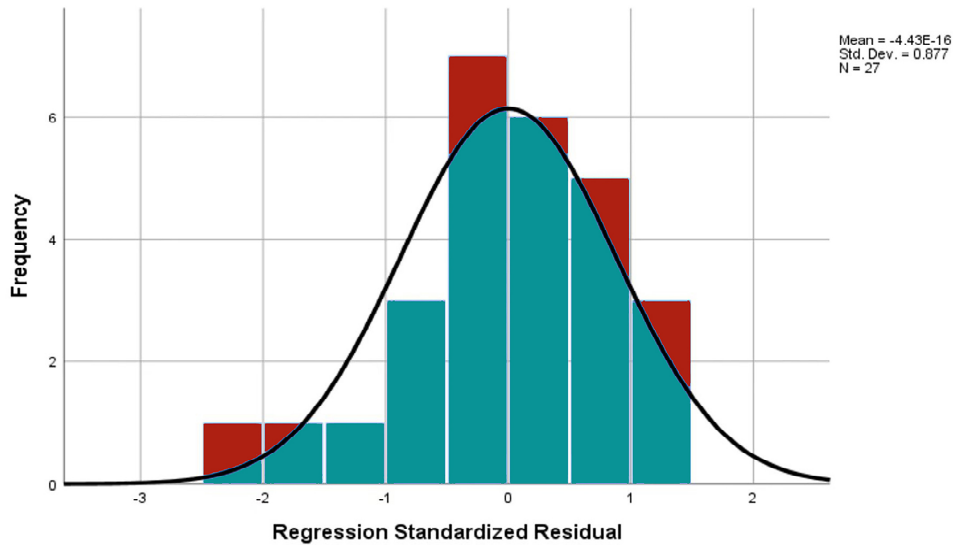


Figure 8 Regression standardised residual (see online version for colours)



A goodness-of-fit analysis was performed. As shown in Table 1, the fit of this multiple linear regression model is $R^2 = 0.885$. Furthermore, as shown in Figure 8, when the histogram of the residual distribution is compared to the normal distribution curve assigned to it, it can be deduced that the residuals of the regression equation conform to a normal distribution and fulfil the regression analysis assumptions. Put simply, it can be deduced that the independent variable y explains 88.5% of the variability observed in the dependent variable. This indicates that the chosen six factors have an impact of 88.5% on the dependent variable 'brightness harmony'. The model fit is considered to be acceptable.

As evidenced by the data presented in Table 2, $F = 25.529$, $p = 0.000 < 0.05$, indicating the statistical significance of the regression model. This finding suggests that a minimum of one of the six independent variables incorporated in the model has a statistically significant impact on the dependent variable, 'brightness harmony'.

Table 1 Model summary

<i>Model</i>	<i>R</i>	<i>R square</i>	<i>Adjusted R square</i>	<i>Std. error of the estimate</i>	<i>Durbin-Watson</i>
1	0.940 ^a	0.885	0.850	0.48384	1.765

Notes: ^aPredictors: (constant) difference in brightness between the primary colour and the bottom interface, brightness of the bottom interface, brightness of the primary colour, brightness of the side interface, difference in brightness between the side interface and the primary colours, and difference in brightness between the side and the bottom interfaces.

Table 2 The analysis of variance^a

<i>Model</i>		<i>Sum of squares</i>	<i>df</i>	<i>Mean square</i>	<i>F</i>	<i>Sig.</i>
1	Regression	35.859	6	5.976	25.529	0.000 ^b
	Residual	4.682	20	0.234		
	Total	40.541	26			

Notes: ^aDependent variable: Preference; ^bPredictors: (constant), primary colour brightness, brightness difference value (bottom interface and primary colour), bottom interface brightness, side interface brightness, brightness difference value (side interface and primary colour), brightness difference value (side interface and bottom interface).

Table 3 shows the dependencies of the respective variables on the dependent variable. A statistically significant positive relationship is found between the dependent variable 'preference' and the independent variable 'the brightness of the side interface', as indicated by the regression coefficient $B = 0.423 > 0$, $p = 0.000 < 0.05$. This suggests that an increase of 1 in 'the brightness of the side interface' will result in an increase of value 0.423 in the regression coefficient for the independent variable 'brightness harmony' when all other variables are held constant.

The same statistically significant positive relationship is found between the independent variable 'the brightness of the primary colour' and the dependent variable 'brightness harmony of colour environments', as indicated by the regression coefficient $B = 0.221 > 0$, $p = 0.000 < 0.05$.

A statistically significant negative relationship exists between the dependent variable 'preference' and the independent variable 'difference in brightness between the side

interface and the primary colour', as indicated by the regression coefficient $B = -0.137 < 0$, $p = 0.000 < 0.05$. This suggests that an increase of 1 in the 'difference in brightness between the side interface and the primary colour' will result in a decrease of the 0.137 value in the regression coefficient for the independent variable 'brightness harmony' when all other variables are held constant.

Table 3 Coefficients^a

<i>Model</i>	<i>B</i>	<i>Standard error</i>	<i>Standardised coefficients</i>	<i>t</i>	<i>Sig.</i>
			<i>Beta</i>		
1 (Constant)	-0.202	0.446		-0.453	0.656
The brightness of the side interface	0.423	0.052	0.845	8.131	0.000
The brightness of the primary colour	0.221	0.046	0.442	4.792	0.000
The brightness of the bottom interface	0.082	0.046	0.164	1.772	0.092
Difference in brightness between the side interface and the bottom interface	-0.028	0.059	-0.051	-0.481	0.636
Difference in brightness between the side interface and the primary colour	-0.137	0.059	-0.247	-2.323	0.031
Difference in brightness between the primary colour and bottom interface	0.061	0.042	0.110	1.443	0.164

Note: ^aDependent variable: brightness harmony.

The remaining three independent variables, 'the brightness of the bottom interface' ($p = 0.092$), 'difference in brightness between the side interface and the bottom interface' ($p = 0.636$), 'difference in brightness between the primary colour and the bottom interface' ($p = 0.164$) had no significant effect on 'satisfaction' ($p > 0.05$).

Furthermore, the variance inflation factor for each variable is less than 5, indicating that there is no multicollinearity among the independent variables, and thus, the analysis results can be considered accurate and reliable.

Consider X1 to denote the brightness of the side interface, X2 to represent the brightness of the primary colour, and X3 to denote the brightness difference between the side interface and the primary colour. The equation that represents the regression model for the age-friendly space in Jinan with respect to brightness harmony is as follows:

$$\text{Brightness harmony} = -0.202 + 0.423 \times X1 + 0.221 \times X2 - 0.137 \times X3$$

The results of the multiple linear regression analysis suggest that the brightness harmony is predominantly impacted by the side interfaces and the primary colour's brightness, and their difference in brightness. The brightness of the side interface is considered the most significant of these factors. Additionally, the results suggest that an increase in the difference in brightness between the side interface and the primary colour tends to decrease harmony.

- 1 The selection of a bright environment aligns with the physiological requirements of older Chinese people. Research has shown that approximately half of people aged 60 and over experience vision difficulties. Additionally, as older individuals' visual muscles age, their pupils become progressively smaller, resulting in the pupils receiving approximately half or more light compared to younger individuals (Yuki et al., 2021). This decline in object recognition ability among the older people in low-brightness environment is an effect of the aforementioned physiological changes. By optimising the brightness levels in the primary visual interface and side interface colour, which are significant areas of daily visual activity, the reflectance of the main visual interface is increased. This results in a greater intensity of reflected light and ultimately increases the overall brightness of the room. Such improvements may prove beneficial for the older people who have reduced visual function.
- 2 The selection of the brightness of the side interface aligns with the psychological preference of Chinese for wall colour constancy. Colour constancy refers to the psychological tendency to maintain a constant perception of the colour of objective objects when the external environment changes. It is an essential characteristic of the colour vision of the human eye (Hurlbert, 2019). The materials used to adorn Chinese floors have transformed, progressing from initial grey bricks to the current wooden floors and tiles. In contrast, the colour palette for interior walls in China has conventionally remained relatively homogeneous. Throughout history, white has consistently been the prevailing colour selection. This is in accordance with the conventional Chinese notion of designating bright colours as suitable for interior side interfaces.
- 3 When older individuals decide on the bottom interface's brightness level, functional requirements are typically the guiding principle. Considering its location in the lowest section of the indoor area, this particular area is seldom the central focus of daily visual attention. However, since older populations have a higher frequency of contact with indoor spaces, they often prioritise functional attributes such as slip resistance, dirt resistance, and durability in their choice of materials. Lower brightness levels on flooring can be used to stabilise or reduce visual stimuli and are often more resistant to soiling (Hussein, 2017). On the contrary, brighter flooring can create a lighter and more serene atmosphere (Fairchild, 2013). In the end, the brightness of the bottom interface is a matter of personal preference; there is no discernible trend in this regard.
- 4 Finally, tracking the history of colour spaces in human psychophysics shows an escalation toward higher complexity of models. Previous research has indicated that when designing interior spaces for older individuals, one must consider the colour of the primary elements within the space. Studies have shown that avoiding excessively vibrant chroma is beneficial (Mahmoud, 2017; Mitton and Nystuen, 2021). Additionally, as assembled in conjunction with our current research, high brightness and neutral, relatively mild colours must be incorporated in the configuration of the primary colour (main furniture) for older individuals. However, note that the visual impact of the primary colour can vary depending on the pattern designs and material choices. Therefore, it is crucial not only to choose appropriate colours for the primary colour (main furniture), but also to ensure that the overall configuration of the space is cohesive and visually pleasing.

3.2 Hue preference for the primary colour experiment

As shown in Table 4, the number and frequency of each primary colour preference test sample is selected. The primary colour palettes of residential interior spaces favoured by older people in Jinan are more varied. A specific proportion of older individuals appointed each colour test sample. The samples were selected in descending order as follows: 5YR (chosen 86 times, with a frequency of 17.2%), 5Y (62 times, 12.4%), 5R (60 times, 12%), 5RP (56 times, 11.2%), 5G (56 times, 11.2%), 5B (54 times, 10.8%), 5GY (35 times, 7%), 5P (33 times, 6.6%), 5PB (31 times, 6.2%), and 5BG (selected 27 times, 5.4%).

Table 4 Results of the primary colour test samples being selected

<i>Colour</i>	<i>Frequency</i>	<i>Valid percent</i>	<i>Cumulative percent</i>
5RP	56	11.2	11.2
5R	60	12	23.2
5YR	86	17.2	40.4
5Y	62	12.4	52.8
5GY	35	7	59.8
5G	56	11.2	71
5BG	27	5.4	76.4
5B	54	10.8	87.2
5PB	31	6.2	93.4
5P	33	6.6	100
Total	500	100	

As shown in Table 5, with a total of 10 test samples and 500 test results, the chi-square goodness-of-fit analysis assumes that each sample is selected the same number of times; that is, the expected number of times for each sample is 50. The colours that exceeded expectations were 5RP, 5R, 5YR, 5Y, 5G, and 5B.

As illustrated in Table 6, asymp. sig. is 0.000 ($p < 0.01$). This finding shows statistically significant test results, thus rejecting the original hypothesis that there is a significant difference in the number of samples selected.

A significant difference exists in the number of samples. Moreover, combined with the frequency of selection, it is concluded that older people in Jinan City have a significant preference for the hue of primary colour according to the degree of preference in descending order of the hue: 5YR > 5Y > 5R > 5RP = 5G > 5B > 5GY > 5P > 5PB > 5BG. The results of this study reveal that a certain number of older people choose the hue of the different primary colours. However, the hues that most older people generally prefer are 5YR, 5Y, 5R, 5RP, 5G, and 5B. From such results, we can see that older people in Jinan City are more inclined to warm hues as a whole, with the top four hues of the primary being warm hues, and the fifth and sixth being neutral and cold hues 5B, respectively. As individuals age, vision gradually declines. Research indicates that warm colours, such as red and yellow, are more distinguishable under low-light conditions due to higher visual contrast. This characteristic enhances the ability of older adults to identify objects and surroundings more effectively (Rooth, 2017). Consequently, the preference for these colours among older adults may partly arise from an increasing

reliance on colour recognition as vision deteriorates (Barbur and Rodriguez-Carmona, 2016).

Table 5 Results of the chi-square goodness-of-fit test (frequency)

<i>Colour</i>	<i>Observed N</i>	<i>Expected N</i>	<i>Residual</i>
5RP	56	50	6.0
5R	60	50	10.0
5YR	86	50	36.0
5Y	62	50	12.0
5GY	35	50	-15.0
5G	56	50	6.0
5BG	27	50	-23.0
5B	54	50	4.0
5PB	31	50	-19.0
5P	33	50	-17.0
Total	500		

Table 6 Results of the chi-square goodness-of-fit test (test statistics)

Chi-square	60.640000
Asymp. sig.	0.000

Beyond visual reasons, social exchange theory posits that individuals seek rewards from their interactions (Cook et al., 2013). Applied to colour preferences, older adults may seek psychological rewards when selecting colours for their spaces or environments. Warm colours often provide a sense of psychological warmth, comfort, and security, which holds particular significance for older adults (Ghotbi et al., 2014; Ho et al., 2014; Torres et al., 2020). With ageing, seniors frequently encounter loneliness, health challenges, and lifestyle changes, all of which intensify their emotional needs. Warm colours can mitigate feelings of loneliness, improve mood, and foster a sense of belonging through their gentle and inviting visual qualities (Sandford, 2011). Consequently, the preference for warm colours among older adults may primarily arise from emotional needs that help them navigate psychological challenges and emotional distress.

In traditional Chinese culture, colours serve not only as visual elements but also as carriers of profound emotional and cultural significance (Tian et al., 2024). The concept of 'colours as symbols of auspiciousness' is a defining characteristic of traditional Chinese colour theory, emphasising that colours are not merely sensory perceptions but also representations of emotions and cultural values. Red often signifies auspiciousness and festivity, while yellow symbolises dignity and grace (Tian, 2021; Zhang et al., 2012). These colours hold distinctive symbolic meanings in Chinese culture, reflecting aspirations for and the pursuit of a better life. This cultural association may lead older individuals to prefer these colours as sources of emotional and psychological support.

However, we also noticed that neutral (5G) and cold (5B) hues are chosen by many older people, which is related to the visual psychological needs of people for hues in interior spaces. Compared to warm hues, cold and neutral hues bring a calmer and colder

visual atmosphere to older people. Additionally, warm hues have a sense of expansion, which reduces the sense of space in vision, and the opposite is true for cold hues (Ghotbi et al., 2014). The specific design process of an age-friendly residential space can be combined with the hue preference of older people and the specific spatial needs to make the corresponding choices.

3.3 Hue preference for experiment

The results of the number and frequency of times each hue preference of bottom interface test sample are presented in Table 7, respectively. There were 256 seniors in total whose primary colour preference was warm. A specific proportion of older individuals appointed each colour test sample. The samples were chosen in the following descending order: 5R (selected 97 times, with a frequency of 37.9%), 5YR (94 times, 36.7%), N (65 times, 25.4%); and a cohort of 244 older people whose predominant preferred colour tended to be a cold tone. A certain number of older people selected all colour test samples. In descending order, the sample selections comprised the following: 5R (selected 104 times, with a frequency of 42.6%), 5YR (110 times, 45.1%), and N (30 times, 12.3%). Further chi-square goodness-of-fit tests shall be performed to ascertain whether a disparity between the samples is statistically significant..

Table 7 Results of the hue preference for bottom interface experiment

<i>Primary colour</i>	<i>Background colour (bottom interface)</i>	<i>Frequency</i>	<i>Valid percent</i>	<i>Cumulative percent</i>
5YR (N = 256)	5R	97	37.9	37.9
	5YR	94	36.7	74.6
	N	65	25.4	100
5B (N = 244)	5R	104	42.6	42.6
	5YR	110	45.1	87.7
	N	30	12.3	100
Total		500	100	

Table 8 Results of the chi-square goodness-of-fit test (frequencies)

<i>Primary colour</i>	<i>Background colour (bottom interface)</i>	<i>Observed N</i>	<i>Expected N</i>	<i>Residual</i>
5B	5R	104	81.3	22.7
	5YR	110	81.3	28.7
	N	30	81.3	-51.3
5YR	5R	97	85.3	11.7
	5YR	94	85.3	8.7
	N	65	85.3	-20.3
Total		500		

The hue preference of the bottom interface test, as shown in Table 8, divided the test population into two categories based on the predominant colour tendency; three test samples were observed in each category. The Chi-square fit goodness-of-fit test assumes

that each sample number has been selected the same number of times, or the expected number of choices for 85.3 instances. Among these individuals, 256 have a warm tone preference as their primary colour preference; 244 have a cold tone preference, the chi-square fit goodness-of-fit test expects the number of choices for each sample to be 81.3 times. Colours: The colours that exceeded the expected value for both data types were coloured 5R and 5YR, and the number of colours chosen for the uncoloured base interface colours did not exceed the expected value.

As indicated in Table 9, the results of both test types show asymp. sig. of 0.000 and 0.026, which are both below the threshold of 0.05, $p < 0.01$. This finding suggests that the test outcomes for both results of test samples are statistically significant. Additionally, it refutes the initial hypothesis that a substantial distinction exists in the sample sizes utilised for each category. Significant differences distinguish the 5R and 5YR test samples from the N samples.

Table 9 Results of the chi-square goodness-of-fit test (test statistics)

<i>Primary colour</i>	<i>5B</i>	<i>5YR</i>
Chi-square	48.82	7.32
df	2	2
Asymp. sig.	0.000	0.026

Notes: 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 81.3.

0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 85.3.

In conjunction with the frequency of sample selection, a notable disparity exists in the quantity of samples chosen; this disparity suggests that older individuals residing in Jinan City also have a substantial inclination toward the colour of the bottom interface. Based on the results of this experiment, both types of older people preferred the colour of the bottom interface to be coloured, and only a small number of older people preferred the uncoloured colour. No statistically significant distinction was observed in the quantity of the two coloured test samples. It is possible to discern that all coloured surfaces in Jinan City are warm based on their hue. Warm colours, as mentioned in the preceding section regarding the results of hue preference in primary colours, typically improve the positivity of the visual environment and evoke feelings of warmth and excitement (Nijdam, 2009). This may be why older individuals favour warm colours. Simultaneously, the interior design industry in China began belatedly (Tojiboev, 2021). During the middle age of this generation of older adults residing in Jinan, most floor coverings were original concrete floors, closely resembling the colourless grey of our current sample. With the development of the interior industry, floor coverings began to exist with a reddish tinge to the traditional Chinese colour of sour wood and a yellowish-orange tinge to the predominantly raw wood colours. This collective memory may have led older people in Jinan to believe that the absence of colour created a lack of decoration. This may be another factor that influences the choice of hue preferences of the bottom interface. The visual impression of having coloured floor coverings over a long period may have led to the result that there is no significant difference between the coloured samples present.

3.4 Hue preference for background (partial side interface)

The test samples were divided into two types of samples according to the difference in the hue preference of the older adults tested for the primary colour. The two types of test samples for the primary colour colours were the 5YR samples of cold tones and the 5B samples of warm tones, respectively. A total of ten test samples comprise each primary colour sample. Thus, the preference score information for 20 test samples was gathered (two categories, ten each). To begin, a separate normality test was conducted on the data of each test sample. Afterward, the data will be further analysed by selecting a suitable method (one-way ANOVA or non-parametric test of Kruskal-Wallis test) based on the normality test results.

Table 10 Tests of normality

Primary colour	Background colour (partial side interface)	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Preference (5YR)	5YR	0.295	256	0.000	0.766	256	0.000
	5Y	0.164	256	0.000	0.903	256	0.000
	5GY	0.142	256	0.000	0.933	256	0.000
	5G	0.138	256	0.000	0.934	256	0.000
	5BG	0.143	256	0.000	0.934	256	0.000
	5B	0.147	256	0.000	0.928	256	0.000
	5PB	0.134	256	0.000	0.929	256	0.000
	5P	0.143	256	0.000	0.932	256	0.000
	5RP	0.144	256	0.000	0.936	256	0.000
	5R	0.135	256	0.000	0.922	256	0.000
Preference (5B)	5B	0.23	244	0.000	0.816	244	0.000
	5PB	0.187	244	0.000	0.905	244	0.000
	5P	0.142	244	0.000	0.933	244	0.000
	5RP	0.139	244	0.000	0.928	244	0.000
	5R	0.139	244	0.000	0.934	244	0.000
	5YR	0.131	244	0.000	0.934	244	0.000
	5Y	0.146	244	0.000	0.927	244	0.000
	5GY	0.145	244	0.000	0.933	244	0.000
	5G	0.182	244	0.000	0.913	244	0.000
	5BG	0.203	244	0.000	0.869	244	0.000

Note: *Lilliefors significance correction.

As shown in Table 10, the normality test was performed on the aggregated data of the satisfaction scores of the two types of test samples, the two types of subgroups, a total of 20 groups of the normality test of the data. Each data group has a significance value of less than 0.05 ($P < 0.05$). It is determined that each data group does not obey the normal distribution. According to the data, do not obey the characteristics of normal distribution, the Kruskal-Wallis test in the non-parametric test will be conducted.

As shown in Table 11, the Kruskal-Wallis test was conducted on the two types of test data, respectively.

Table 11 Test statistics^{a,b,c}

<i>Preference 5YR)</i>		<i>Preference (5B)</i>	
Kruskal-Wallis H	358.729	Kruskal-Wallis H	394.556
df	9	df	9
Asymp. sig.	0.000	Asymp. sig.	0.000

Note: ^aKruskal side interface is test, ^bGrouping variable: group (5YR), ^cgrouping variable: group (5B).

Table 12 Percentiles

<i>Primary colour</i>	<i>Background colour (partial side interface)</i>	<i>Percentiles</i>						
		5	10	25	50	75	90	95
Preference (5YR)	5YR	4	5	5	7	7	7	7
	5Y	2	3	4	5	6	7	7
	5GY	1	2	3	4	6	7	7
	5G	1	2	3	4	6	6	7
	5BG	1	1	3	4	6	6	7
	5B	1	1.7	2	4	5	6	7
	5PB	1	1	2	4	5	6	7
	5P	1	2	3	4	6	6	7
	5RP	1	2	3	4	6	6	7
	5R	1.85	2	4	5	6	7	7
Preference (5B)	5B	4	5	5	6	7	7	7
	5PB	3	4	4	5	6	7	7
	5P	1	2	3	4	6	6	7
	5RP	1	1	2	4	6	6.5	7
	5R	1	1	2	4	5	6	7
	5YR	1	2	2	4	5	6.5	7
	5Y	1	2	2	4	5	7	7
	5GY	1	2	3	4	6	6	7
	5G	3	4	4	5	6	6	6
	5BG	4	4	5	5	6	7	7

The significance of both types of data is 0.000 ($p < 0.05$), indicating a significant difference in satisfaction results between the two types of test samples. Combining the percentile to further determine the specific high and low differences in satisfaction between the test samples is necessary.

Table 12 presents the results of the hue preference for partial side interface of the test people whose hue preference for primary colour is warm (5YR) in descending order: 5YR, 5Y, 5R, 5GY, 5G, 5P, 5RP, 5BG, 5B, and 5PB. The results of the hue preference

for partial side interface of the test people whose hue preference for primary colour is cold (5B), in descending order: 5B, 5BG, 5PB, 5G, 5P, 5G, 5GY, 5Y, 5YR, and 5R.

The hue preference test for the partial side interface yielded statistically significant experimental results. The primary colour has a notable effect on the background colour of the partial side interface. Additionally, there is a significant difference in the order of satisfaction scores between the two sample types. However, through in-depth analyses, we found common features in the satisfaction ratings of the two types of test samples. Whether the primary colour tendency was cold or warm, the older people group had the highest preference for similar colours and a higher preference for neighbouring colours. There is a tendency to decrease preference for colour schemes with increased hue contrast. With such results, we can draw the following conclusion. The older people in Jinan generally prefer to choose the same colours or neighbouring colours to the primary colours as the partial side interface colours. Among them, preference with a similar colour is the highest. A similar colour hue is close to the hue of the primary colour, which can be approximated as the same colour. This means that the approximate number of colours separating the primary and background colours of a partial side interface is one. This is identical to Sagawa's experimental discovery that visual pleasure is inversely proportional to the number of perceptible colours in an image. For the relatively substantial proportion of colours in the visual environment of the residential space, the older people of Jinan preferred to choose the form of colour matching with a smaller number and weaker contrast.

A distinct unity of tone, warm tones, or a combination of warm/cold tones with neutral or cold tones is another characteristic of the contrast between similar and adjacent colours. Overall, the unity of these colour configurations varies marginally. This result resembles Shen et al.'s (1996) observation that the colour scheme utilised in interior design is derived from 'similar tonal sums', which impart a comparatively tranquil visual ambiance to residential areas. This is comparable to the slower pace that senior citizens frequently desire. This aligns with the slow-paced, calm state of life that older people usually seek. Nevertheless, this does not imply that a more 'calm' colour scheme is inherently superior from a design standpoint. In this context, 'calm' refers to a significant portion of the colour configuration that establishes the visual tone and ambiance of the residential space's visual environment. In order to ascertain the ambiance of an age-friendly residential space as a whole, it is also imperative to incorporate auxiliary colours that elicit excitement among older individuals to prevent a completely calm-coloured environment from leading to a dull visual impression. The accent colours in the space are generally the colours of small furnishings like greenery, upholstery fabrics, photos, and pictures. These kinds of small items occupy a small proportion of space, are varied, and can be combined with the different older people's needs on the furnishings. Hence, the strong colours must be compared to embellish the space so that the colour of the space has vitality and tranquility. This colour configuration not only reflects the impression of calm but also increases uplifting mood (Shen et al., 1996).

4 Limitations

This study has several limitations that should be acknowledged when interpreting the findings. First, the experimental design relied on image simulations to evaluate visual effects, which may deviate from real-world environments in several aspects. The

standardised lighting conditions employed in the experiment did not capture the variability of natural light, including changes in sunlight intensity, colour temperature, and dynamic characteristics over time. In actual settings, lighting conditions are influenced by spatial layouts and material reflectance, factors that were not fully incorporated into the experimental framework. Additionally, spatial perception in the study was based on static 2D images, lacking the dynamic perspective shifts intrinsic to real-world, three-dimensional environments. Depth perception and the proportions of objects in real spaces vary based on the observer's position and movement. Furthermore, the materials and textures in the simulations were modelled under preset lighting conditions, which could not replicate the subtle variations in material reflectance and surface texture present in real-world scenarios. Differences in lighting conditions and viewing angles can significantly influence material appearance and texture, leading to variations in colour perception that were challenging to simulate. These discrepancies restrict the external validity of the findings. Future research should explore more realistic scene simulation approaches, such as virtual reality (VR) (Berni and Borgianni, 2020; Dozio et al., 2022; Yildirim et al., 2019) and augmented reality (AR) technologies (Park and Ko, 2021; Xiong et al., 2021). These tools offer immersive visual experiences and can more accurately simulate dynamic lighting, 3D spatial perception (Karnchanapayap and Chaetnalao, 2021; Yildirim et al., 2019), and material reflectance. For instance, VR allows participants to navigate freely within virtual environments, providing a realistic sense of spatial depth and layout changes, while enabling real-time dynamic lighting simulations. Additionally, physically-based rendering (PBR) techniques can enhance the realism of light-material interactions by accounting for surface textures, glossiness (Tewari et al., 2020), and refractive properties. Integrating these technologies with eye-tracking systems could further facilitate the study of spatial perception and visual attention distribution from diverse perspectives.

Second, this study utilised multiple linear regression analysis to investigate the effect of brightness on preferences among older adults. Although this method simplified the analysis and identified fundamental relationships, it might have overlooked the complexity of brightness preferences, which could include nonlinear associations or interaction effects among various factors. Future research could adopt advanced statistical techniques, such as nonlinear regression models, structural equation modelling, or mixed-effects models, to gain a more comprehensive understanding of how diverse brightness environments shape individual preferences.

Additionally, this study focused primarily on large areas of background and primary colours, simplifying the colour design to minimise cognitive load and ensure reliability of the data. Although this approach facilitated management of the experiment, it constrained the analysis of interactions between colours, which might influence preferences of older adults. Future studies should examine interactions and combinations of colours in greater detail, assessing how relationships among different colours affect preference and satisfaction with overall spatial design.

Finally, this study focused on older adults residing in Jinan, China, but did not account for individual differences such as age, health status, cultural background, or education level, which are known to significantly affect colour preferences. The omission of these variables constrains the generalisability of the results. Future research should aim to increase the sample size and include a more diverse participant group. Incorporating stratified analyses or detailed assessments of individual characteristics would provide

deeper insights into the influence of these factors on colour preferences and enhance the representativeness of the findings.

Despite its limitations, this study offers valuable preliminary insights into the colour preferences of older adults, serving as a foundation for future investigations into colour interactions and more complex spatial designs. The findings make significant theoretical and practical contributions to the development of age-friendly environments.

5 Conclusions

To begin with, regarding the visual ambiance of one's residences, the brightness level significantly influences the preferences of older individuals in the context of visual environment preference. This research consists of a classification of the key components of domestic spaces that are age-appropriate in Jinan City. It uses multiple linear regression analysis to discern the impact of these constituents on preference with the brightness of the environment.

The study found that older people in Jinan City generally prefer a high-brightness spatial environment.

The findings of this research indicate that the brightness of the side interfaces significantly influences the overall preference of older individuals. Consequently, to optimise the visual environment, one must select side interfaces in bright colours, including white, which has the highest brightness.

In terms of primary colour (the surface colour of the leading furniture), it is important to consider the practical needs of daily use, such as the resistance to dirt. Furthermore, it is not imperative to designate the colour white, which has the highest brightness, as the primary colour. Rather, it is advisable to minimise the value discrepancy by selecting a high-brightness colour that retains its functionality in the side interface. The ramifications of the brightness of the bottom interface and the brightness difference between the bottom interface and other constituent elements on preference are insignificant and can be amalgamated with specific design requirements for brightness selection.

Second, older people in Jinan City have a marked preference for the hues of the residential interior's component parts.

- 1 Warm hues are preferred by the older people in Jinan as their primary colour process, with a subset of the older people also favouring neutral green tones and cold blue tones. When developing age-friendly residential space, we can combine the hue preferences of the older people with the particular spatial requirements in order to execute the corresponding colour design;
- 2 For the bottom interface, the majority of older people in Jinan City tend to choose coloured paving, and only a few people will choose uncoloured grey paving; the hue preference of partial side interfaces tends to choose the same kind of colours or adjacent colours of the primary colours.

In summary, this study investigates the colour configuration of age-friendly spaces in Jinan. The group preferences for brightness and hue of each colour component were improved. This enhanced and supplemented the theoretical study on the colour configuration of age-friendly spaces. Simultaneously, it serves as an operational reference

for the design of colour configurations in age-friendly spaces in Jinan. Consequently, it contributes to the advancement of age-friendly space design to some degree.

However, this study has several limitations. First, the use of image simulations to test visual effects may not accurately reflect real-world conditions, as it cannot replicate the dynamic changes in natural light or the three-dimensional nature of space perception. Future research could leverage VR and AR to create more immersive and realistic simulations. Second, the study employed multiple linear regression to analyse brightness preferences, which may oversimplify the complexity of preferences. More advanced statistical models, such as nonlinear regression or structural equation modelling, could provide deeper insights into how brightness and other factors interact. Additionally, the study focused primarily on large surface areas and did not consider the interactions between different colours, which could affect preferences. Future work should explore colour interactions in more detail. Lastly, this study focused on older adults in Jinan, China, without considering individual differences such as age, health, or cultural background, which may influence colour preferences. Future research should expand the sample size and include a broader range of individual characteristics to improve the representativeness of the findings.

References

- Anjaria, K. (2022) 'Knowledge derivation from Likert scale using Z-numbers', *Information Sciences*, Vol. 590, pp.234–252, <https://doi.org/10.1016/j.ins.2022.01.024>.
- Barbur, J.L. and Rodriguez-Carmona, M. (2016) 'Color vision changes in normal aging', in Elliott, A.J., Fairchild, M.D. and Franklin, A. (Eds.): *Handbook of Color Psychology*, pp.180–196, Cambridge University Press, Cambridge.
- Beke, L., Kutas, G., Kwak, Y., Sung, G.Y., Park, D.S. and Bodrogi, P. (2008) *Color Preference of Aged Observers Compared to Young Observers*, Vol. 33, No. 5, pp.381–394, Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur.
- Berni, A. and Borgianni, Y. (2020) 'Applications of virtual reality in engineering and product design: why, what, how, when and where', *Electronics*, Vol. 9, No. 7, p.1064.
- Carstensen, L. (2007) 'Growing old or living long: a new perspective on the aging brain', *Public Policy & Aging Report*, Vol. 17, No. 1, pp.13–17.
- Carstensen, L.L. (2021) 'Socioemotional selectivity theory: the role of perceived endings in human motivation', *The Gerontologist*, Vol. 61, No. 8, pp.1188–1196.
- Cheng, Y. and Tan, M. (2018) 'The quantitative research of landscape color: a study of Ming Dynasty City Wall in Nanjing', *Color Research & Application*, Vol. 43, No. 3, pp.436–448.
- Chevreur, M. (2023) *The Principles of Harmony and Contrast of Colours*, Outlook Verlag GmbH.
- Cook, K.S., Cheshire, C., Rice, E.R. and Nakagawa, S. (2013) 'Social exchange theory', *Handbook of Social Psychology*, pp.61–88.
- Dittmar, M. (2001) 'Changing colour preferences with ageing: a comparative study on younger and older native Germans aged 19–90 years', *Gerontology*, Vol. 47, No. 4, pp.219–226.
- Divers, E. (2021) 'Beyond hue: the affective response to value and chroma', *Proceedings of the International Conference of the Color Society of Russia*, Smolensk State University Press, Smolensk, Russia, Vol. 154.

- Dozio, N., Marcolin, F., Scurati, G.W., Ulrich, L., Nonis, F., Vezzetti, E., Marsocci, G., La Rosa, A. and Ferrise, F. (2022) 'A design methodology for affective virtual reality', *International Journal of Human-Computer Studies*, Vol. 162, p.102791.
- Fairchild, M.D. (2013) *Color Appearance Models*, 3rd ed., John Wiley & Sons, Hoboken, New Jersey.
- Fernández-Portero, C., Alarcón, D. and Padura, Á.B. (2017) 'Dwelling conditions and life satisfaction of older people through residential satisfaction', *Journal of Environmental Psychology*, Vol. 49, pp.1–7.
- Ghotbi, M., Farsi, A. and Bdoli, B. (2014) 'Effect of warm and cold colors on athletes' depth perception in ball and no ball games', *Motor Behavior*, Vol. 6, No. 17, pp.43–54.
- Güneş, E. and Olguntürk, N. (2020) 'Color-emotion associations in interiors', *Color Research & Application*, Vol. 45, No. 1, pp.129–141.
- Ho, H-N., Iwai, D., Yoshikawa, Y., Watanabe, J. and Nishida, S.y. (2014) 'Combining colour and temperature: a blue object is more likely to be judged as warm than a red object', *Scientific Reports*, Vol. 4, No. 1, p.5527.
- Hurlbert, A. (2019) 'Challenges to color constancy in a contemporary light', *Current Opinion in Behavioral Sciences*, Vol. 30, pp.186–193.
- Hurlbert, A.C. and Ling, Y. (2007) 'Biological components of sex differences in color preference', *Current Biology*, Vol. 17, No. 16, pp.R623–R625.
- Hussein, M.F. (2017) 'The role of Arabic calligraphy in forming modern interior design', *Modern Applied Science*, Vol. 11, No. 3, p.53.
- Jacobsen, M.H. (2019) *Emotions, Everyday Life and Sociology*, Routledge, Taylor & Francis Group, New York, NY.
- Jeon, E., Han, Y. and Nam, M. (2020) 'How you see yourself influences your color preference: effects of self-construal on evaluations of color combinations', *Psychology & Marketing*, Vol. 37, No. 7, pp.980–994.
- Karnchanapayap, G. and Chaetnalao, A. (2021) 'Virtual reality art as an innovative Buddhist learning tool', *International Journal of Arts and Technology*, Vol. 13, No. 3, pp.255–277.
- Kato, Y., Cheung, T.L.V., Kitaguchi, S., Westland, S., Yasunaga, H. and Sato, T. (2006) 'Cultural preferences for hair colour', in *Proceedings of the International Colour Association Interim Meeting: Colour in Culture and Colour in Fashion*, pp.44–47.
- Lawton, M.P. (1985) 'The elderly in context: perspectives from environmental psychology and gerontology', *Environment and Behavior*, Vol. 17, No. 4, pp.501–519.
- Lenclos, J.P. (2019) 'The geography of colour', in *Colour for Architecture Today*, pp.39–44, Taylor & Francis.
- Li, Y. (2021) 'Exploration on the application of color contrast and harmony in advertising design', *Asian Journal of Social Science Studies*, Vol. 6, No. 3, p.29.
- Mahmoud, H-T.H. (2017) 'Interior architectural elements that affect human psychology and behavior', *ARCHive-SR*, Vol. 1, No. 1, p.10, <https://doi.org/10.21625/archive.v1i1.112>.
- Mahnke, F.H. (1996) *Color, Environment, and Human Response: An Interdisciplinary Understanding of Color and its Use as a Beneficial Element in the Design of the Architectural Environment*, John Wiley & Sons, New York, NY.
- Malik-Moraleda, S., Roca, M. and Gibson, E. (2022) 'Color naming in Tsimane' – Spanish bilinguals indicates that differential experience with content domains affects lexical access', *Scientific Reports*, Vol. 12, No. 1, p.17479.
- Mitton, M. and Nystuen, C. (2021) *Residential Interior Design: A Guide To Planning Spaces*, John Wiley & Sons, New York, NY.
- Munsell, A.H. and Nickerson, D. (1915) *Munsell Color System*, Wadsworth, Howland & Company, Incorporated, Baltimore, MD.

- Nakhodaezadeh, M., Jafarabadi, M.A., Allahverdipour, H., Matlabi, H. and Dehkordi, F.R. (2017) 'Home environment and its relation with quality of life of older people', *Journal of Housing for the Elderly*, Vol. 31, No. 3, pp.272–285.
- Nijdam, N.A. (2009) 'Mapping emotion to color', *Book Mapping Emotion to Color*, pp.2–9.
- Park, J. and Ko, D. (2021) 'Catch me if you can: effects of AR-enhanced presence on the mobile game experience', *Internet Research*, Vol. 32, No. 4, pp.1235–1263.
- Peace, S. (2022) *The Environments of Ageing: Space, Place and Materiality*, Policy Press, Bristol, UK.
- Portillo, M. (2009) *Color Planning for Interiors: An Integrated Approach to Color in Designed Spaces*, John Wiley & Sons, Hoboken, NJ.
- Rooth, M.A. (2017) 'The prevalence and impact of vision and hearing loss in the elderly', *North Carolina Medical Journal*, Vol. 78, No. 2, pp.118–120.
- Sagawa, K. (1999) *Visual Comfort to Colored Images Evaluated by Saturation Distribution*, Vol. 24, No. 5, pp.313–321, Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur.
- Sagawa, K. (2000) *Visual Comfort Evaluated by Number of Categorical Colors in a Colored Image*, Vol. 25, No. 3, pp.193–199, Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur.
- Sagawa, K. and Shimizu, Y. (1996) 'Psychophysical methods for assessing visual comfort for a colored pattern of natural environment', in *Human Vision and Electronic Imaging*, April, Vol. 2657, pp.42–52, SPIE, <https://doi.org/10.1117/12.238748>.
- Saito, M. (1996) 'Comparative studies on color preference in Japan and other Asian regions, with special emphasis on the preference for white', *Color Research & Application*, Vol. 21, No. 1, pp.35–49.
- Sandford, J.L. (2011) *Warm, Cool, Light, Dark, or Afterimage*. In *New Directions in Color Studies*, in Biggam, C.P., Hough, C.A., Kay, C.J. and Simmonds, D.R. (Eds.), p.10, John Benjamins Publishing Company, Amsterdam and Philadelphia.
- Shen, Y.C., Chen, Y.S. and Hsu, W.H. (1996) 'Quantitative evaluation of color harmony via linguistic-based image scale for interior design', *Color Research & Application*, Vol. 21, No. 5, pp.353–374.
- Tang, F. (2021) 'Intelligent colour matching method for 3D character animation based on texture features', *International Journal of Arts and Technology*, Vol. 13, No. 2, pp.123–136.
- Tewari, A., Fried, O., Thies, J., Sitzmann, V., Lombardi, S., Sunkavalli, K., Martin-Brualla, R., Simon, T., Saragih, J. and Nießner, M. (2020) 'State of the art on neural rendering', *Computer Graphics Forum*.
- Tian, F., Razak, H.B.A. and Isa, M.J.B.H.M. (2024) 'The performance of Chinese traditional culture and the design of cultural and creative products under the five-color view', *Cultura: International Journal of Philosophy of Culture and Axiology*, Vol. 21, No. 3, pp.104–120.
- Tian, Z. (2021) 'Cognition and construction of the five-color theory of the color culture of China', *Journal of Chuxiong Normal University*, Vol. 36, No. 2, p.129.
- Tojiboev, I.O.U. (2021) 'Chinese architecture', *Oriental Renaissance: Innovative, Educational, Natural and Social Sciences*, Vol. 1, No. 8, pp.40–42.
- Torres, A., Serra, J., Llopis, J. and Delcampo, A. (2020) 'Color preference cool versus warm in nursing homes depends on the expected activity for interior spaces', *Frontiers of Architectural Research*, Vol. 9, No. 4, pp.739–750.

- Wang, F., Buranaut, I., Zhang, B. and Liu, J. (2024) 'Emotional matching model construction of the interior interface form of age-friendly housing in Jinan city examined using Kansei engineering', *Heliyon*, Vol. 10, No. 7, p.e29129.
- Wilms, L. and Oberfeld, D. (2018) 'Color and emotion: effects of hue, saturation, and brightness', *Psychological Research*, Vol. 82, No. 5, pp.896–914.
- Windley, P. and Scheidt, R. (2015) *Physical Environments and Aging: Critical Contributions of M. Powell Lawton to Theory and Practice*, Routledge, New York, NY.
- Xiong, J., Hsiang, E-L., He, Z., Zhan, T. and Wu, S-T. (2021) 'Augmented reality and virtual reality displays: emerging technologies and future perspectives', *Light: Science & Applications*, Vol. 10, No. 1, pp.1–30.
- Yıldırım, K., Hidayetoğlu, M.L., Gökbulut, N. and Müezzinoğlu, M.K. (2019) 'Effects on students' perceptual evaluations of the wall colors used in design studios by the virtual reality method', *ICONARP International Journal of Architecture and Planning*, Vol. 7, No. 1, pp.99–120.
- Yuki, O., Inoue, Y. and Tango, M. (2021) 'Study on required brightness and apparent color for a life activity: comparison between the young and the elderly', *Journal of Environmental Engineering (Japan)*, Vol. 86, No. 779, pp.35–42.
- Zhang, C., Chen, Y., Dewanker, B.J., Shentu, C., Tian, H., Liu, Y., Wan, J., Zhang, X. and Li, J. (2024) 'Emotional landscapes in urban design: analyzing color emotional responses of the elderly to community outdoor spaces in Yi Jie Qu', *Buildings*, Vol. 14, No. 3, p.793.
- Zhang, X.M., Zhou, Y.X. and Wu, X.P. (2012) 'Knowledge management and the application of the Chinese traditional five-color aesthetic', *Applied Mechanics and Materials*, Vol. 201, pp.1021–1024.
- Zhou, F., Ji, Y. and Jiao, R.J. (2021) 'Emotional design', *Handbook of Human Factors and Ergonomics*, pp.236–251.
- Żurek, J., Rudy, M., Stanisławczyk, R. and Duma-Kocan, P. (2023) 'The effect of Kosher determinants of beef on its color, texture profile and sensory evaluation', *International Journal of Environmental Research and Public Health*, Vol. 20, No. 2, p.1378.