Young people's colour preference and the arousal level of small apartments

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Abstract

It is widely believed that people have preferences in relation to the colour of their interior environment. With the development of the global small apartment industry, it is important to understand well people's colour preference for apartments. This study investigated the apartment colour preference (N = 958) and the arousal level measured as heart rate variability for 70 young Chinese people for 21 colours. The findings indicate that young Chinese people (22-27 years of age) prefer light red, red, yellow, and gray areas of the colour space, and least prefer darker colours in the green, gray, and brown areas of the colour space. In terms of heart rate variability arousal, it was found that colours in the red, purple, and yellow areas of the colour space had the highest effect on heart rate variability arousal, vs gray and brown colours, which were found to have the lowest effect on arousal levels

Keywords: small apartments, colour preference, arousal level, young people

1. Introduction

Colour is one of the key visual dimensions of the environment.[1] In various settings such as stores, malls, restaurants, offices and hospitals, appropriate colour can convey not only product information and features but can also attract customers' attention,[2-6] stimulate their willingness to purchase, and greatly improve brand recognition.[7-12] Previous studies have explored the relationship between colours in various spaces and user preferences.[13-16,7] Colour preference is an important consideration in architecture and interior decoration because people prefer a harmonious environment that makes them happy.[17] Colour schemes used in workplaces and offices found to be more pleasant, attractive, satisfying and dynamic can effectively improve employee performance and accuracy. [18-19] In marketing research, [20] colour, as an important factor of the environmental "atmosphere", induces specific emotions that motivate purchase intention. [21-25] However, consumers' colour preferences for apartment environments have so far received little attention.

As the world's population grows, small apartments are becoming more and more popular, especially in metropolitan areas.[26] In international metropolises such as London, San Francisco and Sydney, the occupancy rate of small apartments accounted for 45% of the local occupancy rate due to the large international student population and employed youth.[27] In Japan, where traditional social life is family-based, about 40% of young people now live in small apartments.[28] In Hong Kong, due to various factors such as cross-city work of young migrant people, multi-generational family homes have decreased, and with the development of urbanisation, the occupancy rate of young people in small apartments has reached over 92%.[29] China is one of the fastest-growing countries in the small apartment industry, and the number of young people living in small apartments rose from 6% in 1999 to 42% in 2019.[30-31] More than 200 million young people live in a small apartment. In the small apartment rental industry, there are apartments with multiple conditions for young people to choose from, and the atmosphere of the apartment plays an important role in marketing.[32-33] In order to compete with other rental housing agencies, rental housing agencies need to implement new interior design strategies to attract the attention of young people. One of the most effective and economic strategies is to choose or modify interior colours. Nevertheless, little is known about the colour preference of young people for small apartment environments.

Many theories have attempted to explain the origins of human colour preference. One discovery found that the colour environment affects human performance and emotional preferences.[34] Colours play an important role in the environment, but people have questions about the exact impact of specific colours on humans and their behaviour.[35] In Bakke's study of 1,095 Dutch people's colour preference, it was found that there was a significant relationship with gender, education level, age, culture and personality traits.[36-37] Moreover, young people's colour preferences have been studied in the past, with many studies indicating that there are significant gender differences.[42-43] Gunter and Furnham highlighted that the popular colours and main colours of various periods of social development had a huge impact on the colour preferences of young people. [44] At the same time, the colour preferences of young people will be consistent with the development trend of popular colours in various periods,[45-47] and young men and women have obvious differences in colour choices.[48-52]

The colour preference shown by people can be divided into three types: phenomenological (i.e., based on experience), biological (i.e., arousal level or neural activity in response to different colours) and ecological (i.e., emotional response to colour).[38] An objective method of assessing the relationship between colour and arousal level that does not rely on self-reporting is the use of physiological measures, such as heart rate variability (HRV).[40] HRV refers to changes in the time intervals between consecutive heartbeats called interbeat intervals (IBIs). HRV is inversely related to emotional intensity and arousal. [90] Kaiser (1984) conducted a systematic review of multiple physiological colour responses and believed that colour is associated with multiple physiological responses. For example, red is frequently associated with excitement, fear, high arousal, etc.[77] Zohdi (2006) also studied the impact of colour and light on physiological states. The results of this study showed significant changes in heart rate after few minutes of exposure to different colours with various intensities. Previous experimental studies have suggested that long-wavelength colours, such as red and yellow, are more arousing than short-wavelength colours, such as blue and green.[39-41,4] In brief, physiological measures, such as HRV, are objective cues for identifying the arousal level induced by space colours.

The main purpose of this study is to explore the colour preferences of young Chinese people in small apartment environments and use HRV to assess the arousal level caused by the colour of the space. Thus, we attempt to answer four questions: (Q1) What is the colour preference of young Chinese people for small apartments? (Q2) What is the arousal level induced by the environmental colour of a small apartment? (Q3) What is the relationship between colour preference and arousal levels in small apartments? (Q4) Does gender affect colour preference and arousal level? This study may also provide a theoretical basis for housing agencies to understand the importance of young people's colour preferences for decorating small apartments.

2. Experiment 1. Young people's colour preference for small apartments

2.1 Participants

The participants in this study were Chinese undergraduate or postgraduate students between the ages of 22 and 27. 1,052 participants took the Ishihara colour blindness test, and 94 participants were eliminated due to varying degrees of colour blindness. A total of 958 participants completed the experiment (491 males and 467 females). In total, 718 participants took part in the first round of the survey (361 males and 357 females); 240 participants took part in the second round of the survey (120 males and 120 females). All individual participants in this study gave written informed consent prior to their participation and were free to withdraw from the study without prejudice. The experiment was reviewed and approved by the Research Ethics Committee of the University of Leeds.

2.2 Scene setting

Before the study, the physical feature data was collected from 200 small apartments from nine large rental housing agencies in China using the convenience sampling method. The preliminary field survey revealed that the typical area of small apartments in China is 10-15 m2. For this study, the floor area was set to 12 m2 to get a typical floor plan of small apartments. The interior wall surfaces and ceilings were covered with one main colour in the current small apartment design, while furniture and floors were decorated in a sub-colour.

The scenes of a small apartment with various colour environments were simulated using a 3D realistic computer rendering program that projected images of a typical small apartment with a total usable area of 12 m2. Facilities such as kitchens and bathrooms were excluded from the scenes. The average illuminance level in the generated scenes was set to 500 lx and had a correlated colour temperature of approximately 4500 K for general lighting and decorations. A 3D realistic computer rendering tool was chosen as the method to generate realistic interior perspectives. This method has been used in previous studies[7,16,56] and verified for its accuracy in representing actual scenes. [57]

HTC Vive HMD was used for the study. It has an OLED display with a resolution of 2160×1200. The refresh rate is 90 Hz, and it provides 110 ° of field of view (FOV). For each colour condition, three 3D scenes (V1-V3) were generated to imitate the participant looking at different perspectives in the apartment from a 4–5 m distance with an angle of view of approximately 40 °. The main colours (selected for large surfaces) and the sub-colours (for furniture and floor) are displayed in Figure 1. Examples of computer-generated scenes with the 21 colour conditions are shown in Figure 2.

2.3 Values of colour scenes

A total of 21 environmental colours and one furniture colour currently used by rental housing agencies were selected from 200 small apartments. In each generated scene, the vertical wall surfaces and the ceiling were covered in the main colour, while sub-colours were used for furniture and floors. The 21 colour samples were organised into seven colour groups. The samples included four primary hues based on Hering's[58] colour opponency theory: red (R), yellow (Y), green (G), blue (B) and three other colours: purple (P), brown (BR) and grey (Gr). 3D rendering software was used to output the RGB and CIE L*a*b* values of the rendering colour of each scene (see Table 1).

2.4 Procedure

The experiment was conducted indoors without daylight. Testing for all sessions took place during the period September to November 2020, and the participants were taken to the specialist space between 10:00 a.m. and 4:00 p.m. They were instructed how to use the VR glasses in order to get used to watching the scene before starting the experiment. At the beginning of the experiment, each participant was asked to look at a 10-sec white screen for chromatic adaptation. Then 21 3D colour scenes appeared on the VR head-mounted display in random order and stayed for 10 sec for the participants to experience each image in all aspects. The order in which the colours were presented was counterbalanced across the participants.[59] After all the presentations were completed, all 21 colour scenes appeared on the same screen, the first part of the experiment was mainly about collecting data about the participants' three most favourite colours.

The second part of the experiment was carried out 7 days after the end of the first part of the experiment. This method has been verified in multiple papers. [53-55] The participants were asked to score 21 colours using a 10-point scale, with 10 points per level and a total of 10 levels. The scoring scale was 0-100 points, with 0 meaning the least favourite and 100 the most favourite colour. [53]

2.5 Statistical analysis

Before calculating analyses of variance (ANOVAs) and Cronbach's alpha, we calculated the average score of the 21 colour preferences. We also used an ANOVA to test whether the different colours differed across genders and calculated Cronbach's alpha coefficient to check the internal consistency reliability of the experiment. Any statistical significance ($\alpha < .05$) was followed up with LSD tests. Bonferroni corrected for multiple comparisons. All statistical analyses were conducted using SPSS v17.0.

2.6 Results

2.6.1 Analysis of young people's colour preference

The first rounds of testing in the first experiment found that, as shown in Figure 3, among the 21 colours from which the participants should choose their three favourite ones as the wall colour for a small apartment, red-1 (33.5%) was chosen most frequently, followed by yellow-1 (26.1) and grey-4 (25.3%). The selection rate was higher than 25%, and the number of participants choosing these three colours was significantly higher than for the other colours. On the other end, green-1 (4.2%) had the lowest selection rate, followed by brown-1 (5.4%), grey-1 (5.3%) and green-1 (6.2%): all of these were selected by less than 10%. Except for red-1-2, yellow-1,3, grey-4 and green-3, the selection rate of the other colours was less than 20%. It seems that more participants choose low saturation colours instead of high saturation colours. The participants preferred warm colours such as red or yellow over cool colours.

2.6.2 Mean scores of 21 colours rated

In the second part of the experiment, the participants scored the 21 colours. The results revealed significant differences among the 21 colours ($F(20, 5019) = 48.29$, $P < .0001$, $\eta_p^2 = 0.72$). After the post-hoc test, it was found that red -1 showed no significant difference to yellow-1 and grey-4 ($P > .05$), but red-1, yellow-1 and grey-4 were all significantly different from the other 18 colours in preference ($P < .001$). Figure 4 shows that most participants preferred red-1 ($M = 82.18$, $SD = 17.39$), yellow-1 ($M = 77.74$, $SD = 17.19$) and grey-4 ($M = 76.81$, $SD = 15.53$). The lowest scores were found for green -1 ($M = 18.23$, $SD = 11.41$), grey -1 ($M = 19.34$, $SD = 16.92$) and brown -1 ($M = 21.52$, $SD = 15.81$). In addition, the results also show that among the seven hues, colour preference decreased with increasing saturation. The chroma difference in each hue also had a significant impact on preference ($F(6, 1428) = 82.47$, $p < .05$, $\eta_p^2 = 0.54$). The post-hoc testing of seven hues showed that (red-1 and (red 2-3), yellow-1 and (yellow 2-3), gray-4 and (grey 1-3, 5), green-3 and (green 1-2)) have significant differences between them ($p < .05$). Blue, brown and purple also have the same differences, but they are not significant ($p > .05$). This shows that the participants preferred the walls of the small apartments to have low saturation colours. Also, the trend in the colour preference ratings of the 718 participants in the first round was the same as that of the 240 participants in the second round.

2.6.3 Gender differences in colour preference

Significant differences were found in the preferences of men and women regarding the 21 colours ($F(20,5019) = 41.477$, $p < .01$, $\eta_p^2 = 0.39$), as well as a significant two-way interaction ($F(20, 5019) = 6.342$, $p < .01$, $\eta_p^2 = 0.64$). A 7 (red vs yellow vs grey vs green vs blue vs brown vs purple) × 2 (gender) ANOVA demonstrated a significant main effect of hue ($F(6, 1428) = 37.13$, $p < .01$, $\eta_p^2 = 0.51$). This shows that men and women have significantly different colour preferences for small apartments, and that the hue has a significant effect on the difference in colour preference between men and women.

Further post-hoc testing showed that there were significant differences between genders in the preference for red-1 ($p < .05$), red-3 ($p < .01$), yellow-1 ($p < .01$), green-1 ($p < .05$), grey-1 ($p < .05$) and brown-1 ($p < .01$). Figure 5 shows that for small apartments that integrate life and sleep, men preferred blue, green, yellow and grey more than women did, and there were significant differences in yellow-1, green-1 and grey-1 compared to women ($p < .05$). Women preferred red, brown and purple, and there was a significant difference between red-1 and brown-1 compared to men ($p < .05$). The results also show that the more saturated the colour, the greater the difference between men and women, which is reflected in red-1 ($p < .05$) and red-3 ($p < .01$). Green and blue also have a difference, although it is not significant ($p > .05$).

3. Experiment 2. Young people's physiological evaluation of the colour of small apartments

3.1 Participants

70 participants who had participated in the first round of the experiment participated in the second experiment (41 males and 29 females). No participant reported any cardiovascular or nervous system problems, and they were instructed not to smoke or drink caffeine or alcoholic beverages, get enough sleep and avoid physical labour for six hours before the experiment. Participation was by informed consent, and the experiment was reviewed and approved by the Research Ethics Committee of the University of Leeds.

3.2 Scenes and colour samples

Experiment 2 used the same scenes and colour samples as Experiment 1.

3.3 Apparatus and materials

Cardiovascular parameters were measured using an infrared pulse plethysmograph (AD Instruments 1020 EC) attached to the tip of the ear, using a sampling rate of 1000 Hz and a 200 Hz low-pass filter. Movement artefacts were removed manually, and the missing heartbeats were reconstructed by interpolation before the number of heartbeats was determined and transformed into the mean heart rate (reported in beats per min; bpm). [90] Finally, the heart rate variability was calculated as the standard deviation variable of the NN intervals, and HRV was measured during exposure to different colour stimuli.[40]

3.4 Procedure

The second experiment was performed 15 days after the end of the first experiment to avoid interference from the first experiment. The participants were taken to the laboratory between 9:00 a.m. and 4:00 p.m. Before the start of each experiment, the objectives and procedures were explained to the participants. During the first 15 min after installation of the heart rate monitor, the participants were asked to remain seated without moving. Their heart rates were recorded for 3 min to determine the resting (baseline) heart rate. Afterwards, they put on VR glasses to watch a white screen for chromatic adaptation. After 10 seconds, 21 3D colour scenes were played. Each colour scene lasted for three minutes to help the participants better experience the colour stimulation in the virtual scene. A 3-minute white screen provided a gradual transition between the different colour scenes to avoid any residual effects on the participants from the previous colour stimulation. After the experiment, the participants rested in the laboratory for ten minutes for chromatic adaptation. This process was conducted twice. Each time, the participant was exposed to a different colour condition. In line with a Balanced Latin Square design, the order in which the colours were presented was counterbalanced across the participants.[59]

3.5 Statistical analysis

This study used a repeated-measures ANOVA and Bonferroni correction multiple comparisons to analyse the HRV data. Any statistical significance ($\alpha < .05$) was followed up with LSD tests. The data are shown as mean ± standard error. The Pearson correlation coefficient was used to analyse whether there is a correlation between colour preference and HRV arousal level. All of the data we tested were analysed by using SPSS 17.0.

3.6 Results

3.6.1 Evaluation of young people's HRV arousal to colour

In the second experiment, it was found that the average difference of the 21 colours had a significant level, as did the effect between groups ($F(20,1380) = 15.477$, $p < .01$, $\eta_P^2 = 0.48$), as shown in Figure 6. This means that for the participants in different colour environments, the HRV arousal level was different, that is, different colours had a significant impact on the HRV of the young people. The colours that had the least impact on HRV were red-3 (M =2.35, SD = 0.64), purple-2 (M =2.43, SD = 0.55) and yellow-2 (M =2.51, SD = 0.60). As previously discussed, an individual's arousal level is inversely related to the HRV, which means that the young people had higher levels of arousal for red-3, purple-2, and yellow-2. Grey-5 (M = 3.86, SD = 0.28), brown-2 (M = 3.68, SD = 0.74) and grey-4 (M = 3.61, SD = 0.25) had the highest HRV values, which means that the young people had lower levels of arousal for grey-5, brown-2, and grey-4. Further post-hoc testing showed that there was no significant difference in HRV activation between red-3 and purple-2 ($p > .05$), but there were significant differences in activation between red-3, purple-2 and other colours ($p < .05$). This also shows that the red-3 and purple-2 environment could produce significant arousal in young people. In addition, this study compared the chroma difference of each hue and further found that red-3 and red 1-2, purple-2 and purple-1 revealed significant differences ($p < .05$), which seems to indicate that the more saturated the colour, the greater the level of arousal in the participants.

3.6.2 Gender differences in heart rate variability level

Figure 7 summarizes the arousal levels of the 21 colours regarding HRV in men and women. The results show that gender and colour have a significant two-way interaction ($F(20,1428)=21.935$, $p <.05$, $\eta_P^2 = 0.36$), and ANOVA demonstrated that the colour has a main effect on the difference of gender-related HRV activation ($F(20,1428) = 30.386$, $p <.05$, $\eta_P^2 = 0.72$). Further analysis of the difference in HRV activation between men and women by colour revealed a significant difference between men and women ($F(1,1428)=10.364$, $p <.05$, $\eta_P^2 = 0.43$). This demonstrates significant differences in the arousal levels of men and women in response to different colours, and proves that colour has a major effect on the difference in HRV activation between men and women.

It was further found that different hues led to different HRV arousal levels for men and women. Men had higher HRV arousal levels for purple, blue, and green, while women had higher HRV arousal levels for red and yellow. Post-hoc testing showed that women had higher HRV arousal levels in red, yellow and brown environments than men, and the difference was found to be significant ($p<.01$). In contrast, men had higher HRV arousal levels in purple, blue 1-2 and green 1-2 environments than women, and there were significant differences ($p<.05$). However, the difference between men and women in the grey environment was not significant ($p>.05$). Moreover, analysing the HRV difference of the colour in each hue to gender, it is found that the HRV difference between men and women showed an increasing trend with the increase of colour saturation, but there was no significant difference ($p>.05$).

3.6.3 Correlation between colour preference and HRV arousal

The Pearson correlation coefficient was used to test the correlation between young people's colour preference and HRV arousal level, The results showed no correlation between colour preference and HRV arousal ($r=0.13$ $p=.72>.05$). Further examination of colour preference and HRV arousal level by gender (male: $r=0.44$, $p=.68>.05$; female: $r=0.51$, $p=.41>.05$) showed that male and female colour preference and HRV arousal did not correlate either. This shows that there is no significant relationship between young people's colour preference and HRV arousal levels for the 21 colour environments examined.

4. General discussion

There are several interesting findings in the present study. Firstly, among the 21 colours, red-1, yellow-1 and grey-4 were preferred the most, while green-1, grey-1 and brown-1 were the least preferred (Q1). Secondly, based on HRV, red-3, purple-2 and yellow-2 had the highest arousal levels for young people, while grey-4, grey-5 and brown-2 had the lowest arousal levels (Q2). Thirdly, when comparing the colour preference and HRV arousal levels for the 21 colours, it was found that there was no significant correlation for both; however, red and yellow were not only the favourite hues, but the HRV activation level was also the highest. (Q3). Fourthly, gender differences were found in both colour preference and HRV arousal.

4.1 Colour preference for small apartments

The study of colour preference of young people for small apartments showed that young people prefer red-1, yellow-1 and grey-4. This was consistent with findings from some previous studies.[60-62] But in this study, grey-4 was identified as being a preferred colour of small apartment environments by young people. In previous studies, grey was generally considered an unfavourable or negative colour.[62] We analysed the participants' reasons for choosing grey. Most participants believed that grey-4 as a light grey is very similar to modern popular colours (retro grey). Many high-end fashions such as Diro or some advertising posters often use lighter grey as the main colour, and the participants believed that this is a trendy colour. Besides, we also found that young people prefer low-chroma colours as the environmental colours of small apartments. The results show that the three most preferred colours for young people are light colours (low chroma), and the least preferred ones (green-1, grey-1 and brown-1) are dark (high- chroma) colours, which is consistent with previous research.[63]

This study also found that there are significant gender differences in environmental colour preferences. Women were found to like red, brown and purple more than men did, especially red-1. This is consistent with a large number of previous publications. Whether it is the preference research of colour patches or the colour research of carriers such as the environment or interface, women's preference for pink (red-1) seems to appear to develop early in childhood. [19,49, 64] This gender-stereotyped preference emerged from the development of gender-specific roles in childhood. [64] In contrast, men preferred blue, green, yellow and grey more in our study than women did. Men's preference for cool colours is also affected by the development of their role in the process of growing up, [49] and many studies have shown that this gender preference is difficult to change due to the attributes of the colour carrier. [64,81] There are also some studies which suggest that gender differences in colour preference might arise from associations of different specific objects between the two genders. [45,81] Therefore, there is no single theory that can explain all the findings about gender differences in colour preference. In the future, a more comprehensive and evidence-based study is needed to determine gender differences in colour preference.

Furthermore, some studies have shown that the reason why people prefer warm colours in their living rooms is because warm colours can increase positive emotions and make a room feel more spacious.[40] On the other hand, people prefer low-chroma or cool colours in their bedrooms to help them sleep better and to relieve tension. [4] For small apartments, this is comparable with the common functional area of activity room and bedroom. The young Chinese people who participated in this study preferred light-warm colours for this comprehensive environment. This result may show that the participants believed that light-warm colours could improve the spaciousness of small apartments and increase positive emotions (such as safety and warmth). [64] Therefore, this confirms that the colour preference in the living space varies depending on the type of activity for which it is intended [73] and affects the mood and performance of the target population in the area in the long term.[80]

4.2 HRV arousal level caused by the environmental colour

This study also proved that colour affects the HRV arousal level of young people in small apartments. The results show that warm colours in small apartment environments cause higher HRV arousal than cool colours and greys. The results are consistent with previous studies.[41,65,66,4] The results of the 21 colours on the HRV of the participants show that the order of the environmental colour of the small apartment on the young people's HRV arousal is: red, purple, yellow, blue, green, brown, grey (R >P >Y >B >G >Br >Gr). This also proves previous studies indicating that the long-wavelength colours red and yellow are more arousing than the short-wavelength colours blue and green.[39] However, Wilson believes there is a possible U-shaped relation with arousal in the visible spectrum, with the colours at the ends (i.e., red and purple) being more arousing than the colours at the centre (e.g., green).[67] Two hues of grey and brown were added in this study, and it was found that for grey and brown, the arousal level was lower than for the main colour. Therefore, the results of this study are consistent with the principle of colour arousal level of R> O> Y> G <B <P. [67]

There were also significant differences in the HRV arousal of men and women in the environment colour of small apartments. For women, warm colours caused higher arousal levels than cool colours. Compared with men, red and yellow led to higher levels of arousal in women. Men were more aroused by purple and blue, while men and women were less aroused by green, grey and brown. This fully shows that the HRV arousal level of men and women has a U-shaped relation in the visible spectrum, and that the colours at both ends are more likely to cause arousal in both men and women.[39] This also shows that the HRV arousal level and the colour preference of men and women are consistent.

Our study also found that among the seven hues, colours with a higher level of saturation were more capable of arousing higher HRV, while colours with a lower level of saturation led to less HRV arousal. This is consistent with some other studies. Colours with high chroma will strongly affect a human's visual perception and physiological response, especially when performing some highly mental workload tasks (such as visual tracking, comparison tasks[75-76]), and physiological representations will react strongly (for example, physiological signs such as brain cerebral oxygenation, HRV and galvanic skin response[77]). Such colours have a promoting effect on task performance[75] but being in such an environment for a long time will cause mental tension and even negative emotions such as depression and anxiety[78-79].

4.3 The relationship between colour preference and HRV arousal level

The comparison of the environment colour of the small apartment on the young participants' preference and their HRV arousal level shows that the colour preference of warm over cool colours matches with the high arousal levels induced by warm colours over cool colours. The red environment caused the highest HRV arousal, and light red (red-1) was also the most popular environment colour. Young people not only need to perform work or other activities in small apartments, but also need to sleep and rest in them. A small apartment offers an environment that has to be suitable for multiple functions, so in this environment, colours are needed to generate a certain level of activation for people. Moreover, in small apartments, men and women prefer light colours rather than grey or dark colours, which shows that light colours can make a small apartment feel more spacious and relieve mood swings.[70] For women, apartments in the red environment caused the highest HRV arousal, and the pink environment was also the most preferred one. For men, on the other hand, apartments in the purple environment caused the highest HRV arousal, but purple was not necessarily the least preferred colour. Therefore, in this study, this relationship was found only to be true for women and not for men.

In 21 colour scenes, this study found that the higher the chroma, the stronger the HRV arousal level. However, the young people preferred low-chroma colour environments. Some studies have found that high-chroma scenes can significantly arouse human physiological responses. This type of theory has reference significance for the colour design of high-alert working environments (e.g., industrial plants or nuclear power plant control rooms)[82], while strongly saturated colours can be used in a small area (e.g., traffic signs) instead of in the entire environment.[48] For small apartments, high-chroma colours may produce a sense of depression, which has been verified in some extreme environments, such as the internal environment of a space station or a submarine. [83-84] A large number of studies have found that colours with high chroma or strong contrast can cause severe visual stress, which in turn induces negative emotions, because high chroma increases the cerebral oxygenation of the visual cortex of the brain. [85,92-93] Mahnke (1996) believes that the colour design in a man-made environment must refer to the colour matching of a natural scene. When artificially applied chroma exceeds the appropriate level in a natural scene, it will cause discomfort. [86] Similarly, in the colour scenes of this study, the wood colour used most frequently in the furniture of 200 small apartments was selected. The wood colour as the mainstream furniture colour is largely due to the use of colours in the natural scene, and may also be due to the production process caused by the low cost. Some studies believe that the wood colour in environmental decoration is a kind of mild and affinity colour, [87] which does not interfere with the main atmosphere of the environment[86] and has the ability to heal the mind. [88] Therefore, when designing the colour matching of the internal environment of small apartments, more attention should be paid to the colour preference of young people, and the relationship between colour and human HRV arousal could provide a reference for the basic hue of this kind of multifunctional environment.

4.4 Limitations and future directions

There are several limitations to our study. Firstly, this study performed colour rendering of typical small apartment scenes, and obtained 21 colour scenes to study colour preference and HRV arousal. This method allows participants to fully immerse themselves, to experience the effects of colours in a specific environment, and is a method used in many previous studies[40,72,74]. But there are also some studies that use colour patches for the participants to test the impact of colour[53,91]. Obviously these two methods are completely different. Future studies could compare the similarities and differences between the participants' preferences and HRV arousal for colour environments and colour patches. Secondly, according to the relevant literature, in addition to gender, age, ethnicity and cultural factors also affect personal colour preferences. Some studies have shown that in some European countries, people prefer cool colours such as blue as the colour of apartments.[73] Thirdly, this study used the most frequently used wood-coloured furniture in small apartments and 21 environmental colours to generate a typical small apartment to ensure the validity of the experiment. This method is consistent with other studies.[40,72,74] However, some studies have found that the contrast between the colour of the decorations and the atmosphere colour in the environment can also cause different visual perceptions.[89] In the future, the influence of different decoration or furniture colours on the environment colour should also be studied. Therefore, this study provides new empirical evidence for young Chinese people's environmental colour preference in small apartments. During the Covid-[1]9 pandemic, it may provide insights into people's colour preference during the long period of home isolation and lay the foundations for future theoretical and practical research. This study is the first part of a series of small apartment colour research studies.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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