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A Study on the Effect of Green Vision in Inter-House Spaces on Mental Fatigue

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Abstract:

As a necessary passageway and leisure place for public space in residential areas, the inter-house space has a high value of roaming experience. In the course of this study, the effect of the green view rate of inter-residential space on the experience of public space is discussed by means of a field experiment. Subjects' levels of mental fatigue before and after experiencing the three scenes are compared. The effect of green space green-visual rate on recovery from mental fatigue was analysed. The results of the analysis showed that the rate of green vision did influence the experience of the inter-house space. A correlation analysis was conducted to investigate the intrinsic link between the green view rate and the recovery from mental fatigue, which could not only further promote the healthy development of the urban residential landscape, but also significantly improve the quality of the urban living environment. The final conclusion is that a threshold range of 40-45% for greenery is the best for recovery from mental fatigue, and will contribute to the improvement of greening indicators in residential areas in the future.

***Keywords**: inter-housing space; mental fatigue recovery; green vision rate; residential areas; correlation analysis*

I. INTRODUCTION

In recent years, economic indicators of greenery have often been used in community construction. In the planning and construction of blueprints for a particular area, designers often use the technical and economic indicator "greening rate" to measure the degree of greenery in the community, which is an important quality indicator to examine the greening of the landscape in a residential area [1]. "The 'green ratio' is simply the percentage of the community area that is green and provides a clear and simple indication of the extent of greenery within the site area. For a clear and intuitive understanding of the greenery of an area is known by the term 'green ratio'. However, another concept, the green space ratio, is seldom mentioned [1]. The 'green space ratio' refers to the proportion of the total green space between houses or the total area of public green space and public services to the total area of residential land [1]. The green space ratio is more relevant to people's residential life and is a relatively straightforward way of expressing it. The green space ratio is a direct reflection of the level of greenery in a community [1]. However, this method of calculation has certain shortcomings, as it does not reflect the quality of greenery

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on a three-dimensional level, and there are some unreasonable quantification methods.

Another common indicator used to assess the level of greenery in a neighbourhood is the Green View Index [1]. "The concept of Green View Index was pioneered by the academic Yoji Aoki [2] and is simply understood as the percentage of green in the view of the area that is visible to the human eye. Compared to greenery and green space ratio, the green view rate is simpler, more straightforward and more intuitively accurate. Yoji Aoki also delved into the interrelation- ship between green perception and the perception of spatial green mass. Since then, a number of scholars and experts have further researched the specific measurement and application of the green ratio, and have created a basic theoretical framework based on experimental data [3].

Time is also one of the variables that need to be considered in the research in order to be able to effectively measure the optimum greenery for a residential site in a community area. As the greenery rate is a dynamic value. It is related to the growth cycle of plants and the maintenance of the green belt. Different times of the year can lead to a wide variation in the results [4]. Therefore, the experiments were generally conducted during the months of June to July, when the plants have the best landscape impact, grow most abundantly from June to July and are instantly available for green-visibility photography. Through the study, it was found that places such as parks and green spaces in the city can actually be replaced by spaces with a higher green vista, which can also achieve the same effect of relieving the pressure of residents' lives [5]. Green spaces can provide people with places for leisure and recreation, and have a good and positive effect on improving the mental health of residents [6].

Taking three existing residential areas in Harbin City as an example, the study takes the space between homes and mental fatigue as the object of research, and through the field experience of green space scenes, and discusses the impact of green vision rate on the recovery of mental fatigue of residents, to determine what range of green vision rate is more effective in the recovery of mental fatigue, so that the findings of the study can provide reference for the design of green space in residential areas, and create a more suitable living environment for urban residents. The findings of this study can be used as a reference for the design of green spaces in residential areas, creating a more suitable living environment for urban residents.

II.DATA ACQUISITION ADN CONCEPT AND IMAGE ANALYSIS

2.1 Study Scope and Site Selection

The study area is the south of the Songhua River in Harbin, with a total area of 1001.62 km^2; the three main residential areas are Daoli District, Nangang District and Xiangfang District. The selected residential areas are Democracy Home in Daoli District; Hongqi Residential Model New District in Nangang District; and Yuanchuang Shade House in Xiangfang District.

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2.2 Acquiring Images

According to the study, the angle of the field of view that the human eye can involve is about 80~160°, the angle of the upper and lower field of view is generally about 130°, and the horizontal field of view of the eye is about 60° [7]. In accordance with the average height of Chinese adults published by the Chinese Health Planning Commission in 2015, the research work was carried out to obtain images at a controlled height of 1.5 to 1.6m [8], as shown in Fig 1.

Using a camera to capture an image at a fixed location is a simple way to simulate human eye vision and requires little equipment and is relatively simple to operate. This is why it has become the most common method of testing green vision today. By analysing the imaging principle of the camera, we know that the lens is most effective if the focal length is controlled at 24 mm, and that the field of view of the human eye is also the closest [7].

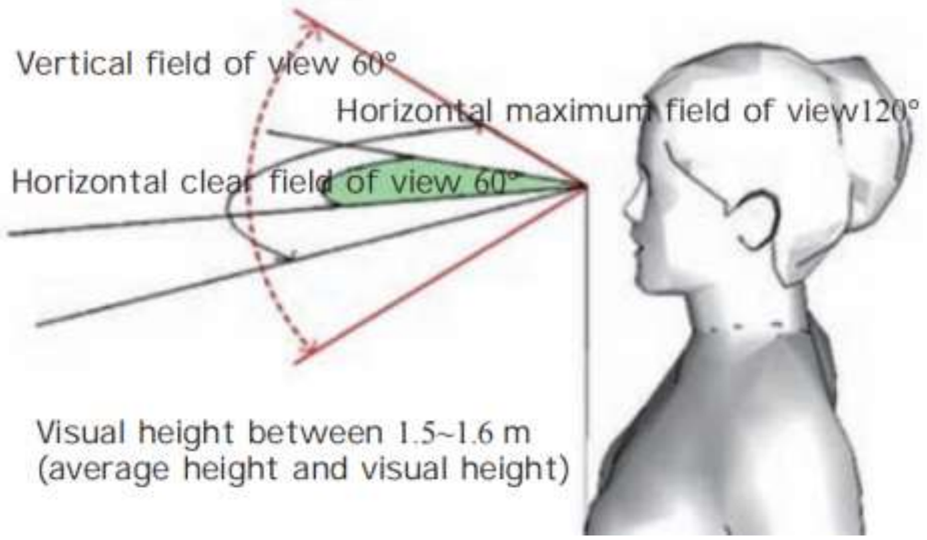

Fig 1: The average field of view of the human eyes
Redrawn from references [8]

2.3 Green Spaces between Houses

An inter-residential green space, as the name suggests, is a green space where greenery is planted. It has now become a key component of the urban residential green space system. It is an [9] and is therefore very closely linked to the daily life of the neighbourhood.

The green belt of residential land is often planted mainly with shrubs and flowers. According to the different characteristics and functions of the plants and their ornamental value, a scientific and reasonable mix of green and deciduous plants is used to adjust the ecological structure according to the growth rules of the plants and to create a multi-level integrated composite ecology. To make the artificial plants more closely resemble the original plant community layout, the morphological changes of the plants between each season should also be considered. The green space between houses is very closely linked to the life of the residents, and also has certain practical and ornamental properties [9], so it is necessary to study the

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green space between houses in urban residential areas.

2.4 Indicators for Assessing Mental Fatigue

Due to experimental constraints, we have considered the parameters for assessing mental fatigue and have chosen to use heart rate variability (HRV), which is generally regulated by the autonomic nervous system and is a phenomenon of sinus heart rate variability over a specific period of time [10]. Medical research has shown that the autonomic nervous system is quite sensitive to the detection of mental fatigue and that feedback is rapid. Therefore, using heart rate variability as the main indicator for assessing mental fatigue can accurately reflect the fatigue index of the body over a short period of [10].

In general, the following methods are commonly used to analyse heart rate variability: time-domain analysis and non-linear analysis. The time-domain analysis has shown that the HRV index is sensitive to the onset of mental fatigue [11]. In addition, some experts have used the heart rate variability index to analyse the mental fatigue of drivers through frequency domain analysis, showing a high correlation between the frequency spectrum of 0.1 Hz and the level of fatigue [12]. Meanwhile, some domestic experts and scholars have also used HRV to test different values in the awake and fatigued states, showing that there is a significant difference in HRV between the awake and fatigued states [13]. This makes it easier to capture dynamic HRV and to measure and analyse HRV [14] anytime, anywhere. HRV is an important indicator of mental fatigue due to its accuracy, responsiveness and ease of access to data [14].

2.5 Green Rating Calculation and Statistics

Most of the spaces in front of the house chosen for this experiment are rectangular in shape, similar to the walking space of the road in front of the house. Since people are constantly changing their position when moving around the green space between the houses, and the green vista is a static and quantifiable value, the green vista should be controlled for static transformation [15]. By taking into account the speed of adults during walking, sections of the road can be divided, with cross sections taken at 1.5 metre intervals, and then five consecutive sections of the road can be selected as the mean value of the green rate [15]. In addition, in the process of using pictures for the calculation of the green-visibility of a particular road section, different location points should also be taken into account. If the location of the person is used as the base point, divided into east, south, west and north by geographical location, the green-visibility of the pictures in these four directions will be weighted and averaged to give the value of green-visibility at this observation point.

According to the experimental requirements, the value of the green rating needs to be calculated with a basic accuracy rather than estimated. According to current statistics, the main software tools commonly used to calculate the Green Sight Ratio are GIMP and Photoshop [8]. For this experiment, we have chosen to use Photoshop, which has a function that allows the green areas of a photograph to be selected to include various elements such as mountains, coloured plants and water, while excluding distracting elements such as buildings, cars and pedestrians from the calculation [8]. This method is already

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considered accurate, but it is not very efficient and takes a long time to post-process [16].

The percentage of green plant pixels in the overall image pixel value is calculated as the percentage of the green view of the location in this direction, depending on the location selected for the photograph. This is shown in TABLE I.

The formula for calculating the green rating is:

Green Vision = (green pixel value in the photo frame / total pixel value in the photo frame field of view) ×100%

The specific operation is as follows: import the photo into Photoshop CS6, create a new layer and activate it, select the green part of the selection with the magic wand tool, create a selection and fill it with black to form a colour block, which is blocked by people, buildings, landscape vignettes, cars and other force majeure factors are not included, open the Photoshop CS6 histogram, at this point the information table The value shown in the "Pixels" column is the total pixel value of the green image, after which the same operation can be carried out again, during the second operation, the whole image can be selected and the number shown in the "Pixels" column is the pixel value; the calculation is carried out according to the formula to The green percentage of the photograph is then averaged over the different directions, as shown in Fig 2 and 3.

Fig 2: Original rendering of green view (author's own drawing)

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Fig 3: Diagram of the process of calculating the green-visibility ratio (self-drawn by the author)

III. EXPERIMENTAL PROCEDURE

According to the empirical sample, a sample size of ≥ 30 [17] was selected, a total of 40 students were selected as the sample for this experiment, of which a total of 22 were male and 18 were female, 19 of these 40 were design students.

Mental fatigue has many different states and is very complex, involving changes in human emotions. Typically, when a person is mentally fatigued, they tend to be very agitated, depressed, have difficulty concentrating on a task, are easily irritated when faced with a problem, and have a much lower desire to interact with others around them [18]. Mental fatigue is not only found in the working adult population, but is also very common in the student population. In recent years, as academic pressure has increased and the frequency of daily assignments and examinations has continued to rise, research has found that [19] increased exposure to green spaces is significantly associated with reduced health risks in sub-healthy populations, and that prolonged exposure to green environments can have a beneficial effect on people's physical and mental health. The subjects selected for this experiment were all postgraduate students who were between the ages of 24-30. The results of this study will be more significant as this group is under great academic pressure and is therefore prone to mental fatigue and other related symptoms, and can recover more quickly from mental fatigue than those already in the workforce.

In order to obtain the best results for the study, the time period was chosen to be between 13:00 and 18:00. After the subjects arrived at the experimental site, they were first allowed to familiarise themselves with the environment for about 5 minutes to adjust their heart rate, and then the researcher did the pre-experimental training to understand the experiment and to make sure that the apparatus could be worn properly and walked around freely, following the steps as follows.

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First, the students were given a 2-minute impromptu inner monologue speech, followed by a quick calculation of a slightly more difficult mathematical problem. After the calculations were completed, the students were asked to fill in the POMS Mindfulness Scale, the Fatigue Scale and the Visual Analogue Scale according to their emotions and fatigue at the time. This was followed by a live green space scene experience. There were a total of 3 experimental scenes and the participants were asked to choose the one that made them feel the most relaxed and comfortable after the experience. After the students had experienced all 3 scenes, they were asked to select one of the three scenes. The whole process was recorded in real time for later analysis. Finally, the POMS Mindfulness Scale, the Fatigue Scale and the Visual Analogue Scale were completed once again. The three scenes chosen for the experiment are shown below in Fig 4 to 6.

Scene 1:

Fig 4: Red Flag Residential Model New District GVI

Scene 2:

Fig 5: Farrer Utopia GVI

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Scene 3:

Fig 6: Democratic Homes GVI

TABLE I. Calculation of average scenario green-view rates

	GVI (average)
Scene 1	42.92%
Scene 2	47.28%
Scene 3	35.77%

Note: Green Visibility Ratio (GVI)

IV. RATING OF MENTAL FATIGUE

4.1 Subjective Scale Evaluation

POMS Mood Scale: In psychology, it is believed that people are more likely to experience symptoms [20] of mental fatigue when they are in a state of emotional instability. In this study, the State of Mind Scale was used to provide a comprehensive assessment of the subjects' emotional state at the time of the experiment.

The Fatigue Scale—14: The Fatigue Scale—14 [21] was developed by Trndie Chalder and other psychiatrists. The scale has good reliability and validity [22-23] and is a good indicator of the degree of fatigue and fatigue symptoms in a sample with a medical condition (fatigue is the main symptom) and in a healthy sample, with two groups measuring the severity of fatigue, the psychological impact of fatigue and the close relationship between fatigue and rest and sleep. Fatigue is a relatively abstract psychological state and is particularly strong for the subjective feelings of the individual. Typically, we can divide fatigue into two main categories, mental fatigue and physical fatigue, which are also intrinsically linked. The fatigue

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scale in this study was able to measure the level of fatigue of the subjects and the results obtained were relatively intuitive.

Mental fatigue visual scale: This scale consists of a scale of 0 to 150, where 0 means no mental fatigue and 150 means that they feel extremely mentally fatigued. In the course of the study, this scale was used as the best way to self-evaluate the level of fatigue [24-26].

4.2 Objective Physiological Data

LOPE ECG monitor: The monitor model ER2 is used to measure real-time ECG waveforms by handheld or chest-worn measurement. Once the measurement is complete, the data is transferred to a cloud platform where it can be further analysed. Because the ECG signal acquisition technology is relatively mature and simple to use, it is also possible to extract data on heart rate variability from the data, which is a good response to sympathetic- vagal interactions.

This range of advantages has made HRV signals a popular research project in the medical field [27]. The analysis of HRV signals allows for the mapping of time and frequency domain variability, which in turn can reflect the level of fatigue of the subject [28]. As the sympathetic and parasympathetic nerves are constantly changing, so is the heart rate. In order to obtain more accurate data, the high-frequency component of heart rate variability is extracted and used to make a comprehensive assessment of the changes in the parasympathetic [29-30] nervous system. Therefore, the index of [31] HRV is used in the course of the experiment and the output data are shown in Fig 7 to 10.

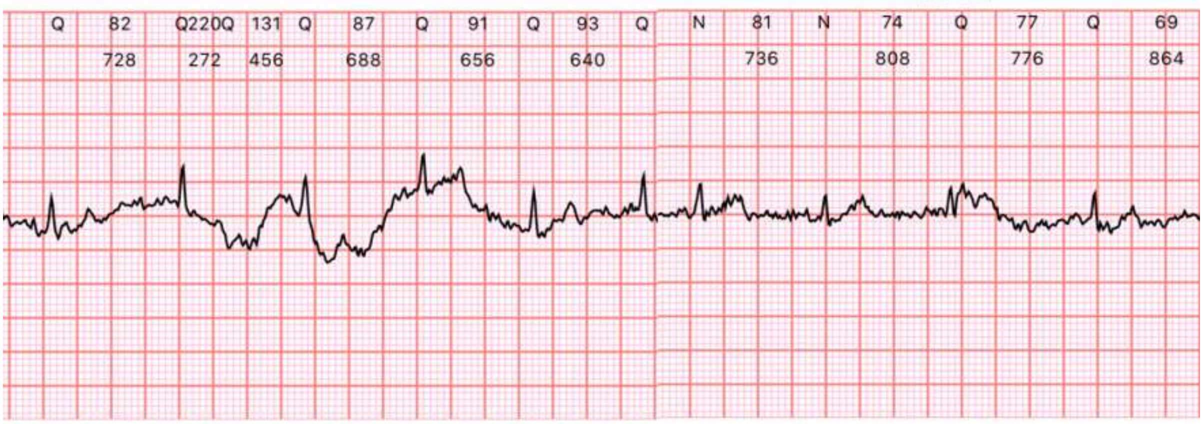

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Fig 7: Experimenter I physiological data output graph (author's own drawing)

Fig 8: Plot of experimenter two physiological data output (author's own drawing)

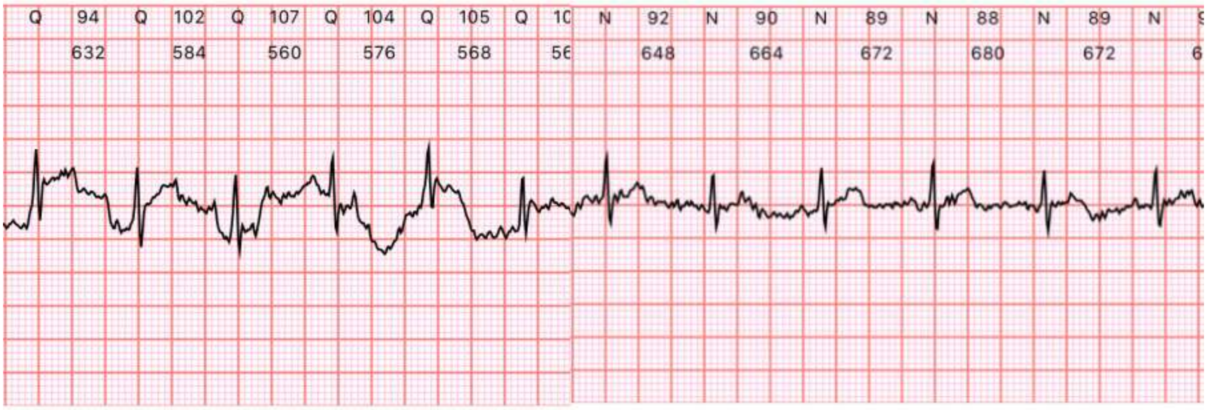

Fig 9: Plot of experimenter tri-physiological data output (author's own drawing)

Fig 10: Experimenter IV physiological data output graph (author's own drawing)

4.3 Mental Fatigue Recovery Effects

4.3.1 Subjective mental fatigue recovery effects

In the course of the study the effectiveness of the subjects' recovery from mental fatigue was verified in two main ways: subjectively and objectively. For the subjective evaluation, the following scales were used: the POMS Mindfulness Scale and the Fatigue Visual Analogue Scale, the results of which are shown in

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TABLE II.

TABLE II Descriptive statistics for recovery from subjective mental fatigue (author's own drawing)

	Average value	Standard deviation	Minimum value	Maximum value	Skewness	Kurtosis
Emotion Scale	11.28	7.22	2.01	25.00	0.690	-0.655
Fatigue Scale	2.10	1.473	0.00	6.00	1.087	1.246
Fatigue visual simulation	2.38	1.14	0.00	5.00	1.089	-0.59

In the subjective evaluation, the use of different evaluation methods led to the same conclusion that when subjects experienced the green space scene, it was more conducive to helping them recover from their mental fatigue. Almost all subjects had very good results in terms of self-rated fatigue recovery.

By performing a Pearson correlation test, it was possible to develop that there was no significant difference between the different genders, in terms of the effectiveness of mental fatigue recovery. Therefore, we can draw a tentative conclusion that there are no significant differences in the effectiveness of the species mental fatigue recovery methods depending on gender (e.g. TABLE III).

TABLE III. Gender and mental fatigue recovery effects (author's own graph)

	Emotion Scale	Fatigue visual simulation	Fatigue Scale
Correlation coefficient	-0.251	-0.170	-0.246
Significance	0.119	0.272	0.140

In the process of selecting the subjects, the subjects were divided according to the differences in their professions into two groups, design-related and non-design-related. The correlation test showed that there was no significant difference between the two groups on the POMS Mood and Fatigue scales, but the results obtained on the VAS Mental Fatigue Visual Analogue Scale showed a significant negative correlation between design majors and mental fatigue recovery. This result may be due to the fact that design-related students are more sensitive to visual aspects and therefore subjectively assessed that this method did not have the desired effect on recovery from mental fatigue, see TABLE IV.

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TABLE IV. Professional and mental fatigue recovery effects (author's own graph)

	Emotion Scale	Fatigue visual simulation	Fatigue Scale
Correlation coefficient	0.075	0.346*	-0.217
Significance	0.643	0.016	0.179

*, at the 0.05 level (two-tailed), the correlation is significant.

4.3.2 Objective mental fatigue recovery effects

For the objective evaluation, the main purpose of the experiment was to monitor the changes in the subjects' heart rate using the ER2 chest-worn device and to assess the effect of mental fatigue recovery by analysing this data. During the test, the average value was chosen because of the specific changes in heart rate between the fatigue generating process and the experience of green space,as shown in TABLE V.

Based on the physiological data from the ER2 Chest Wearing Instrument, the subjects showed a large variability in heart rate during the early stages of mental fatigue. During the experience, the HRV leveled off, and when the subjects experienced the green scenario for approximately 3 minutes, they were then asked to fill out the scale, at which point their HRV gradually fluctuated slightly. Analysis of the data showed that after experiencing the green scenes for a period of time, the subjects' mental fatigue did relax to a certain extent, confirming that the green space scenes experienced by people do have a mental fatigue recovery effect, see Fig 11.

Fig 11: Diagram of the process of change in physiological indicators (author's own drawing)

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Table V. Descriptive statistics for recovery from objective mental fatigue (author's own drawing)

	Average value	Standard deviation	Minimum value	Maximum value	Skewness	Kurtosis
HRV	-2.54	7.23	-0.05	-11.51	1.360	3.89

Note: Heart rate variability (HRV)

In the analysis of the intrinsic link between gender and HRV, it was found that there was no significant difference in the recovery of HRV by gender. In addition, there were no significant differences in the recovery of physiological indicators between subjects of different professions and the correlation between the two was also not significant, as shown in TABLE VI and TABLEVII

TABLE VI Gender and objective mental fatigue recovery effects (author's own graph)

	Recovery of heart rate variability
Correlation coefficient	-0.177
Significance	0.430

TABLE VII Professional and objective mental fatigue recovery effects (author's own graph)

	Heart rate variability
Correlation coefficient	0.118
Significance	0.615

V. THE EFFECT OF SPATIAL GREEN-VISIBILITY ON RECOVERY FROM MENTAL FATIGUE

5.1 The Relationship between Spatial Greenness and Recovery from Mental Fatigue

The effects of green vision and mental fatigue recovery for the different scenes were combined and analysed to produce TABLE VIII.

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TABLE VIII. Effect of scene green vision and recovery from mental fatigue (author's own drawing)

Scenes	Level of recovery from mental fatigue	Correlation coefficient	Significance
Scene 1	Emotions	0.327*	0.040
Scene 2		0.396*	0.012
Scene 3		0.127	0.436
Scene 1	Fatigue	-0.135	0.406
Scene 2		-0.310	0.052
Scene 3		-0.184	0.255
Scene 1	Visual fatigue simulation	0.068	0.676
Scene 2		-0.194	0.229
Scene 3		0.149	0.358
Scene 1	Heart rate variability	0.131	0.581
Scene 2		-0.056	0.815
Scene 3		0.048	0.841

*, at the 0.05 level (two-tailed), the correlation is significant.

From the photographs taken of the experimental sites, it can be seen that the scenes in the selected experimental sites are a mixture of trees and shrubs, with more trees in Scenes 1 and 2 and more shrubs in Scene 3. It is clear from the data obtained that for scenes 1 and 2, it is easy to see that the recovery from mental fatigue is more effective if the subject is in a scene with a greater percentage of greenery. In addition, it can also be seen that there is an upper limit to the recovery from mental fatigue, which means that there is an optimal threshold range, and when a certain spatial green rate has reached the optimal range, then the recovery effect will increase, and on the contrary, the recovery effect will decrease.

Based on the above correlation analysis, a prior regression analysis was conducted on the relevant variables to obtain a regression equation, through which the effect of spatial green vision rate on the recovery effect of mental fatigue could be obtained. It was found that in Scenarios 1 and 2, there was a positive correlation between the recovery of mental fatigue and the green vision rate, with the coefficients showing significance, and the effect of the constant term was not significant. In the process of testing the regression equation, more data were needed to test the constant term, as detailed in TABLE IX

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TABLE IX. Parameters of the linear regression (two-way choice) equation (author's own plot)

	R	R^2	F	B	Sig.
Scene 1	0.27	0.073	1.411	9.605	0.000
				0.293	0.250
Scene 2	0.426	0.182	3.994	6.900	0.019*
				0.659	0.041*
Scene 3	0.479	0.229	5.348	6.817	0.012*
				0.919	0.033*

*, Sig. <0.05, coefficient test significant.

Note: **R** is the correlation coefficient, $\mathbf{R}^2$ is the coefficient of determination of goodness of fit, **F** is the overall truth, and **B** is the regression coefficient.

VI. CONCLUSION

This paper quantifies the results of the experiment and finds that if the space has a suitable green-visibility ratio, it will greatly help people recover from mental fatigue. In addition, the paper also discusses the extent to which different scenes with different greenery have an impact on the recovery from mental fatigue, and explores the inherent link between the two. This paper mainly adopts a combination of quantitative analysis and subjective analysis, moving away from the previous monolithic scale evaluation. As heart rate is relatively intuitive, non-invasive and portable, HRV was selected as the physiological data indicator to assess the change in the subjects' mental fatigue status before and after experiencing the green scenes in the house space.

This analysis led to the following conclusion: most people felt that the combination of trees and shrubs helped them to recover from mental fatigue. Secondly, when the subjects experienced different scenes with different greenery rates, people subjectively preferred scenes with greenery rates in the range of 40-45%. Finally, by gender, there were some differences in the choice of spatial element characteristics.

This study, although highly manipulative, immersive or fatiguing, and susceptible to external factors such as traffic noise, bird song, playfulness, temperature, humidity and other changes in the actual environment can affect the results that the researcher is trying to measure. Moreover, the subjects were all postgraduate students aged 24-30, which is relevant and may have many factors that will be taken into account in the future, such as career, income, employment status, family conditions and background, emotional situation, life experience or social experience, etc. By considering more influential factors together, more accurate findings will be obtained and the results of the study can be further enhanced. The

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generalisability of the findings can also be further enhanced.

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