

Exploring the Integration and Aesthetic Value of Chinese Painting Art in the Exterior Design of Modern Housing Buildings

Hongbo Zhang^{1,*}

¹ College of Art, Zhengzhou University of Science and Technology, Zhengzhou, Henan, 450064, China

Corresponding authors: (e-mail: zhanghongbonankai@126.com).

Abstract The rapid development of the construction industry and the deepening reform of spiritual civilization construction, the public's aesthetic level is also improving, which puts forward more diversified demands for housing building appearance design and decoration. The article proposes an aesthetic evaluation method of modern housing building appearance design with VR eye movement data tracking. Semantic difference analysis is used to design the questionnaire of modern housing building appearance design, and factor analysis is used to obtain the main influencing factors of housing building appearance design. VR eye-tracking technology is introduced to integrate Chinese painting art and modern housing building exterior design in a virtual scene, and the eye movement data of the subjects are obtained, so as to analyze the influence of the integration of Chinese painting art and modern housing building exterior design on the subjects' gaze time and visual comfort. The mean value of the subjects' evaluation scores on the housing building exterior design fused with Chinese painting art was 3.283 points, and the longest total time spent on the modern housing building exterior fused with Chinese painting art was about 2750.94 s, and the shortest total time spent on the simple building exterior was only 175.98 s. When the color purity and luminance of the Chinese painting art and the modern housing building exterior design exceeded 82.1% or 65%, respectively, it would significantly reduce the subjects' visual comfort. Incorporating the art of Chinese painting into the architectural appearance design of modern housing requires choosing relatively warm colors and diverse elemental symbols as a way of highlighting its aesthetic value in architectural appearance.

Index Terms modern housing, building appearance design, Chinese painting art, VR eye tracking, factor analysis method

I. Introduction

Chinese painting is a traditional form of painting in China, and one of the most popular forms of painting among art lovers. Chinese painting is a painting made by ancient people using ink, mineral pigments, vegetable pigments and other colors, and utilizing the techniques of writing and brushwork to create paintings on silk and rice paper. Chinese paintings are also framed and made into scrolls for easy transportation and preservation [1]-[4]. Chinese paintings are mostly landscapes, figures, birds and flowers, as well as various folk customs, is the ancients of the natural environment, social life, political and economic, as well as cultural and artistic aspects of knowledge and expression, after thousands of years of inheritance and development, the art of Chinese painting has been in the composition, brushwork, as well as chapping, etc. to form a fixed pattern [5]-[8], a profound influence on the other types of paintings painting techniques and the content of the subject, the use of ink and ink outlines made of Chinese paintings also have a different from other Chinese painting also has a different mood from other paintings of beauty, the pen is free to go, the overall line of the dashing spirit, local details but carefully carved, whether it is landscape flowers and birds or characters, all give a person with the form of both God and the feeling of the spirit of Yuxiu [9]-[12].

Architectural design performance contains a variety of different disciplines of knowledge, so architects need a long time to learn and experience accumulation, to be able to complete the task of architectural design, in which the architects of the artistic expression and the environment and other aspects of the mastery of the level of their own ability [13]-[16]. Because in the past, most of the Chinese house building types are relatively single, and with a very strong regional color, so the architectural expression often lacks novelty [17]-[19]. With the continuous development of China's economy, people's demand for aesthetics is also higher and higher, so the use of Chinese painting elements in modern architectural design has also received widespread attention [20], [21].

This paper proposes an evaluation method of modern housing building exterior design based on VR eye tracking

technology, which clarifies the aesthetic value of the art of Chinese painting in the exterior design of modern housing buildings through the eye movement data of the subjects in the virtual scene, and innovates the research method of the integration and development of the art of Chinese painting and the exterior design of modern housing buildings.

The full application of the art of Chinese painting in the exterior design of modern housing buildings gives modern housing buildings higher artistic value and stronger artistic color. Based on the introduction of the basic functions and constituent elements of the appearance of modern housing buildings, this paper discusses the necessity and feasibility of integrating the art of Chinese painting with the appearance design of modern housing buildings. The relevant questionnaire of modern housing building appearance design is constructed by semantic difference analysis method, and the main factors affecting modern housing building appearance design are mined by factor analysis method. Then we use VR eye tracking technology to build a virtual scene to analyze the eye movement data of the subjects when they are looking at the Chinese painting art and modern housing building exterior design, so as to clarify the audience's gaze time and visual comfort on the housing building exterior after the integration of the Chinese painting art, and to provide a new path for the integration of the Chinese painting art and the modern housing building exterior design, as well as for the presentation of the aesthetic value.

II. Modern housing building exterior design integrating the art of Chinese painting

The application of Chinese painting art in the exterior design of modern housing buildings can better present innovative and diversified artistic features, more perfectly reflect the aesthetic charm of modernism, and form unique and practical design concepts and design features. In the diversified development of architectural aesthetics, the integration of the art of Chinese painting can better highlight the “nutrition” and value of the discipline, and continuously provide the architectural design industry with new and modern modeling methods to create modern housing buildings that are sought after and favored by the public.

II. A. Basic Functions and Components

II. A. 1) Basic functions of the exterior of housing buildings

The basic function of the exterior of a house is to enclose the internal space, and the exterior of the house is constructed in the form of a wall, and its exterior as a whole consists of a variety of factors, including the arrangement and combination of form, color, texture, and scale in the visual form, which partly creates its own material and aesthetic attributes. As mentioned in “Two Views, Three Qualities,” the exterior image needs to respond to external factors such as the surrounding spatial environment and human history, and harmonize the housing body with the surrounding area and the city through the exterior. From this point of view, housing appearance is an important part of place shaping, with the attribute of place, which covers the overall function of housing appearance in a more comprehensive way, and can be divided into the following three points:

(1) Material function - mainly refers to the appearance as part of the enclosure of the internal space of the housing, to undertake the functions of protection, filtration, use and so on. In terms of protection, in order to create a quality living environment, the exterior part of the housing should have selectivity, protection and filtration of external factors. In terms of use, the exterior needs to be recognizable so that residents can effectively use the exterior structure and facilitate the function of communication between residents.

(2) Aesthetic function - housing appearance is a way of presenting emotion and culture, and housing appearance with intrinsic aesthetic value is not only a response of belonging to the emotion of the residents, but also a concrete expression of regional culture, which is of great significance to the creation of a distinctive urban landscape.

(3) Place function is an important means of giving residents a sense of belonging, a major tool for shaping residents' living places, and an important part of the overall living experience.

II. A. 2) Components of the exterior of housing buildings

With the development of technology and changes in communication methods, the determination of appearance elements is not only limited to fixed perspectives, such as advertising media, digital art, and other extensions have greatly enriched the vocabulary of architectural appearance. In this process, the appearance is often not static, but dynamic and continuous. On the one hand, the building itself is in continuous “dialog” with itself, and on the other hand, it is also in long-term coexistence with the architectural space of the street. It can be seen that changes in the appearance of the building are a way of communicating information about the city, which is essentially an output of feelings, both perceived and influenced by the elements of communication.

The classification of appearance components of housing buildings is shown in Figure 1, and is summarized from the level of architectural visual representation from shallow to deep as architectural form elements, architectural perceptual elements, and architectural metaphorical elements [22]. The viewer grabs the visual images generated by the material elements, and then combines them with the real-world psychological feelings, generates the immaterial aesthetic consciousness and value framework through brain processing, and carries out replication,

continuation, and re-creation through the act of cultural communication. By physically “restoring” the suspended elements, it can be found that three elements play a role, namely, the object of communication (architectural form), the subject's sensory experience and emotions (perceptual feelings), and the value elements (cultural metaphors) that can be deeply interpreted and deposited.

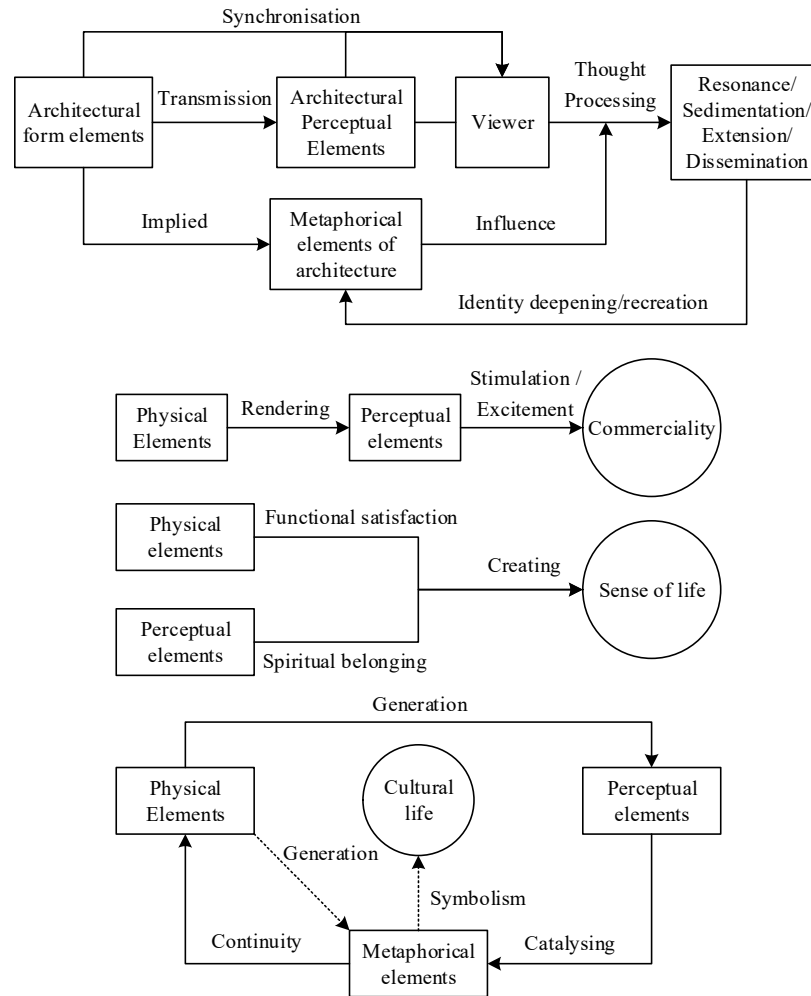


Figure 1: Classification and operation of the elements of the building exterior

II. B. Integration of the art of Chinese painting with the exterior design of housing buildings

II. B. 1) Characteristics of expression in the art of Chinese painting

Chinese painting is a national treasure, a representative of the level of artistic development, and its value is unquestionable. Chinese painting contains many elements such as dots, lines, surfaces, colors, textures and so on. Dot is one of the most basic elements in Chinese painting, which can be combined with other elements to form new works in addition to composing works alone, and different concentrations and humidity of dots bring different visual feelings, and their application in the development of painting is extremely wide.

Line is also a crucial part of Chinese painting, is the most concise means of expression, many writers in the development of painting pay special attention to the use of lines, and will use different forms of expression of lines to make the painting emotion better conveyed. Different painters have different aesthetic tastes and artistic cultivation, and therefore use different techniques when depicting lines.

Surface is also a basic element of Chinese painting, which has many expressive techniques, such as color separation and ink splashing, and is dependent on the existence of lines. Painting is a creative method that conveys the artist's creative intent through the scientific application of points, lines and surfaces. Chinese painting is mainly composed of poetry, calligraphy, painting and printing, which are combined to create a finished product with unique characteristics, which is what makes Chinese painting so special. Context is the core content of artistic creation, which can convey people's pursuit of art and inner feelings, and it also gives Chinese painting a sense of mystery,

which makes it have a unique charm and enhances its attractiveness to the audience.

II. B. 2) Building Appearance of Integrating the Art of National Painting

Chinese painting has a long history, unique artistic charm, unique artistic form and emotional expression, and has important application value in architectural appearance design. Architectural appearance designers need to deeply explore the art form and aesthetic value of Chinese painting, understand the cultural connotation, historical tradition and regional characteristics of Chinese painting, and integrate it with the concept and method of architectural appearance design, so as to convey the spiritual connotation and artistic value of the elements of Chinese painting to the people through the architectural appearance, to show the unique charm of Chinese traditional culture, and to promote the inheritance and promotion of traditional culture.

The art of Chinese painting has strong regional characteristics, reflecting the local cultural traditions and aesthetic concepts, designers can combine the cultural background and historical characteristics of Chinese painting to draw design inspiration and highlight the regional culture. Northern Chinese painting art belongs to the category of brushwork, rigorous composition, structural integrity, color matching rigorous atmosphere. Southern Chinese painting art belongs to the category of writing, beautiful composition, smooth lines, delicate emotions, designers should be clear about the characteristics of different regional Chinese paintings, extract the required elements of Chinese paintings, design the appearance of buildings with regional characteristics.

Designers should break through the traditional design thinking constraints, and adopt diversified design elements and design materials to create diversified architectural appearance design. Designers can integrate the elements of Chinese painting into the architectural decoration design, and design the light and shadow structure that changes with time, so as to make the architectural appearance design more dynamic beauty. The use of Chinese painting elements in architectural design is the inheritance and promotion of traditional culture, and architectural designers need to clarify the connotation and value of Chinese paintings to enrich the cultural connotation and artistic characteristics of the building as a whole.

III. Aesthetic experience of modern housing building exterior design based on eye movement data

Modern housing building design not only pursues practicality, but also has certain requirements for design effect. In order to objectively enrich the connotation of modern housing building exterior design and enhance the artistic aesthetics of modern housing building exterior design, integrating and applying the elements of Chinese painting art in modern housing building exterior design is also an important direction for modern art and architecture design work. This chapter mainly gives the method of analyzing the aesthetic experience of modern housing building exterior design based on eye movement data, using VR eye movement technology to obtain the results of the audience facing the modern housing building exterior design with the integration of the art of Chinese painting, and exploring the trend of the aesthetic experience of the audience, so as to provide support for the in-depth integration of the art of Chinese painting with the design of modern housing buildings.

III. A. Factor Analysis and SD Methods

III. A. 1) Factor Analysis Basics

Factor analysis is a statistical technique method for extracting common factors from multiple sets of variables, using dimensionality reduction to convert multiple evaluation indicators into a number of evaluation indicators and to evaluate the results [23].

The goal is to perform a better analysis by using X to represent the original and standardized variables, ε is used to represent the special factors that only have an effect on X , and $F_1, F_2, \dots, F_m (m < p)$ is used to represent the standardized common factors. The steps of the factor modeling are as follows:

(1) $x = (X_1, X_2, \dots, X_p)'$ is the observed random vector with mean vector $E(X)$ of 0 and covariance matrix $COV(X)$ of Σ , where covariance matrix Σ is equal to correlation matrix R .

(2) $F = F_1, F_2, \dots, F_m$, where $(m < p)$ is the unobservable variables, their mean vector $E(F)$ is 0 and covariance matrix $COV(F)$ is 1, which means that the components of vector F are independent of each other.

(3) $\varepsilon = (\varepsilon_1, \varepsilon_2, \dots, \varepsilon_p)'$ is not related to F and the covariance matrix Σ_ε of $E(\varepsilon) = 0$, ε is a diagonal square matrix. Then:

$$COV(\varepsilon) = \Sigma_{\varepsilon} = \begin{bmatrix} \sigma_{11}^2 & 0 & \\ & \sigma_{22}^2 & \\ 0 & & \sigma_{pp}^2 \end{bmatrix} \quad (1)$$

That is, the components of ε are also independent of each other and then the model:

$$\begin{cases} X_1 = a_{11}F_1 + a_{12}F_2 + \dots + a_{1m}F_m + \varepsilon_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \dots + a_{2m}F_m + \varepsilon_2 \\ \dots \\ X_p = a_{p1}F_1 + a_{p2}F_2 + \dots + a_{pm}F_m + \varepsilon_p \end{cases} \quad (2)$$

These steps mentioned above constitute the factor model. Following the above model, it is converted into the following matrix:

$$X = AF + \varepsilon \quad (3)$$

where the matrix is:

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1m} \\ a_{21} & a_{22} & \dots & a_{2m} \\ \dots & \dots & \dots & \dots \\ a_{p1} & a_{p2} & \dots & a_{pm} \end{bmatrix} \quad (4)$$

The above procedure is a factor loading matrix. The factors are then analyzed to obtain the common factor that has the greatest degree of influence on each factor. The specific method is:

Step1 Based on the identified problem, select the variables to be analyzed and test the applicability of factor analysis to the analyzed variables. It is important to note that before conducting factor analysis, the researcher must first perform a correlation matrix on the raw data. When the correlation coefficient in the model is greater than 0.35, the model is not suitable for factor analysis.

Step2 Extraction of Public Factors. The main methods of public factor extraction using SPSS include principal component analysis, generalized least squares, generalized least squares and so on. In this paper, principal component analysis is used.

Step3 Clarify the specific number of factors. The number of public factors should not be too much, not too little, not too much. If it is too small, it will result in the loss of information about the original variable information, therefore, in factor analysis, the appropriate number of public factors must be selected.

Step4 Use rotation to make factor variables easier to interpret. The use of rotation gives a better description of the factors and makes the factors interpretable by name.

Step5 Name the common factors. The naming of factors can be decided arbitrarily according to the experience of researchers without going through strict regulations.

Step6 Calculate the factor scores. The parsing results are analyzed and evaluated in depth, and the factors are scored comprehensively to get the relevant conclusions.

III. A. 2) Survey design based on SD methodology

Based on the perspective of housing residents, this survey investigates the subjective feeling of users on the various elements of modern housing architectural appearance design integrating the art of Chinese painting and overall residential satisfaction, and its main steps are as follows:

(1) Survey object selection. Considering the volume ratio, layout form and appearance design of the settlements, 12 representative sample housing neighborhoods in T city are selected.

(2) Pre-survey. A pre-survey was conducted on the selected sample housing neighborhoods and their residents to preliminarily determine the main problems reflected by the residents of the neighborhoods, in order to further define the focus of the study and guide the design of the questionnaire.

(3) Factor adjective selection. According to the existing literature and the national gold medal housing architectural design assessment index system, the general factors of modern housing architectural design are selected, and combined with the special factors added by the pre-sample housing community and residents' research. Table 1 shows the performance of the factors and adjectives of the psychological feelings of the residents of modern housing building exterior design, which mainly contains two categories of appearance characteristics and experience feelings.

Table 1 The factors of psychological feeling and the adjective

Type	Psychometric factor	Adjective
Appearance characteristics	Aesthetic	Ugly - Beautiful
	Sense of order	Untidy - Ordered
	Scale sense	Cramped - Expansive
	Style	Ancient - Modern
	Color	Dim - Bright
	Coordination	Abrupt - Harmonious
Experience feeling	Position feeling	Lost - Determined
	Attraction	Resistant - Attracted
	Abundance	Monotonous - Rich
	Fun	Bored - Interesting
	Culture	Thin - Thick
	Activity	Stiff - Active

(4) Sample data sources. The survey was conducted among residents of the 12 sample housing neighborhoods, with 20 to 40 questionnaires distributed in each neighborhood.

(5) Preliminary analysis based on residents' survey. Based on the statistics of the results of the sample housing architectural appearance design questionnaire, combined with the SD curve, the characteristics of housing architectural appearance are preliminarily analyzed from the perspective of the residents' psychological feelings.

(6) Analysis of factors influencing the satisfaction feeling of housing building appearance design. Using the method of mathematical statistics, through the correlation analysis between the factors of housing building appearance design, factor analysis and multivariate analysis of factors and objective indicators, the satisfaction feeling of modern housing building appearance design is obtained in a more comprehensive way.

III. B. Eye Movement Data Acquisition and Quantitative Metrics

III. B. 1) VR eye movement data acquisition

In general, human visual attention is always focused on the object to be cognized so that the consciousness can successfully capture the perceptual stimulus. With the rise of VR technology, eye tracking technology can realize the real-time tracking of the user's gaze focus in the virtual reality environment. And the virtual scene is highly stable and less intrusive, data acquisition is easy and highly accurate, and the visual region of interest can be temporally recognized and reconstructed. Therefore, compared with the real scene, the experimental setup of eye tracking in VR environment is more flexible, which can control the data collection and environment settings, and enhances the possibility of research in the neighborhood of modern housing building exterior design.

Based on the above analysis, this study relies on VR eye-tracking technology to conduct perception experiments of modern housing architectural appearance design, i.e., by constructing a virtual spatial environment of modern housing architectural appearance that typically integrates the art of Chinese paintings in a 3D VR environment, simulating the real visual activity behavioral environment of human beings, and tracking the visual perception behaviors of experiencers of the modern housing architectural appearance in the immersive VR environment [24]. Integrate the spatial behavior and visual perception of the crowd, so as to achieve the purpose of analyzing the perception and behavioral patterns of modern housing building appearance of experiencers with different backgrounds.

The human eye visual angle and sensitivity have the dynamic distribution law of attenuation, according to the principle of this behavior can realize the tracking of the change of the visual center, so as to analyze the human's perceptual attention in the environment, as well as the degree of attraction of the environment to the human's visual cognition.

By simulating and expanding the mechanism of visual sensitivity change in the human eye, we set the visual heat value as C , the time of focusing on the object as T , the eye-tracking scanning order as n , the visual sensitivity as VA , and the angle of view as α , and calculate the formula as:

$$C = \sum_{i=1}^n T \times VA \quad (5)$$

$$VA = (1/2)^{\alpha/2.5^\circ} \quad (6)$$

Of these, $i = 1, 2, 3, \dots, n$, $\alpha \in 0 \sim 30^\circ$.

III. B. 2) Quantitative indicators for eye movement data

In addition, for the acquisition of VR eye tracking data, this paper also chooses the time before first gaze, first gaze duration, and total gaze duration as evaluation indexes. Pre-first gaze time indicates the time spent before reaching

the area of interest (AOI) for the first time, and the shorter this time indicates that the area attracts visual attention faster. First gaze duration is the duration of a single gaze point, the longer the duration, the more difficult it is to interpret the information (when the user has a specific task) or the more attractive the area is and the more interested the user is in it (when the user has no task and is free to view it). Longer total gaze durations indicate that the audience spends longer interpreting the information, matching the user interface, and memorizing it. Eye-skipping frequency (SR) and pupil uneasiness index (PUI) were also chosen to analyze the audience's changes in perceiving the architectural appearance of modern housing incorporating the art of Chinese painting. Then:

$$SR = \frac{N_s}{N_t} * 100\% \quad (7)$$

where N_s is the number of eye jumps that occurred when the subject performed a visual task, and N_t is the total number of eye movements per visual task.

$$PUI = \frac{1}{(N - 32) * \Delta t} * \sum_{i=2}^N |d_i - d_{i-1}| \quad (8)$$

where N is the total number of samples, d_i is the average value of continuous data, and Δt is the period of continuous data.

The different indicators can effectively show the degree of audience's favor towards the modern housing building appearance design which integrates the art of Chinese painting, and provide reference for optimizing the modern housing building appearance design.

IV. Practical analysis of the aesthetic value of modern housing building exterior design

Architecture is a form of cultural expression, and beautiful and classic buildings can perfectly show modern culture. The appearance of buildings can also directly reflect contemporary culture, and architectural designers need to focus on the appearance of buildings in order to effectively show architectural culture and let people feel the culture of the times through the appearance of buildings. The art of Chinese painting conveys the cultural heritage of China for thousands of years, and integrating it with the exterior design of modern housing buildings can help to enhance the uniqueness of the exterior of modern housing buildings, so that residents can experience the art of Chinese painting in their daily lives.

IV. A. Factor analysis of the appearance of housing buildings

IV. A. 1) Questionnaire validity testing

After the article was conducted SD questionnaire design was completed, 200 residents were randomly selected for 12 sample housing neighborhoods to distribute questionnaires, and a total of 196 valid questionnaires were obtained. The questionnaire data were imported into the SPSS software for the reliability test. The test results are shown in Table 2.

The alpha coefficient value of the overall reliability test was 0.905, and the alpha coefficient values of the appearance characteristics and experience perception were 0.917 and 0.893, respectively, which were greater than 0.75, showing that the reliability of the overall questionnaire and the subscales was good. The KMO = 0.904 > 0.85 and p-value (Sig.) = 0.002 < 0.01 in the validity test indicate that the questionnaire data are highly significant at the 1% level, and the questionnaire passes the KMO test and Bartlett's spherical test. It can provide real and reliable data for the factor analysis of the components of housing building appearance nowadays.

Table 2: Reliability coefficient and KMO, Bartlett test results

Dimension	Appearance characteristics	Experience feeling	Total
α coefficient	0.917	0.893	0.905
Item	6	6	12
KMO value		0.904	
Spherical test	Approximate card	10547.358	
	DF	679	
	Sig.	0.002***	

IV. A. 2) Sample mean analysis

The author selected a total of 15 photos as experimental objects, including 5 photos of traditional building body appearance (coded as T1~T5), 5 photos of housing building appearance (coded as H1~H5) which integrated the art of Chinese painting, and 5 photos of simple building appearance (coded as O1~O5), and standardized the size and resolution of the photos. The data obtained from the questionnaire were used to count the SD results of each

sample, and the SD curve was obtained as shown in Figure 2.

The SD line graph shows that subjects' evaluations of all samples were generally excellent, with a mean score of 3.283 for the evaluation of the exterior design of the three different types of housing buildings. In addition, all 12 groups of adjectives had positive scores, excluding the subjects in Group O, whose scores fluctuated more, while the scores of the remaining two groups fluctuated less. After statistics and comparative analysis of the SD results of the three groups of samples, it was found that, from the overall trend of the folds, the subjects felt more positively about the experience of the three groups of housing building exterior design scenes, in which the mean scores of the samples in Groups T and H were 3.298 and 3.647 respectively, significantly higher than the mean of the sample scores in Group O (2.903) and the scores of the housing building exteriors that were fused with the art of Chinese painting were 0.349 points higher than the ones without fusion of the and the score of the architectural appearance of housing with the integration of Chinese painting art is 0.349 points higher than that of the non-integrated one. The reason is that the design style of modern housing buildings integrated with the art of Chinese painting contains the corresponding artistic conception of Chinese painting, which gives the appearance of modern housing buildings more historical and cultural connotations, and conveys more intuitive and specific information about Chinese painting art, making it easier for participants to get immersive experience and feelings during the tour.

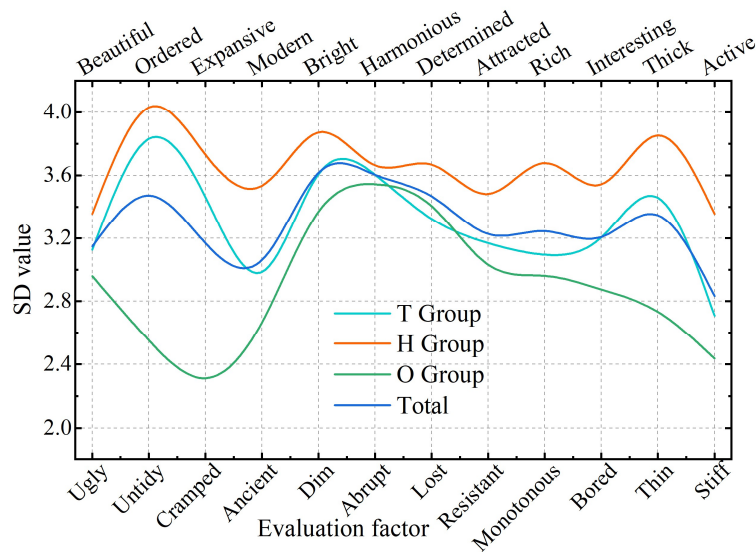


Figure 2: Sample mean distribution

IV. A. 3) Multi-factor analysis of variance

In this paper, the SD data were factor analyzed to obtain the structure of all the data to reflect the target spatial characteristics with the data, and three common factors were extracted, i.e., the eigenroot value, pre-rotation variance, and post-rotation variance are shown in Table 3, where the VIR and CIR are the variance explanation rate and the cumulative explanation rate, respectively. The composite factor loading coefficients after rotation are shown in Table 4. The eigenroot values are all greater than 1. The variance explained ratio of the three factors after rotation is 34.519%, 26.838% and 20.175%, respectively, and the cumulative variance explained ratio after rotation is 81.532%. By analyzing the 3 composite factor loading coefficients, the 3 composite factors were allowed to replace the original 12 factors. The elements with higher loadings in factor 1 are color, attractiveness, richness, interestingness, culture, and activity, whose factor loading values are higher than 0.85, mainly describing the psychological feelings of users in the process of viewing the exhibition, and this paper summarizes these factors as experience factors. The elements with higher loadings in factor 2 are sense of order, coordination, orientation, attractiveness, and their factor loadings are all over 0.75, mainly describing the users' feelings towards the architectural space, and this paper summarizes these factors as spatial factors. The elements with higher loadings in factor 3 are aesthetics, scale, style, and color, which are mainly related to the description of the appearance of housing buildings and building scale, and this paper summarizes these factors as appearance factors.

Based on the results of the factor analysis, the factor score points were solved for each modern housing building appearance perception factor, and the distribution of the perception evaluation score points of modern housing building appearance design was obtained as shown in Figure 3. Among all the samples, the highest value (1.624) and the lowest value (-0.804) of the experience factor score point appeared in samples H3 and O1, respectively,

but the value of its spatial factor score point was relatively high (0.915). Among the appearance factor score points, sample H2 has the highest value (1.964) and sample H4 has the lowest value (-1.273). Based on the analysis of the factor score points, it can be clear that the influence of different modern housing building exterior design samples on the audience's perception evaluation, relatively speaking, the highest scores of the experience factor and the appearance factor are the modern housing building exterior design samples integrating the art of Chinese painting. This fully demonstrates the feasibility of integrating the art of Chinese painting into the exterior design of modern housing buildings, which effectively enhances the audience's experience of the exterior of modern housing buildings and promotes the artistic development of the exterior design of modern housing buildings.

Table 3: Total variance interpretation rate

Factor	Characteristic root			Differential explanation rate		
	Root	VIR	CIR	Root	VIR	CIR
F1	5.338	42.615%	42.615%	4.176	34.519%	34.519%
F2	3.179	13.741%	56.356%	2.624	26.838%	61.357%
F3	2.003	10.679%	67.035%	2.048	20.175%	81.532%
F4	1.674	6.814%	73.849%	-	-	-
F5	1.226	5.274%	79.123%	-	-	-
F6	0.958	4.803%	83.926%	-	-	-
F7	0.672	3.669%	87.595%	-	-	-
F8	0.536	3.372%	90.967%	-	-	-
F9	0.379	2.838%	93.805%	-	-	-
F10	0.323	2.375%	96.180%	-	-	-
F11	0.281	2.016%	98.196%	-	-	-
F12	0.204	1.804%	100.00%	-	-	-

Table 4: Rotational factor load factor

Name	Factor load factor			Common degree
	Factor 1	Factor 2	Factor 3	
Aesthetic	0.183	0.207	0.857	0.737
Sense of order	0.072	0.759	0.215	0.702
Scale sense	0.165	0.183	0.763	0.773
Style	0.196	0.195	0.819	0.536
Color	0.867	0.174	0.738	0.748
Coordination	0.238	0.783	0.181	0.731
Position feeling	0.246	0.792	0.176	0.653
Attraction	0.889	0.805	0.153	0.648
Abundance	0.893	0.219	0.182	0.709
Fun	0.851	0.197	0.218	0.626
Culture	0.864	0.223	0.237	0.714
Activity	0.905	0.246	0.256	0.775

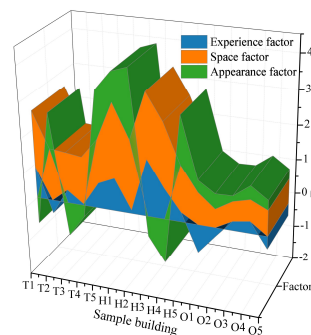


Figure 3: Perceptual evaluation score point distribution

IV. B. Analysis of eye movement indicators for housing construction

IV. B. 1) Analysis of attention time

In order to explore the relationship between the time before first gaze (TFT), the duration of first gaze (FTLD) and the total gaze duration (TFDT) of the eye movement indexes and the exterior design of modern housing buildings, the analysis was carried out based on the eye movement data. The eye movement data of subjects from three groups of different categories of modern housing buildings were counted, and the relevant elements of modern housing building exterior design were categorized into six types: roof, doors and windows, plants, texts, mountains, and water bodies. Table 5 shows the gaze time of modern housing building exterior design.

In the total time before the first gaze, the subjects spent the longest time on the modern housing architectural appearance with Chinese painting art (H), and the shortest time on the simple architectural appearance (O), which was about 2750.94 s. The modern housing architectural appearance with Chinese painting art was rich in complexity, and it took a period of time for the subjects to analyze the aesthetic features contained in it and to make a visual response. Visual response and find their own visual interest points. In the total duration of the first gaze, the longest time spent by the subjects on the modern housing architectural appearance (H) with the integration of Chinese painting art is 147.18 s. The integration of Chinese painting art in the design of the modern housing architectural appearance makes the mood space expressed more complex and diverse, and the richness of the aesthetic values and connotations will increase the time spent by subjects, which is of strong interest to the subjects. The duration of the first gaze of the text is the longest at 46.27s, with the strongest interest pull, and the text in the exterior design can be used to learn about the appearance of the housing building. The difference between the total gaze durations of the samples is small, and the difference between the longest and the shortest is only 146.17 s. The largest mean value of the total gaze durations of the AOI is 10.79 s for the text, and the smallest is 0.98 s for the water body. In the design of the exterior of modern housing buildings incorporating the art of Chinese painting, the subjects were insensitive to the changes in the water body of the building exterior but were attracted by the aesthetic features of its lines upon closer inspection.

Table 5: The design of modern housing design (s)

	AOI	Roof	Windows	Plants	Texts	Mountains	Water	Total
TFT	T Group	201.34	1151.48	415.14	18.46	57.96	153.46	1997.84
	H group	535.78	1396.74	589.57	10.51	34.79	183.55	2750.94
	O Group	0.461	0.337	127.51	0.374	28.65	18.65	175.98
	Average time of each AOI	13.57	17.42	9.59	8.73	22.51	14.94	-
FTLD	T Group	8.51	20.28	6.74	9.48	12.34	16.52	73.87
	H group	17.95	43.77	12.69	46.27	15.87	10.63	147.18
	O Group	0.07	0.24	6.43	8.95	7.42	2.85	25.96
	Average time of each AOI	0.36	0.33	0.27	0.31	0.38	0.27	-
TFDT	T Group	90.46	275.83	60.14	30.25	183.49	46.48	686.65
	H group	195.78	334.31	95.42	6.84	169.51	30.96	832.82
	O Group	82.17	253.05	161.37	5.74	150.27	46.46	699.06
	Average time of each AOI	1.95	2.06	4.08	10.79	6.24	0.98	-

IV. B. 2) Impact of different elements

In order to further clarify the influence of different constituent elements in the exterior design of modern housing buildings incorporating the art of Chinese painting on the subjects' eye movement behaviors, based on the data of eye movement behaviors under the six types of roofs, windows and doors, plants, texts, mountains, and water bodies, one-way one-way analyses were conducted on the frequency of eye jumps (SR), frequency of gaze (FR), mean number of gazes (MNO), and average time of gaze (ATO) by using the SPSS ANOVA. Table 6 shows the results of the one-way ANOVA for the different components.

As can be seen from the table, there is no significant difference ($\text{Sig} > 0.05$) between the frequency of eye hopping, frequency of gaze, average number of gazes and average time of gaze, indicating that the degree of awareness and concern of subjects for the architectural appearance of different types of modern housing is close to each other. In terms of the average number of gaze times, the differences between the different constituent elements are small, and the subjects' gaze times on the text element are the most, about 5.78 times. In terms of the average gaze time factor, the differences between the six different constituent elements were not significant, with the largest and

smallest extreme difference of 0.45 s. In terms of the frequency of eye-beating, the differences between the different constituent elements were also small, with the subjects' eye-beating frequency for the plant element being the largest, at about 6.42 times/s, compared to the relatively low level of attention paid to windows and doors, at 5.18 times/s. This suggests that the incorporation of the plant diversity features in the architectural appearance of housing with the art of Chinese painting is more concentrated and tends to attract the most attention. In terms of the frequency of attention, the test results were similarly varied. Among them, the gaze frequency of mountain and water components is relatively high and close, respectively 94.86 times/s and 95.17 times/s. This shows that when integrating the art of Chinese painting in the design of the exterior of modern housing buildings, the introduction of different types of mountains and waters can more effectively stimulate the exploration interest of the subjects, and further show the aesthetic value of the art of Chinese painting in the design of the exterior of housing buildings.

Table 6: Analysis of single factor variance analysis

Index	MNO	ATO	SR	FR
Sig.	0.572	0.953	0.278	0.846 sec/s
Roof	5.46 sec	10.42s	5.79 sec/s	82.41 sec/s
Windows	5.51 sec	10.79s	5.18 sec/s	83.78 sec/s
Plants	5.39 sec	10.83s	6.42 sec/s	92.69 sec/s
Texts	5.78 sec	10.38s	5.65 sec/s	91.05 sec/s
Mountains	5.63 sec	10.65s	5.81 sec/s	94.86 sec/s
Water	5.27 sec	10.54s	5.54 sec/s	95.17 sec/s

IV. B. 3) Visual comfort analysis

The application of Chinese painting art in modern housing building exterior design aims to show the aesthetic value of Chinese painting art. The exterior design of housing buildings relies on the color matching of Chinese painting art to provide audiences with a more direct visual aesthetic impact. In this paper, we analyze the pupil anxiety index and the purity and brightness of the colors in the exterior design of housing buildings, so as to clarify the impact of different color conditions on the visual comfort of the audience. Based on the calculation formula of the pupil uneasiness index in the previous paper, the relationship between PUI and the color attributes of the building appearance was obtained by combining the eye movement data as shown in Figure 4. Among them, Fig. 4(a)~(b) shows the trend of PUI change between color purity and brightness, respectively.

In the color purity of housing building exterior design, the change of PUI between different color purity is more significant. The housing building exterior design with red as the dominant color has the smallest PUI (0.131) and the highest visual comfort when the color purity is 55.5%, and when the color purity is in the range of 45%-65%, the subjects' PUI for the housing building exterior design stays at a low level. In the housing building exterior design with green as the main color, the subjects' pupil uneasiness index was the smallest (0.147) and the most comfortable in visual perception when the color purity reached 61.4%, and the pupil uneasiness index was highly stable and smallest when the color purity was 50%-72%. When the purity is lower than 82.1%, the pupil anxiety index of the red appearance is lower than that of the green appearance, indicating that the comfort level of the warm color appearance is higher than that of the cold color appearance in the middle and low purity, and if the purity exceeds 82.1%, the pupil anxiety index of the subjects in the red appearance will be increased dramatically. It indicates that when the modern housing building appearance design for the integration of the art of Chinese painting, the use of high purity colors for the appearance design will bring visual discomfort to the residents, eye fatigue increases, affecting the residents' living experience.

In terms of interface color brightness, the results show that when the hue and purity of the housing building exterior design remain unchanged, the color brightness in the range of 50%-70% pupil uneasiness index is relatively stable, and the pupil uneasiness index is the smallest (0.137) at around 59.6%, and the subjects have the highest level of visual comfort. When the brightness of the spatial color changes from 0% to 50%, the subjects' pupil uneasiness index decreases significantly, and when the brightness of the spatial color exceeds 65%, the subjects' pupil uneasiness index increases gradually, but the trend is smoother compared with that of the low brightness. It indicates that when the modern housing building exterior design is integrated with the art of Chinese painting, medium and high brightness colors have higher visual comfort than low brightness colors.

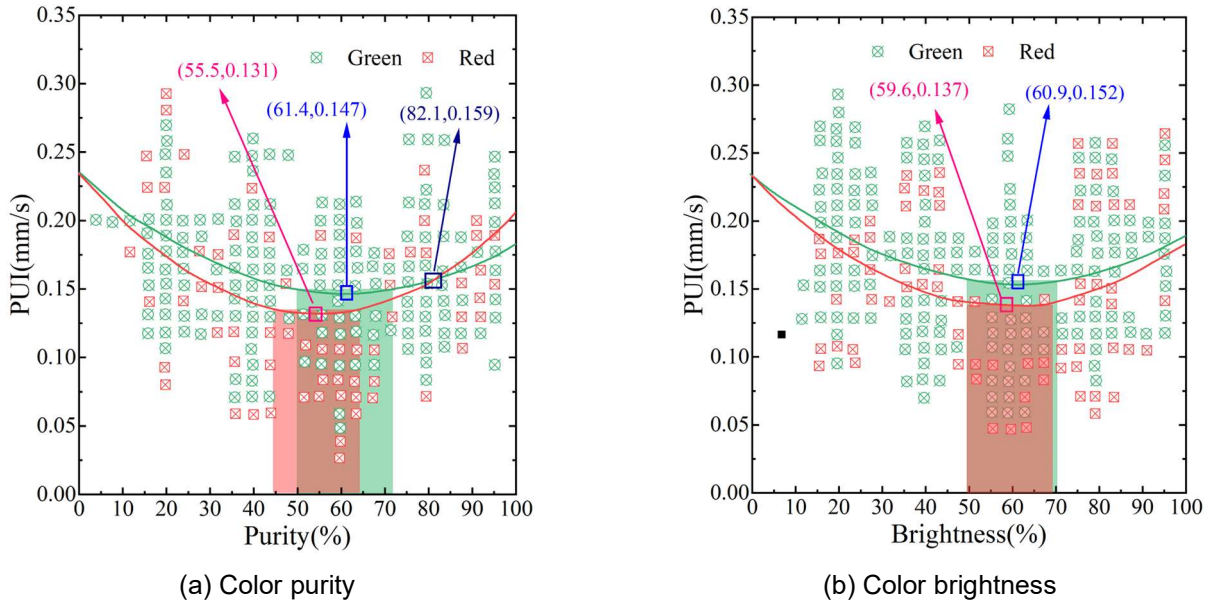


Figure 4: The relationship between PUI and color properties

IV. C. The Art of Chinese Painting Integrated into the Exterior Design of Housing Buildings

IV. C. 1) Design Diversity

Ancient Chinese buildings had a clear hierarchy, and the decorations or color paintings of each component of the building such as the pedestal, columns, walls, beams, openings, algal wells, buckets and other parts of the building were generally painted directly in the form of Chinese paintings. According to the different uses of the building and the differences in form, different styles of Chinese paintings are adopted for painting and decoration, such as Hexi painting, Su-style painting and so on.

In the exterior design of Chinese-style housing buildings, elements of Chinese paintings can also be directly applied to the exterior accessories. The framing of Chinese painting works in various forms, such as fans, screens, scrolls, banners, mirror frames, plaques, couplets, etc. can be directly used in the decoration of the environment, which is conducive to the formation of cultural awareness and aesthetic taste. In addition, Chinese painting utensils such as brushes, ink, paper, ink stone, table, seal and other elements directly applied to the interior environment furnishings, is also one of the more commonly used design methods to create the atmosphere.

IV. C. 2) Natural matching of colors

Landscape architecture is a flexible and guiding part of landscape design, and the impression given by architecture is often more impactful for visitors. In the modern housing building appearance design, the designer can draw on the traditional Chinese painting for the way of expression of the building, to create a nebulous, hidden aesthetic effect. In the traditional ink landscape painting, although the painting often appear pavilions and pavilions and flying eaves palace, but these buildings are often hidden in the clouds and mist, presenting the atmosphere of the fairyland, as if the fairy palace is generally ethereal, hidden, very mood and mood.

And in the green landscape painting, the building is more with powder bricks and tiles of the gorgeous image. For modern landscape design, the latter style tends to have a wider audience from the theme and audience. Designers can design the shape style of the building into a classical style, use bright colors, use modern building materials, and appropriately combine wood and stone to create a housing building with a classical flavor.

V. Conclusion

This paper analyzes the performance of aesthetic value of modern housing building exterior design integrating the art of Chinese painting using SD factor analysis and eye movement data, and explores the impact of modern housing building exterior design integrating the art of Chinese painting on the audience's visual comfort. The mean value of the subjects' evaluation scores of the housing building exterior design with the integration of Chinese painting art was 3.283, and the score of the housing building exterior with the integration of Chinese painting art was 0.349 higher than that of the one without the integration. The total time spent by the subjects on the modern

housing architectural appearance with the integration of the art of Chinese painting was the longest about 2750.94s, and the total time spent on the simple architectural appearance was the shortest about 175.98s. The subjects' gaze frequency on the constituent elements of the landscape in the design of the housing architectural appearance was relatively high and close to the same level, which was 94.86 times/s and 95.17 times/s, respectively. Higher than 65%, the visual comfort of the subjects showed a significant decrease. When integrating the art of Chinese painting into the exterior design of housing buildings, warm color expressions should be chosen to enhance the audience's visual comfort, and the aesthetic value of the art of Chinese painting should be demonstrated through various types of Chinese style symbols.

Funding

Henan University Humanities and Social Science Research General Project: A Study on the Integration and Inheritance of the "27 Spirit" in the Teaching of Fine Arts Education in Henan University under the Vision of Great Thought and Politics (Project number:2024-ZZJH-448).

References

- [1] Liu, Y., Simatrang, S., Sirvesmas, V., & Joneurairatana, E. (2024). The Expressive Techniques and Spirit of Chinese Landscape Painting with Brush and Ink. *Kurdish Studies*, 12(2), 6147-6161.
- [2] Chen, Y., Chiu, K. W. D., & Ho, K. K. W. (2018). Facilitating the Learning of the Art of Chinese Painting and Calligraphy at Chao Shao-an Gallery in Hong Kong. *Micronesia Educator Journal*.
- [3] He, B., Gao, F., Ma, D., Shi, B., & Duan, L. Y. (2018, October). Chipgan: A generative adversarial network for chinese ink wash painting style transfer. In *Proceedings of the 26th ACM international conference on Multimedia* (pp. 1172-1180).
- [4] Sullivan, M. (2023). *Chinese art in the twentieth century*. Univ of California Press.
- [5] Liong, S. T., Huang, Y. C., Li, S., Huang, Z., Ma, J., & Gan, Y. S. (2020). Automatic traditional Chinese painting classification: A benchmarking analysis. *Computational Intelligence*, 36(3), 1183-1199.
- [6] Law, S. S., & Blishen, T. (2024). *Reading Chinese painting: beyond forms and colors, a comparative approach to art appreciation*. Shanghai Press.
- [7] Hung, C. C. (2018). A study on a content-based image retrieval technique for Chinese paintings. *The Electronic Library*, 36(1), 172-188.
- [8] Lu, Y., Guo, C., Lin, Y., Zhuo, F., & Wang, F. Y. (2020). Computational aesthetics of fine art paintings: The state of the art and outlook. *Acta Automatica Sinica*, 46(11), 2239-2259.
- [9] Lin, D., Wang, Y., Xu, G., Li, J., & Fu, K. (2018). Transform a simple sketch to a chinese painting by a multiscale deep neural network. *Algorithms*, 11(1), 4.
- [10] Wang, C., Su-Lynn, G., & Chen, A. (2020). From Chinese aesthetic to art and design: exploring Chinese aesthetics of Chinese ink painting to create contemporary art. *The International Journal of Visual Design*, 14(1), 11.
- [11] Yuan, T. (2024). A Study on the Characteristics of Contemporary Chinese Painting from Micro Perspective. *International Journal of Advanced Culture Technology*, 12(1), 108-115.
- [12] Zhou, L., Wang, Q. F., Huang, K., & Lo, C. H. (2019, September). An interactive and generative approach for chinese shanshui painting document. In *2019 International conference on document analysis and recognition (ICDAR)* (pp. 819-824). IEEE.
- [13] Totten, C. W. (2019). *Architectural Approach to Level Design*. CRC Press.
- [14] Davis II, C. L. (2019). *Building Character: The Racial Politics of Modern Architectural Style*. University of Pittsburgh Press.
- [15] Neufert, E. (2019). *Architects' data*. John Wiley & Sons.
- [16] Ching, F. D. (2023). *Architecture: Form, space, and order*. John Wiley & Sons.
- [17] Xeumei, Y., & Manteghi, G. (2024). THE VALUE OF TRADITIONAL ARCHITECTURE AND ITS ENLIGHTENMENT TO CONTEMPORARY ARCHITECTURAL DESIGN. *Lim Hock Ann, AP. Dr.*
- [18] Nijhuis, S., & de Vries, J. (2019). Design as research in landscape architecture. *Landscape journal*, 38(1-2), 87-103.
- [19] Pevsner, N. (2024). *The sources of modern architecture and design*. Thames & Hudson.
- [20] PZhang, M. Y., & Zo, H. (2020). A Study on the Features of Chinese Traditional Calligraphy and Landscape Painting in Wangshu's Architecture-Focus on the Space Creation Techniques of Chinese Traditional Calligraphy and Landscape Painting. *Journal of the Architectural Institute of Korea Planning & Design*, 36(4), 113-121.
- [21] Zou, W., & Yeo, S. Y. (2022). Investigation on the painting materials and profile structures used in ancient chinese folk architectural paintings by multiple analytical methods. *Coatings*, 12(3), 320.
- [22] Yunqiu Xiang & Xinbo Yun. (2023). Study on the Application of Tujia Architectural Culture in the Western Part of Hubei in Rural Tourism Landscape Design. *Urban Design*(2).
- [23] Yurong Zhong, Kechen Liu, Chen Jiqiu, Xie Zhe & Weiling Li. (2024). Alternating nonnegative least squares-incorporated regularized symmetric latent factor analysis for undirected weighted networks. *Neurocomputing* 128440-128440.
- [24] Michale Casale. (2024). Evaluating the Accuracy of a Novel Motion Tracking Sensor Technology as part of a Full-Body Immersive VR Rehabilitation System. *Archives of Physical Medicine and Rehabilitation*(4), e184-e184.