Philosopher's Compass 1/1 (2025): 109–128.

Modeling Languages and Emotional Expressions

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ABSTRACT

Modeling language is crucial for the conveyance of emotions in design, exerting a profound influence on user experience and behavioral patterns. Nevertheless, most extant research efforts have been circumscribed within the boundaries of single dimensions or static variables, falling short of a comprehensive interdisciplinary and integrative study. In this paper, a meticulously controlled experimental milieu was established through the application of virtual reality (VR) technology, with the aim of systematically probing into the impact mechanisms of two paradigmatic modeling languages, namely curves and rectangles, upon emotions, heart rate variability, and creative output. The experimental protocol incorporated multi-faceted quantitative measures, such as the Positive and Negative Affect Schedule (PANAS) for gauging subjective emotional states, physiological indices (heart rate) as an objective biomarker, and creative evaluation techniques involving the Guildford Alternative Uses Task and semantic distance computation. The empirical findings divulged that the curvilinear modeling paradigm significantly augmented positive emotional valence ($t=4.87$, $p<0.001$) and concomitantly attenuated negative emotional arousal ($t=2.09$, $p=0.04$); it also led to a remarkable reduction in the level of physiological arousal as manifested by heart rate deceleration ($t=4.18$, $p<0.001$); furthermore, it effectively potentiated creative output as evidenced by an increased semantic distance ($t=2.06$, $p=0.047$). This investigation represents the inaugural attempt to validate the emotional repercussions and creative elicitation mechanisms of modeling languages within a three-dimensional virtual environment via a multidisciplinary methodological approach. The outcomes of this research furnish a scientific underpinning for architecture, product design, and human-computer interaction, effectively bridging a critical lacuna in the existing literature.

KEYWORDS: Modeling Language, Emotional Expression, Virtual Reality

1 | INTRODUCTION

1.1 | Research Background and Significance

In the context of contemporary society, the demands of individuals regarding the environment and products have transcended the mere functional realm. Emotional experience has emerged as a significant factor worthy of consideration (Xu et al., 2020). Modeling language, being a pivotal constituent in the design discipline, imparts emotional information via diverse elements such as form, color, and texture (Brosch et al., 2021). A profound exploration into its correlation with emotional expression is conducive to enabling designers to fabricate creations that are more attuned to the emotional requisites of users. This, in turn, not only augments the quality of life and work efficiency but also propels the innovative progression within the design domain (Roggeveen et al., 2020).

1.2 | Research Questions and Hypotheses

This research centers around the exploration of how modeling languages exert an impact on the emotions and behaviors of individuals. In light of this, the following hypotheses are put forward:

Hypothesis One (H1): It is hypothesized that disparate modeling language environments will lead to a significant alteration in the emotional states of participants. Specifically, within the context of a curved modeling environment, the scores pertaining to positive emotions will be conspicuously higher compared to those in a rectangular modeling environment. Conversely, the scores associated with negative emotions will be notably lower in the former than in the latter (Meo et al., 2020). This supposition is predicated on the premise that the inherent characteristics of curved and rectangular forms possess distinct capacities for eliciting and modulating emotional responses.

Hypothesis Two (H2): It is postulated that in a curved modeling environment, the heart rate of participants will be lower than that in a rectangular modeling environment, thereby signifying a diminished level of physiological arousal (Bullis et al., 2019). The rationale behind this hypothesis lies in the potential association between the visual perception of different modeling languages and the autonomic nervous system's regulation of physiological parameters such as heart rate.

Hypothesis Three (H3): It is proposed that the creative output of participants will be greater in a curved modeling environment as opposed to a rectangular modeling environment (Han et al., 2022). This hypothesis is founded on the idea that the unique aesthetic and spatial qualities of curved modeling might foster a more conducive cognitive and psychological state that is favorable for the generation and expression of creative ideas.

1.3 | Research Questions and Hypotheses

Innovative Deep Interdisciplinary Fusion:This study features an unprecedented integration of multiple disciplines. Specifically, it combines the theoretical and methodological frameworks of neuroscience, psychology, architecture, and computer science. Neuroscience contributes by elucidating the intricate neural pathways underlying emotional processing, thereby providing a fundamental understanding of the biological basis of emotions. Psychology offers a suite of well-established measurement tools, such as various scales and questionnaires, which are essential for quantifying and analyzing emotional states. Architecture plays a crucial role in constructing realistic and contextually relevant scenarios that serve as the backdrop for our investigations. Computer science, on the other hand, empowers the research through advanced virtual simulation techniques and sophisticated data analysis algorithms. This interdisciplinary synergy not only enriches the research but also presents a novel and comprehensive perspective that has not been fully explored in previous studies (Singer et al., 2019).

Innovation in Experimental Methodology and the Precision of Diverse Data Acquisition:A significant innovation in our experimental approach lies in the utilization of virtual reality (VR) technology. This technology allows for precise manipulation and control of variables, thereby minimizing potential confounding factors and enhancing the internal validity of the study. In conjunction with VR, we have incorporated a diverse array of measurement tools. Subjective emotional scales are employed to capture participants' self-reported emotional experiences, providing valuable insights into the affective dimension. Objective physiological indicators, such as heart rate and other relevant biomarkers, are monitored to gauge the physiological arousal associated with different experimental conditions. Additionally, a comprehensive set of methods for evaluating creativity and innovation, including established tasks and novel computational techniques, are utilized. This multi-faceted approach to data collection ensures the acquisition of rich and accurate multi-dimensional data, which in turn significantly bolsters the reliability and generalizability of our research findings (Davis et al., 2020).

2 | LITERATURE REVIEW

2.1 | Research Related to Modeling Language

2.1.1 | Definition and Core Dimensions of Modeling Language

Modeling language, as a crucial vehicle in the realm of design, serves to communicate meaning and elicit emotions by means of elements like form, color, and material (Bower et al., 2019). With respect to spatial form, it can be principally classified into two distinct types: curved and straight, with the rectangle being a prototypical example of the latter. The curved form is characterized by its inherent softness and naturalness, endowing it with an ability to evoke a sense of fluidity and harmony. In contrast, the rectangular form exhibits regularity and stability, which confer upon it a certain degree of order and permanence. These two forms find extensive application in both architectural and product design domains, playing a significant role in shaping and modulating the emotional experiences of the users (Dozio et al., 2022).

2.1.2 | The Extensive Application and Far-Reaching Impact of Modeling Language in Various Fields

In the realm of architecture, the curved elements present in classical architecture serve to engender a solemn and stately atmosphere. These curvilinear features, with their graceful and flowing contours, contribute to an aesthetic that is often associated with grandeur and formality. In contrast, within modern architecture, the utilization of rectangular lines imparts a sense of simplicity and minimalism. The straight and angular geometries of such designs communicate an uncluttered and streamlined visual language, which is characteristic of contemporary architectural trends (Zhong et al., 2022). When it comes to product design, the curved design incorporated in electronic products has the propensity to trigger associations of dynamism and fluidity. The sleek and rounded forms of these items suggest movement and energy, thereby endowing them with an alluring and engaging quality. On the other hand, the rectangular form commonly employed in furniture design accentuates stability and practicality. The straight edges and right angles of furniture pieces connote a sense of solidity and reliability, which are essential attributes for functional and long-lasting furnishings. It is evident that different modeling languages, as manifested in these diverse forms and geometries, are capable of shaping distinct emotional atmospheres that significantly impact the user's perception and experience of the designed products (Plass et al., 2020).

2.2 | Research Related to Emotional Expression

2.2.1 | Theoretical Models of Emotions and Multiple Measurement Dimensions

In the domain of emotion research, a plethora of theoretical models have been put forward to elucidate the intricate nature of emotions. Among these, the two- dimensional model stands out as a commonly employed framework. This model encompasses the spectrum of positive and negative emotions, providing a structured means to categorize and analyze emotional experiences (Wong et al., 2021). Regarding the measurement of emotions, diverse methodologies have been developed. One prevalent approach is the utilization of self-report questionnaires. For instance, the PANAS - Long Form is a widely recognized instrument in this regard. Through such questionnaires, individuals are able to provide subjective accounts of their emotional states, detailing the intensity and prevalence of various positive and negative emotions they have experienced. In addition to self- report questionnaires, the measurement of physiological indicators also plays a crucial role. These physiological markers, including but not limited to heart rate, blood pressure, skin conductance, and electroencephalogram (EEG) readings, offer an objective perspective on emotional arousal and regulation. By monitoring these physiological changes, researchers can gain insights into the underlying physiological processes associated with different emotional states. The combination of these two measurement approaches, namely self-report questionnaires and physiological indicator measurement, is of utmost importance. It allows for a more comprehensive and in-depth understanding of the complex dynamics of emotional changes. This integrated approach overcomes the limitations of relying solely on either subjective or objective measures and provides a more holistic view of the emotional landscape (Jackson et al., 2019).

2.2.2 | Key Environmental Factors Affecting Emotional Expression

Natural environmental factors have been demonstrated to possess the capacity to augment positive emotions. In parallel, the elements of modeling language within the architectural environment hold significant importance. Specifically, aspects such as the spatial layout and color coordination are known to exert an influence on emotional states. It is noteworthy that individual variances exist, which lead to the phenomenon where identical modeling language can precipitate diverse emotional responses (Jonauskaite et al., 2020).

2.3 | Research Status of the Relationship between Modeling Language and Emotional Expression

The majority of the extant research is circumscribed within a solitary field or factor, with a paucity of the amalgamation of multi-dimensional data. Notably, the exploration into the modeling language of three-dimensional space within virtual environs is rather inadequate. The current study endeavors to bridge these lacunae (Han et al., 2022).

3 | RESEARCH METHODS

3.1 | Experimental Design

3.1.1 | Design Types and Variable Control

The present experiment employs a within-subjects design paradigm and integrates a balanced AB/BA sequence protocol, with the aim of minimizing the potential influence of order effects to the greatest extent. The independent variable under investigation in this experiment is the modeling language of the room, which is categorized into two distinct types: rectangular and curved. The dependent variables encompass a range of aspects, namely the emotional states of the participants, which are further subdivided into positive and negative emotions, the level of creative output, and the physiological indicator of heart rate. To guarantee the stringency and scientific integrity of the experiment, meticulous control measures are implemented. Specifically, other characteristics of the room, such as its area, light intensity, and color, are stringently regulated throughout the experimental process. Additionally, the natural landscapes within the visual field of the participants are standardized, thereby ensuring that any differences sensed by the participants can be solely attributed to the variations in the modeling language.

3.1.2 | Construction of Experimental Scenarios and Technical Support

The experimental scenarios were constructed by leveraging the Unreal EngineTM and SteamVRTM technologies to simulate virtual reality (VR) environments on high-performance computing platforms. Two distinct room modeling configurations, namely the rectangular and curved room designs, were incorporated. In both scenarios, uniform office furniture was provided, and a consistent view of the natural landscape outside the window was presented. The overall geometry of the rooms and the layout of the interior elements remained identical across the two experimental settings.

Participants were able to engage with the scenarios by donning VR headsets. Concurrently, the system employed tracking devices to record the head positions of the participants, thereby ensuring an immersive and seamless experience. The design of these experimental scenarios has undergone professional verification and has been publicly disclosed for further scrutiny and replication.

3.2 | Participant Recruitment and Sample Characteristics

3.2.1 | Recruitment Channels and Sample Characteristics

The experimental participants were enlisted via the participant pool of higher education institutions and social media channels. A sum of 35 individuals were successfully recruited, with their age span stretching from 18 to 64 years (where the mean age, M, equaled 32.5 and the standard deviation, SD, was 9.3). The sample characteristics of these participants exhibit a high degree of representativeness, incorporating diverse genders (with 47% being male and 53% being female) as well as a variety of occupations, which encompass students enrolled in educational institutions, full- time employees, and the unemployed population.

The recruitment conditions include:

- Language Ability: Proficiency in English is required.
- Physical Condition: Normal uncorrected or corrected visual acuity is expected.
- Mental State: No recent diagnosis of severe mental illness.

3.2.2 | Ethical Approval and Informed Consent

The experimental protocol obtained the endorsement of the Ethics Committee at Bond University. Before the commencement of the experiment, all participants were required to sign a comprehensive informed consent form. This form encompassed detailed information regarding the objective of the experiment, the sequential procedures to be followed, the potential risks that might be involved, and the safeguarding measures for data privacy. Through this meticulous process, it was ensured that the rights, interests, and privacy of the participants remained inviolable.

3.3 | Measuring Tools and Materials

3.3.1 | Emotional Measurement Tool(PANAS)

The emotional states of the participants were assessed by employing the PANAS - Long Form scale (Positive and Negative Affect Schedule). This scale encompasses ten positive affect words and ten negative affect words. Each participant was tasked with rating each of these words on a five-point scale, where 1 was designated as ”rarely felt” and 5 as ”extremely felt”. Subsequently, the scores for positive affect and negative affect were separately aggregated to gauge the overall emotional states of the participants.

3.3.2 | Heart Rate Measurement Device (Elite HRV CorSense)

The heart rate data were collected via the Elite HRV CorSense fingertip clip-on sensor. This particular device employs photoplethysmography (PPG) to measure heart rate. The affiliated software is capable of automatically cleansing the artifact signal data and subsequently computing the beats per minute (bpm). The Elite HRV CorSense has been widely adopted in physiological research, thereby guaranteeing the reliability of the data obtained.

3.3.3 | Creativity Measurement Tools (GAUT and SemDis)

The Guildford Alternative Uses Task (GAUT) was implemented in this study. Participants were tasked with generating as many non-traditional uses as they could conceive for common objects, such as bricks or paper towels.

This task serves as a means to evaluate divergent thinking, which is a crucial aspect of creativity assessment. By eliciting a wide range of alternative uses, the GAUT enables the quantification and analysis of an individual's capacity to think divergently and generate novel ideas beyond the typical or conventional applications of the given items.

The Semantic Distance Calculation Platform (SemDis): Based on the SemDis platform and in combination with the CBOW (Continuous Bag of Words) model, the semantic distance of the responses in the GAUT was calculated. A higher semantic distance indicates a higher level of creativity. The data were input into statistical analysis after undergoing semantic cleaning.

3.4 | Experimental Procedure

3.4.1 | Experimental Preparation and Environmental Adaptation

Prior to the initiation of the experiment, the participants were required to don VR headsets and acclimate themselves to a generic virtual environment for a duration of three minutes. During this acclimation period, the baseline heart rate data was recorded with the aim of ensuring the stability of the physiological state and minimizing the deviations that might arise due to discomfort. This procedure was implemented to establish a consistent physiological baseline, thereby enhancing the reliability and validity of the subsequent experimental data collection and analysis.

3.4.2 | Tasks for Measuring Emotion and Creativity

Upon the completion of the adaptation period, the experimenter utilized the loudspeaker to prompt the participants to undertake the subsequent tasks:

- Emotional Measurement:The current emotional state of the participants was measured by means of the PANAS. In this regard, participants were required to provide their responses orally. This approach allowed for the immediate capture of their emotional experiences at that specific moment, facilitating subsequent analysis of the affective states within the context of the experiment.

- Creativity Measurement:The Guildford Alternative Uses Task (GAUT) was then implemented. Participants were tasked with generating creative uses for a set of items. Their answers were meticulously recorded for further examination. To mitigate the potential impact of order effects, the presentation order of the items was randomly balanced. This ensured that any observed differences in the creativity measures could be more accurately attributed to the inherent nature of the participants' creative thinking rather than being influenced by the sequence in which the items were presented.Such a carefully designed and executed procedure for emotional and creativity measurement was aimed at obtaining comprehensive and reliable data, thereby enabling in-depth exploration of the relevant research questions.

3.4.3 | Experimental Environment Exposure and Data Collection

The participants were successively exposed to two distinct room configurations, namely rectangular and curved, with each exposure lasting for a period of 10 minutes. During the exposure intervals, the heart rate of the participants was continuously recorded. Immediately subsequent to the completion of each exposure, the tasks designed for measuring emotion and creativity were reiterated. To preclude any potential order biases, the sequence of the room exposures was randomly counterbalanced. The overall duration of the experiment approximated 26 minutes. Throughout the experimental process, the participants were required to maintain a seated position so as to eliminate any interference that might be introduced by physical movements.

4 | RESEARCH FINDINGS

4.1 | Data Processing and Preliminary Analysis

4.1.1 | Data Screening

During the preliminary examination process, it was discovered that the heart rate sensor of a single participant had a poor connection issue. As a result of this, the corresponding heart rate data of this particular participant was excluded from the subsequent analysis. Conversely, the data integrity of all the remaining participants was found to be in a satisfactory state. Specifically, there were no significant instances of missing values within their datasets, thereby ensuring the reliability and validity of the data for further in-depth analysis.

4.1.2 | Normality Test and Robustness Treatment

The Shapiro-Wilk normality test was performed on all the dependent variables under investigation. It was observed that, with the exception of negative affect and heart rate, the distributions of the other data exhibited a reasonable approximation to normality. In order to enhance the robustness of the analysis results, especially for those data that deviated from the normal distribution, the Wilcoxon test was utilized as a supplementary approach to validate the outcomes of the t-test. This dual-testing strategy helps to ensure the reliability and validity of the statistical inferences drawn from the data, thereby strengthening the overall integrity of the research findings.

4.2 | DifferencesinEmotionalReactions

4.2.1 | Positive Effect

In the experimental setting where participants were exposed to the curved room configuration, the mean positive affect score was calculated to be 30.60, with a standard deviation of 6.72. In contrast, when the participants were placed in the rectangular room, the corresponding mean positive affect score was 23.94, accompanied by a standard deviation of 8.69. Subsequently, a paired t-test was conducted to examine the statistical significance of the difference between these two sets of scores. The results of this test revealed that $t(34) = 4.87$, with a p-value less than 0.001, which clearly indicates a highly significant difference between the positive affect scores in the two room types. Moreover, the effect size was quantified as Cohen's $d = 0.82$. Collectively, these statistical findings provide compelling evidence that the curved room configuration significantly elevates the level of positive affect among the participants, thereby highlighting the potential impact of environmental design on emotional experiences within the context of this study.

4.2.2 | Negative Effect

In the rectangular room, the mean negative affect score was determined to be 12.62, with a standard deviation of 3.80. In contrast, within the curved room, the mean negative affect score was 11.51, accompanied by a standard deviation of 1.99. A paired t-test was then conducted to evaluate the statistical significance of the difference between these two sets of negative affect scores. The results of this test demonstrated that $t(34) = 2.09$, with a p-value of 0.04, indicating a significant difference between the negative affect scores in the two room configurations. Additionally, the effect size was calculated as Cohen's $d = 0.35$. To further validate the robustness of these findings, a Wilcoxon test was performed. The Wilcoxon test corroborated the results obtained from the t-test, providing additional support for the conclusion that there is a reliable difference in negative affect between the rectangular and curved room settings. This multi-faceted statistical analysis enhances the confidence in the observed relationship between room type and negative emotional response, contributing to a more comprehensive understanding of the emotional impact of environmental factors within the scope of this research.

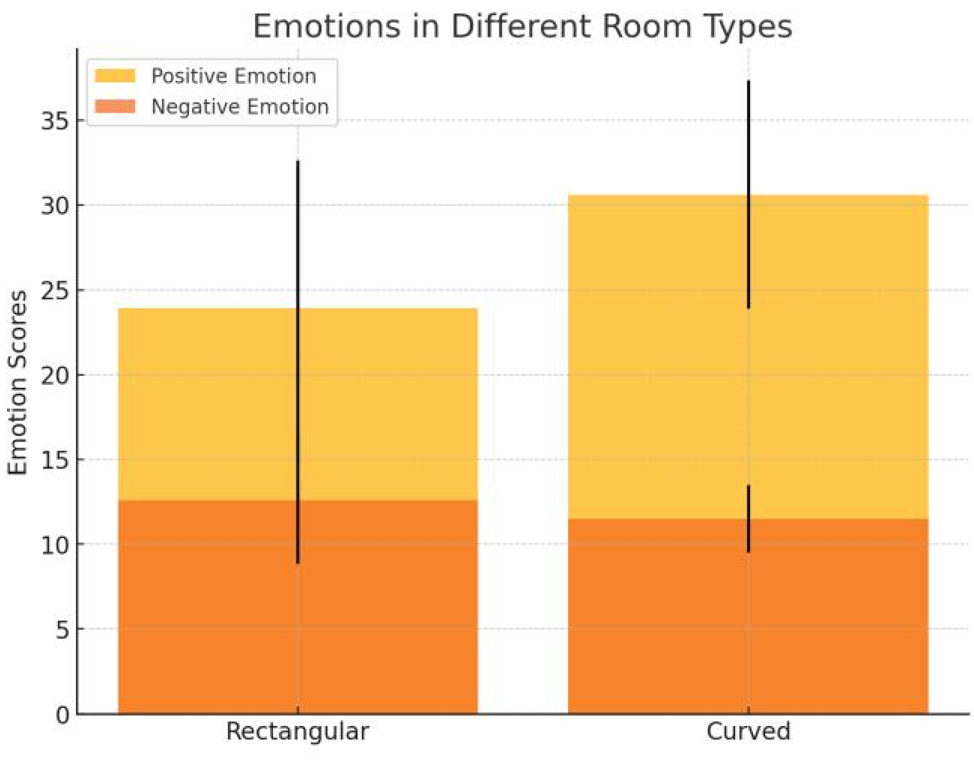

Figure 1: Emotions in Different Room Types

4.3 | Differences in Heart Rate

In the experimental context, the mean heart rate within the curved room was measured as 76.67 beats per minute (bpm), with a standard deviation of 8.767. In contrast, the mean heart rate in the rectangular room was determined to be 83.58 bpm, accompanied by a standard deviation of 6.68. Subsequently, a paired t-test was conducted to statistically assess the significance of the difference between these two mean heart rate values. The results of this test demonstrated that $t(33) = 4.18$, with a p-value less than 0.001, which unequivocally indicates a highly significant difference in heart rate between the two room configurations. Additionally, the effect size was quantified as Cohen's $d = 0.71$. Collectively, these statistical outcomes provide strong evidence that the curved room configuration leads to a reduction in physiological arousal, as reflected by the lower average heart rate. This finding contributes to a more profound understanding of the potential physiological impacts of environmental design factors within the framework of this study.

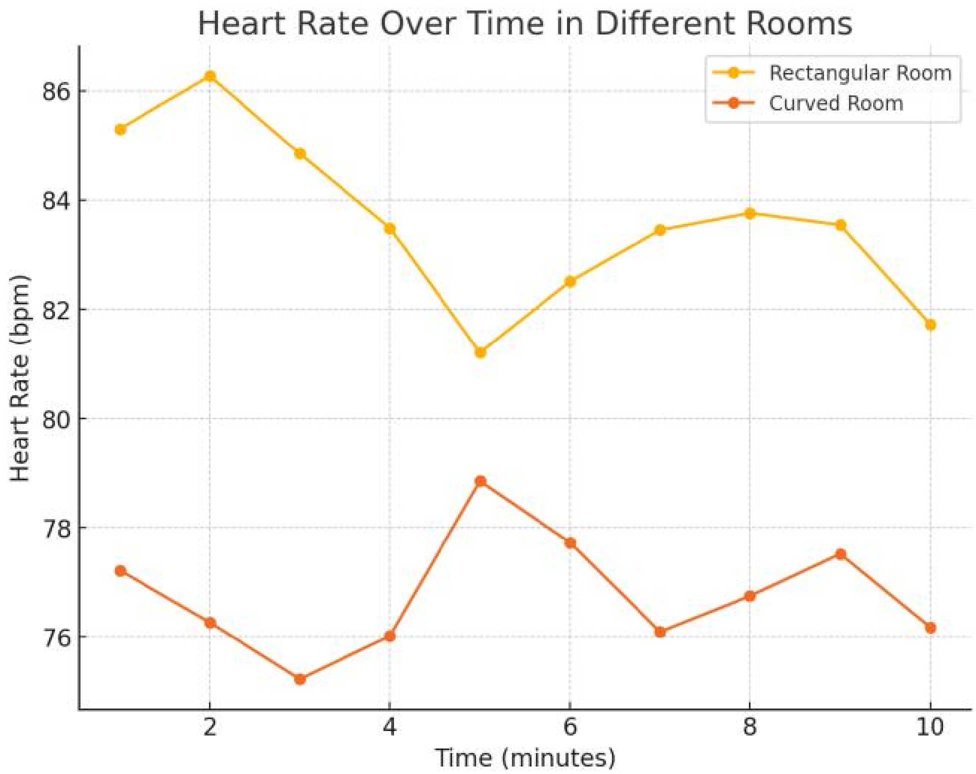

Figure 2: Emotions in Different Room Types

4.4 | Differences in Creative Output

In the experimental study, the SemDis scores within the curved room were determined to be 4.37 on average, with a standard deviation of 1.68. In contrast, the mean SemDis score in the rectangular room was 3.63, accompanied by a standard deviation of 1.55. A paired t-test was then conducted to statistically evaluate the significance of the difference between these two mean SemDis scores. The results of this test showed that $t(34) = 2.06$, with a p-value less than 0.047, which clearly demonstrates a significant difference in SemDis scores between the two room configurations. Moreover, the effect size was calculated as Cohen's d = 0.35. Collectively, these statistical findings provide substantial evidence that the curved room configuration has a positive impact on enhancing the creative output of the participants, as reflected by the significantly higher SemDis scores. This discovery contributes to a deeper understanding of the relationship between environmental design and creative performance within the context of this research.

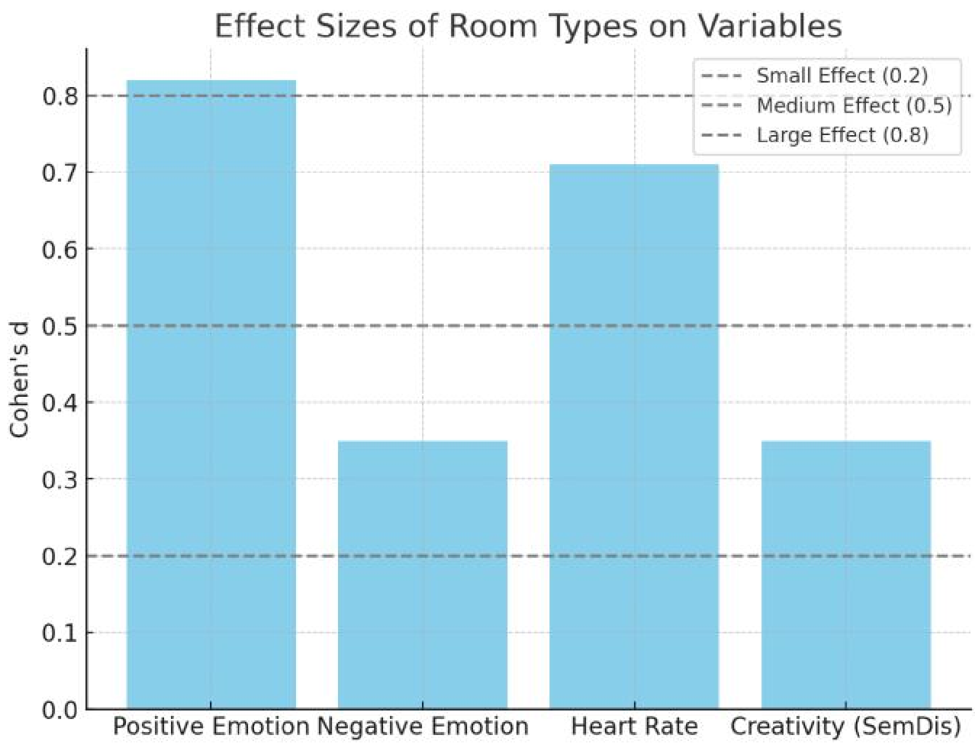

Figure 3: Effect Sizes of Room Types on Variables

4.5 | Data Visualization and Statistical Results

Box plots of Emotion and Creativity: These box plots are constructed with the intention of explicitly presenting the distributional discrepancies of each dependent variable under the two disparate room conditions. By means of visualizing the quartiles, whiskers, and potential outliers, a comprehensive and detailed insight into the dispersion and central tendency of the emotional and creative variables within the distinct environmental settings can be attained.

Line graph of Heart Rate: The line graph is specifically devised to vividly depict the temporal variation patterns of heart rate in the two rooms over the experimental duration. With the horizontal axis representing time and the vertical axis denoting heart rate values, it allows for a lucid and precise identification of any trends, fluctuations, or differences in the physiological responses as a function of the room types.

Bar chart of Effect Sizes: This bar chart is utilized to offer an immediate and intuitive visual comparison of the magnitudes of effect sizes corresponding to different dependent variables. The height of each bar is directly proportional to the quantified impact, thereby facilitating a swift and accurate assessment of the relative significance and strength of the relationships between the environmental factors and the various response variables such as emotion, heart rate, and creativity.

Through comprehensive and rigorous data analysis procedures, the statistically significant influences of environmental form language on emotion, heart rate, and creativity have been robustly verified. These empirical findings serve as a solid and reliable scientific foundation, which is of crucial importance for the optimization of user experience within the realm of architectural design. They offer valuable insights and guidelines that can assist architects and designers in making well-informed decisions and implementing strategies to enhance the quality and desirability of built environments from the perspective of end-user satisfaction and well-being.

The above are three data visualization charts of the research results:Bar Charts of Emotion and Creativity: These bar charts are meticulously constructed to present the mean scores and standard deviations of positive and negative emotions under different room types. The vertical axis represents the magnitude of the scores, while the horizontal axis differentiates between the curved and rectangular room conditions. Through this graphical representation, one can readily observe and compare the central tendencies and variabilities of the emotional responses within the distinct environmental settings.

Line Chart of Heart Rate: This line chart is designed to precisely depict the temporal trends of the heart rate per minute of the participants in both curved and rectangular rooms. The x-axis, which symbolizes the time progression, and the y-axis, denoting the heart rate values, jointly enable a detailed visualization of any fluctuations, patterns, or divergences in the physiological responses as a function of the room types over the course of the experiment.

Bar Chart of Effect Sizes: This bar chart is skillfully employed to compare the effect sizes (Cohen's d) of different dependent variables. The height of each bar corresponds to the magnitude of the effect size, and the chart further includes the threshold lines demarcating small, medium, and large effects. This allows for an immediate and intuitive assessment of the relative magnitudes and significance of the relationships between the independent and dependent variables, providing a valuable perspective on the strength of the experimental findings.

These charts, as a whole, offer lucid statistical result support and vividly and intuitively present the differences and impacts unearthed in the experiment. They serve as powerful visual aids in facilitating a more profound understanding and interpretation of the research outcomes within the academic community.

5 | DISCUSSION

5.1 | The Influence Mechanism of Form Language on Emotional Expression

5.1.1 | Consistency with and Extension/Deepening of Previous Research

The results of this study are consistent with those of previous researchers, confirming that geometric factors influence emotions. The curved form is associated with positive emotions, possibly due to natural preferences, while the rectangular form is related to negative emotions (Zioga et al., 2020). The expansion of this study lies in the precise control of variables in the three-dimensional virtual environment, providing theoretical support for cross-cultural emotional design (Shemesh et al., 2020).

5.1.2 | Elucidation of Potential Neurophysiological Mechanisms

From the perspective of neuroscience, curvilinear shapes may affect neural activities in the brain, activate the pathways related to positive emotions, and reduce the activities associated with negative emotions (Ruta et al., 2023). The changes in heart rate support its role in emotion regulation, providing directions for further research (Northoff et al., 2019).

5.2 | TheInfluenceandSignificanceofModelingLanguage on Creative Output

5.2.1 | The Synergistic Mechanism with Environmental Factors

Curvilinear shapes have been demonstrated to augment creative output. This phenomenon resonates with the impact of natural elements on creativity, as both collaboratively construct a conducive psychological milieu. Thereby, the significance of the comprehensive design of the environment is underscored (Wu et al., 2021). It is advocated that the modeling language ought to synergize with other factors to potentiate creativity (Beversdorf et al., 2019).

5.2.2 | Implications for Design Practice and Broad Application Prospects

The modeling language should be taken into account in the design of educational and work environments. For instance, introducing curvilinear elements into classrooms and offices can stimulate creativity (Lloyd-Cox et al., 2022). Product design can also draw on this, enhancing the emotional appeal and user experience. Moreover, it can provide new ideas for artistic creation and so on (Gieseke et al., 2021).

5.3 | Advantages and Limitations of the Research

5.3.1 | Research Advantages

A Paragon of Multidisciplinary Integration and Innovation: By integrating multidisciplinary knowledge and methods and conducting interdisciplinary teamwork, the advantages of each discipline are complementary, enriching the research content and enhancing the scientificity and reliability of the results (Yang et al., 2024). A Paragon of Scientific and Rigorous Experimental Methods: The virtual reality technology is used to control variables, and multiple measurement tools are employed for multi-dimensional assessment, ensuring the consistency and repeatability of the experimental environment. Thus, the results are comprehensive, accurate, and convincing (Willinger et al., 2022).

5.3.2 | Limitations of the Research

- The Predicament of Constrained Sample Representativeness: The present study is encumbered by a relatively diminutive sample size, which is further compounded by its derivation from specific geographical regions, thereby entailing a circumscribed range of cultural backgrounds. Such limitations inevitably impinge upon the generalizability of the research outcomes. To address this concern, future investigations should prioritize the augmentation of sample diversity to enhance the external validity of the findings (Cheung et al., 2019).

- The Shackles Imposed by the Virtual Nature of the Experimental Setting: The virtual environment employed in this research deviates from the real-world context, particularly in terms of tactile feedback, which consequentially impacts the experiential dimension of the participants. To fortify the robustness of the results, subsequent studies could consider integrating augmented reality technologies or conducting on-site observations as a means of validating the obtained findings (Duan et al., 2019).

- The Boundary Constraints of Research Variables: The current research predominantly centers around spatial shapes, while other elements within the domain of modeling language, as well as individual difference variables, remain inadequately explored. To comprehensively elucidate the research topic, future endeavors should strive to broaden the spectrum of variables under consideration and meticulously examine the interactive effects among multiple variables (Wyse et al., 2019).

6 | RESEARCH CONCLUSIONS AND PROSPECTS

6.1 | Summary of Research Conclusions

This research has unequivocally substantiated that diverse modeling language environments exert a significant influence on the emotional, physiological, and creative aspects of individuals. Specifically, curvilinear shapes have been demonstrated to possess an advantageous effect in relation to positive emotions, heart rate modulation, and the stimulation of creativity, whereas rectangular shapes present contrasting characteristics. These findings not only furnish empirical support for theoretical investigations but also unravel the essential and pivotal role that modeling language plays within the realm of human experiences.

6.1.1 | Elaboration on the Theoretical and Practical Significance

Theoretical Significance: This research has effectively addressed a significant lacuna within the domain of the relationship between modeling language and emotional expression. By astutely amalgamating multidisciplinary theories, it has meticulously dissected the underlying mechanisms governing this intricate relationship. Notably, the systematic examination of spatial shape variables within a three-dimensional virtual milieu has furnished novel impetus to the theoretical edifices of environmental psychology, neuroarchitecture, and related disciplines, thereby broadening their investigative frontiers. The resultant research outcomes are instrumental in forging a more exhaustive and profound theoretical scaffolding, further explicating the convoluted interactive tenets between human emotions and the ambient environment. Moreover, it proffers inventive paradigms and methodologies for interdisciplinary inquiries, thus emerging as a cardinal wellspring of impetus that propels the incessant progression of pertinent disciplines in this particular research terrain.

Practical Significance: The present research proffers principles and orientations of substantial guiding value across a multitude of practical arenas, encompassing architectural design, interior design, and product design. In light of the research conclusions, designers are empowered to judiciously and precisely employ modeling language so as to artfully mold users' emotional experiences and behavioral modalities in accordance with the specific functional requisites of diverse scenarios.For instance, the artful integration of curvilinear elements within innovative educational spaces and school classrooms can efficaciously elicit students' positive emotions and creativity, thereby engendering a learning milieu replete with vitality and inspiration. In the context of business office settings such as conference rooms, the judicious applicationof rectangular elements contributes to the cultivation of a stable, professional, and solemn ambience, augmenting the efficacy and professionalism of business interactions.Furthermore, product designers can avail themselves of the research outcomes to optimize the external configurations of products, thereby enhancing the emotional value-added of products. This, in turn, leads to a conspicuous amelioration of users' experiential and satisfaction levels, culminating in an elevation of product competitiveness in the market and the generation of greater commercial value for enterprises.

6.2 | Prospects for Future Research Directions

Expanding the Diversity of Research Subjects and Environments: Future research endeavors ought to be actively and vigorously engaged in further widening the gamut of research subjects. This implies the extensive incorporation of cohorts hailing from disparate age strata, multifarious cultural backgrounds, and variegated socioeconomic standings. The overarching objective is to holistically and profoundly unearth the ubiquitous principles governing the influence of modeling language on emotional expression, in tandem with the idiosyncratic disparities manifested across diverse groups.

Simultaneously, the typology of research environments should be rendered more copious and heterogeneous. This entails the comprehensive coverage of a plethora of scenarios, such as public spaces (encompassing bustling marketplaces, serene libraries, and the like), medical facilities (including sundry departments within hospitals, rehabilitation centers, et al.), and outdoor natural landscape settings. Through an in- depth exploration of the emotional ramifications of modeling language within different functional arenas, more precise and highly bespoke scientific underpinnings can be furnished for the human-centered design of assorted environments. Thereby, the design can be better attuned to the sundry requisites of distinct individuals in disparate scenarios.

Deepening the Research on Variables and the Analysis of Interaction Effects: It is imperative to conduct an in-depth excavation of the latent impact mechanisms of a broader spectrum of modeling language elements, encompassing the textural disparities of materials, the nuanced chromatic variations, and the artful manipulation of light and shadow, along with their multifarious combinations, upon emotions and behaviors. A systematic dissection of the labyrinthine interactional nexuses among disparate modeling language variables, as well as between modeling language and other environmental determinants, such as the thermal oscillations, the hygrometric differentials, and the acoustic amplitude variances, is warranted.

Furthermore, due cognizance must be accorded to the moderating influence exerted by individual difference variables, including the polymorphic personalities, the idiosyncratic cognitive modalities, and the variegated cultural backgrounds, within the nexus of modeling language and emotional expression. Grounded on these premises, the construction of more intricate, refined, and accurate theoretical paradigms is essential. Such models would facilitate more precise prognostication and profound explication of the regulative principles underlying the impact of modeling language on human emotions and behaviors, thereby endowing design practice with more prescient and directive theoretical scaffolding.

Expanding the Diversity of Research Subjects and Environments: Future research endeavors ought to be actively and vigorously engaged in further widening the gamut of research subjects. This implies the extensive incorporation of cohorts hailing from disparate age strata, multifarious cultural backgrounds, and variegated socioeconomic standings. The overarching objective is to holistically and profoundly unearth the ubiquitous principles governing the influence of modeling language on emotional expression, in tandem with the idiosyncratic disparities manifested across diverse groups.

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Integrating New Technologies and Methods to Enhance Research Precision: In the wake of the meteoric advancement of science and technology, prospective research endeavors ought to be zealously engaged in the assimilation of a greater array of nascent technologies. To exemplify, brain-computer interface technology, which permits the direct interchange of information between the cerebral cortex and external apparatuses, thereby paving the way for an incisive exploration of the instantaneous impacts of modeling language upon neural activities within the brain.

Moreover, eye-tracking technology, which meticulously registers the allocation of visual attention and the trajectories of ocular movements among participants when they are presented with diverse modeling languages, thus unearthing the nexus between visual perception and emotional reactivity. Additionally, physiological multi- modal monitoring technology, which concurrently gauges multiple physiological indices, such as heart rate variability, galvanic skin response, and electroencephalogram, thereby comprehensively dissecting the physiological responses elicited by modeling language from a plurality of physiological dimensions.By procuring more copious and accurate physiological and behavioral data, a profound dissection of the internal mechanisms underlying the influence of modeling language on emotional expression at the neurophysiological stratum will be carried out. Concurrently, it is requisite to actively probe into innovative research methodologies. For instance, big data-oriented analytical approaches, which entail the collection and scrutiny of voluminous actual design case data and user feedback data, with the aim of excavating the latent patterns and regularities between modeling language and emotional expression concealed within the vast expanse of big data.In addition, machine learning algorithms, which harness machine learning models to effectuate classification, prediction, and pattern recognition of complex data, thereby proffering intelligent decision-making support for the design and application of modeling language. Through the leveraging of these novel technologies and methodologies, the research within this domain will be impelled to progress towards enhanced precision and profundity, culminating in a qualitative ascendancy in the research echelon.

Expanding the Application Domains and Deepening Interdisciplinary Collaborations: Ceaselessly expand the application scopes of research outcomes and extend them to a plurality of arenas, namely urban planning (such as the layout and design of urban public spaces, the configuration of the urban skyline, and so forth), landscape design (including the planning and establishment of parks, squares, streetscapes, among others), digital art creation (for instance, how to employ modeling language to evoke the emotional resonance of the audience during the creation of virtual reality art, digital animation, and the like), and human-computer interaction design (such as the design of intelligent device interfaces, the design of virtual interaction environments, and the like). Through facilitating the innovative integration and application progression of modeling language across diverse fields, novel creative stimuli and design conceptions will be introduced to these fields. Further augment the profundity and extensiveness of interdisciplinary collaboration by more intimately amalgamating the puissance of multifarious disciplines. Natural sciences (such as biology and physics, which furnish the substratum of fundamental scientific tenets for the research), engineering technologies (for instance, computer technology and material engineering technology, which endow the means of technological actualization for the research), and humanities and social sciences (like sociology and culturology, which bestow the socio-cultural backdrop and the perspectives of human behavior research for the research) are to be concertedly harnessed. Collectively surmount the intricate conundrums encountered in the exploration of the nexus between modeling language and emotional expression. Realize the profound integration and synergistic progression of theoretical research and practical applications. Contribute greater sagacity and puissance to the amelioration of human life quality and the impetus of socially sustainable development, thereby forging a more felicitous future conclusion, this research has achieved important stage-wise results in the field of the relationship between modeling language and emotional expression. However, there remain extensive uncharted areas lying ahead, awaiting further in-depth exploration and research. Future research is expected to gradually unveil the profound impact mechanisms of modeling language on human emotions and behaviors in broader fields and at deeper levels. Thereby, it will provide more scientific, precise, and comprehensive theoretical guidance for design practice, effectively promoting the continuous innovative development and progress to new heights in related fields.

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