Examining the Spatial Perception of Users of Verbally Generated 3D Virtual Space Visualizations

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Abstract

Background To understand the visual discrepancy during design critique and consultation, we evaluate the Associative Words Generator© (AWG©) application to visualize three-dimensional spaces and objects based on spoken words (verbalizations).

Methods The study encompassed a total of 36 respondents, with each group—students (S), studio lecturers (L), clients (C), and designers/architects (D/A)—comprising nine respondents. Equipped with a virtual reality VR device linked to the AWG© application, each respondent assessed the outcomes of the 3D room visualization generated by AWG©. We gauged the depth of associative words and established a semantic model to describe the perceived environment, employing a seven-point Likert questionnaire based on Semantisk Miljobeskrivning (SMB) environmental quality dimensions.

Results The findings demonstrate that the student and studio lecturer groups exhibit a similar inclination towards evaluating the pleasantness–affection dimension, while the client and designer/architect groups demonstrate a shared tendency to rate the pleasantness–complexity dimension.

Conclusions Notably, AWG© proved effective in reducing the visual discrepancy gap among student and lecturer groups, as well as client and designer groups during design critique.

Keywords Interior Spatial, Virtual Reality, Spatial Perception, Network Analysis, Associative Word

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Citation: Junaidy, D. W., Adharamadinka, M., Kusumah, G. K., Darmakusuma, R., Ginalih, C. T., Sakya, K. A., & Mawali, L. (2024). Examining the Spatial Perception of Users of Verbally Generated 3D Virtual Space Visualizations. *Archives of Design Research, 37*(1), 61-83.

http://dx.doi.org/10.15187/adr.2024.02.37.1.61

Received : Sep. 12. 2023 ; **Reviewed :** Dec. 06. 2023 ; **Accepted :** Dec. 14. 2023
pISSN 1226-8046 **eISSN** 2288-2987

1. Introduction

Design critique is crucial in a design process that involves verbal communication between two or more parties, where information exchange on deep impressions, analysis, and feedback takes place. However, obstacles such as inaccurate delivery or meaning acceptance are often encountered because of blurred perceptions. Moreover, equalising perceptions in this process through verbal and visual language communication takes time. Design processes involving designers and clients or studio lecturers and students take several sessions to complete, including brainstorming. Brainstorming requires a more qualified design understanding from the designer or studio lecturer for discussion guidance and meaning agreement. The gap in design knowledge between parties can cause incongruent perceptions and expectations, both in textual and verbal forms, resulting in wasted time. Therefore, identifying an appropriate method to minimise such disparities is important.

The delivery of abstract perceptions during brainstorming ideally can be clarified by describing every word communicated by each party. These words can be analysed using associative word network techniques to identify in-depth impressions and thereby help bridge the different perceptions of meaning as the parties intended. We conducted experiments on groups of students (S), studio lecturers (L), clients (C), and designers/architects (D/A) to validate the AWG© application that we have developed in the previous study (Adharamadinka et. al., 2023) for bridging the perceptions of meaning regarding interior space design in the design critique practice of these groups. The AWG© application features the ability to visualize three-dimensional spaces and objects based on spoken words (verbalization) during the brainstorming process. Analyzing verbalizations from the brainstorming process of paired groups is one way to understand the deep impressions conveyed by each utterance during the design critique and brainstorming processes. The abstract perceptions of each respondent involved in the brainstorming process can occur due to differences in knowledge regarding the perception of object shapes, object colors, object textures, object positions, and other factors among each pair of respondent groups. Furthermore, to align perceptions among each pair of respondents, visual stimuli are provided, which can be visualized in three dimensions using the AWG© application—a visual three-dimensional space generator application. In the experiment, respondents used the AWG© application, which was equipped with a set of virtual reality (VR) instruments. This experiment included two validation test methods. The first method was for identifying the verbalization of spoken words in response to the imagery and visualization of several interior space simulations, as characterised by expressive words containing utterances and adjectives associated with each other, to respond to spatial stimuli. Here, the verbalization was done in real time or spoken directly by the respondents. In the second method, human impressions (affective preferences) on built environment were measured, using the semantic environmental description (Semantisk miljöbeskrivning/SMB) to describe the perceived environment (Küller, 1972; 1975; 1979; 1980; 1991). The data were obtained through a seven-scale Likert questionnaire survey regarding six SMB dimensions: pleasantness, complexity, unity, enclosedness, affection, and originality. The results of this assessment were then processed using correlation analysis, specifically between dimensions in each group of respondents to see the pattern of assessment of the visualization of interior spaces. This study focuses on respondents' sensation in response to virtual spatial visualization, measured through the depth of associative words and the SMB dimension with the highest significance.

2. Related work

2. 1. Use of virtual reality as a design consulting medium

Portman et al. (2015) defined VR as a communication component in a computer-made synthetic space that attaches humans as an integral part of the system. The latest head-mounted VR devices, such as the Oculus Rift, provide users with an immersive experience. Immersion—through images, sounds, and other stimuli in a VR system—is the perception of being physically present in a non-physical world as if one is truly in that place (Freina and Ott, 2015). VR replaces the user's perception of the surrounding environment with a computer-generated 3D environment so that the real environment is no longer needed for cognitive experiences (Kim et al., 2013; Lanier, 1992).

VR technology can provide a higher-quality simulation of the environment and interaction between humans and space. As such, there is an opportunity to develop simulation tools and interactions between humans and space in spatial design (Kuo and Cheng, 2008). The VR environment provides the sensation of a spatial or physical presence (Lee, 2004). These sensations affect the effectiveness of users in processing spatial relationships in their environment. Hence, the use of VR as an educational tool requires careful consideration of the relationship between spatial presence and spatial ability (Özgen et al., 2019). VR learning environments allow learning more immersive interactive features such as the creativity component of digital environments (Casakin, 2007; Dorst and Cross, 2001; Özgen et al., 2019). Users gain an emotional and rational perception of a realistic 3D environment after having an immersive experience in a VR environment. Therefore, there is potential here for developing new ideas to increase empathy concerning spatial needs (Ji et al., 2018). In cognitive learning domains such as thought processes, problem-solving, verbal information, concept formation, and information processing, digital media such as VR-based learning can strengthen the learning design (Dede, 2008).

The literature shows that the features, outcomes, and impacts offered by VR can be used as a means of consulting in the field of spatial design. VR can potentially be used in various forms of interaction in the field of spatial design, both professionally and educationally.

2. 2. Development of virtual reality–Associative Words Generator©

Based on previous research (Adharamadinka et. al., 2023), the Associative Words Generator© (AWG©) application has been developed for visually computing verbal expressions using a vocal database generation method integrated with interior visual assets. The application can help get the most powerful, significant, and unverbalized associative meanings based on the user's preferences of the visual perception of space.

Based on the responses obtained previously, to determine the associative word that has the strongest relationship with the keyword, the selection is made by looking at the largest total distribution value of each associative word obtained. After getting the distribution value of associative words for each word order that comes up, weighting is conducted for each associative word order. The collected survey data are used as a database in which there are various associative meanings that are the same and different. The order of the frequencies in the database also affects the results to be generated. In the formation of a three-dimensional space, this is done by building a room that has four walls, floors, ceilings, and furniture items. Every wall, floor, ceiling, and furniture item is made according to the inherent associative properties of words, has weight and frequency value, and is combined with C# programming language algorithms. Associative words that have been collected from keyword stimuli in each perception dimension will correlate with other associative words and become a resource for the creation of three-dimensional visual assets.

The space generated based on the input in the sentence and program fields results in a mix of visual assets. The results generated change randomly each time the VR button is pressed. The resulting room atmosphere contains elements of the words associated with the perceptual dimension keywords that already exist in the AWG database. The final result can be viewed using the Oculus Rift (VR equipment) from a first-person perspective. Figure 1 below illustrates the interface of the 3D AWG© spatial visualization generator application and an example of three-dimensional generation results. The interface design of AWG© reveals three interface design bars in Figure 1 below. In the topmost column, there is a function to input sentences perceiving the desired space (with a database still in development). In Figure 1, it is written, "this space is very spacious and natural." Consequently, in the second column below, upon pressing the "extraction" button, keywords listed in the AWG© database, namely "spacious" and "natural," will automatically appear. In the bottommost third column, upon pressing the "associative" button, associative words will emerge, accompanied by weight values indicating the proximity of profound impressions. Once all the data is input, the final button "VR" will provide a spatial visualization based on the input data in the database. Pressing the "VR" button more than once will present various spatial options in terms of spatial composition, objects, and others while maintaining the same associative weight score (Out-Degree Centrality Score).

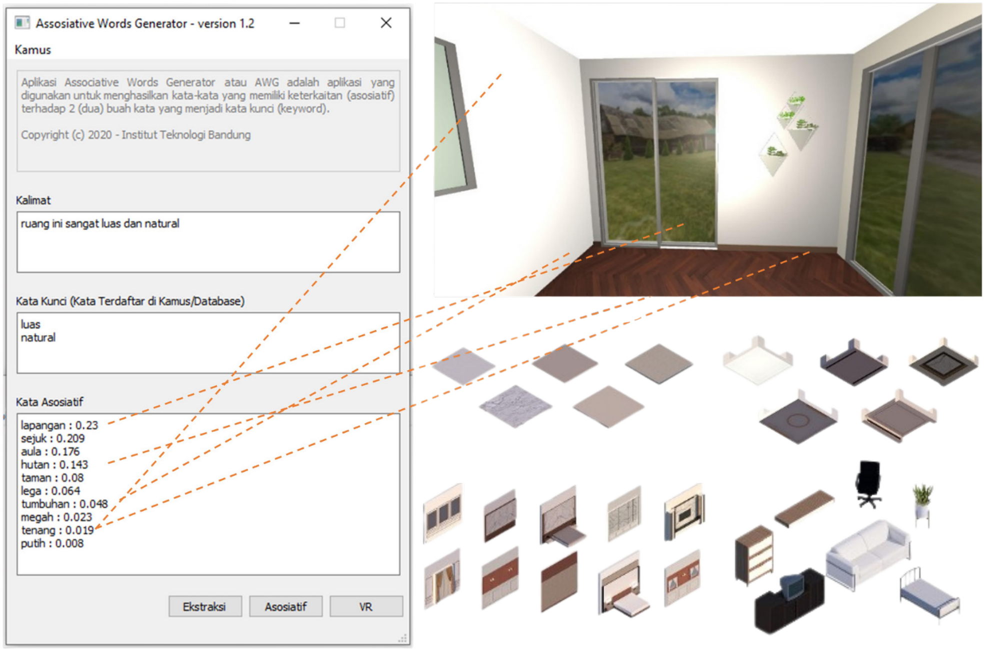

Figure 1 Associative Words Generator interface

2. 3. Semantic Environment Description (SMB) to measure the impression of space

In previous studies on the dimensions of user resilience to interior spaces, researchers in the field of linguistic cognition and computer science believe that a word has a rich and broad essence of meaning when used to express an event (Junaidy et. al, 2020). The essence of a word can contain implicit and metaphorical associations (Taura et. al., 2010; Nagai et al., 2011; Georgiev and Nagai, 2011). Here, a common method for measuring human impressions of the interior environment is applied, together with the results of the SMB, which is intended to describe a systematic depiction of the environment. The investigated environment can be interior, exterior, or simulated spaces (Küller, 1991). According to Laike (1999), the SMB method is easy to manage and use, and has high validity. SMB measures the overall environment based on a questionnaire with a 1–7 (1 = little; 7 = very) scale to identify how well each adjective is grouped into the eight SMB factor dimensions. When used to assess real-world environments, SMB achieves a high degree of stability in group sizes of 15–20 individuals (Küller, 1991; 1975). SMB claims to be able to measure the average level of a person's impression of the environment such as a room, building, or landscape in a simulation (Küller, 1991). In addition, SMB can also measure the level of a person's impression of the perceived well-being. The scale in the SMB uses adjectives about the environment given an interval of 1 to 7; then, the adjectives are divided into eight dimensions of environmental quality: pleasantness, complexity, unity, closedness, social status, potency, affection, and originality. Table 1 below shows the division of these eight dimensions of environmental quality in the SMB theory.

Table 1 Dimensions of environmental quality of the semantic environment description (SMB) theory (Küller, 1991)

Dimensions of Environmental Quality (Semantic Environment Description)	Description
Pleasantness	Environmental quality when the respondent feels at home, beauty, and security (stimulating, secured, idyllic, good, pleasant) and (ugly, boring, brutal)
Complexity	Degree of variation, intensity, and level of contrast (lively) and (subdued)
Unity	A unified environment so that it is coherent and functions as a whole (consistent, whole)
Enclosedness	Feelings of being enclosed and limited (closed) and (open, airy)
Potency	Feeling the presence of strength and power in the parts of the environment (masculine, potent) and (fragile, feminine)
Social Status	Evaluation of the built environment in terms of socio-economic and maintenance aspects (expensive, well-kept, lavish) and (simple)
Affection	Affective qualities leading to a sense of familiarity, often related to environmental age (modern, new) and (timeless, aged)
Originality	There is a novelty or something that the respondent has never experienced (curious, surprising, special) and (ordinary)

According to Küller (1977), pleasantness is influenced by various things; therefore, it is difficult to predict the interpretation of pleasantness. However, pleasantness may be interpreted as being influenced by the balance between complexity and unity. For example, if the unity value is too high and the complexity value is too low, an environment may be considered boring and not very pleasant. Meanwhile, if the unity is too low and the complexity is too high, this will create a messy impression. Complexity has to do with the amount of detail. Unity relates to the assessment of the harmony of various elements in a single unit. Enclosedness is influenced by the actual size of the room, colour, window size, and the number of demarcations or boundaries in the environment. Social status is a social and economic evaluation of the environment. Affection is influenced by the element of familiarity according to the respondents. Originality is influenced by unusual objects according to the respondent's experience.

In this study, we focus on measuring the spatial sensation and perception of each group of respondents by validating the generation of a three-dimensional virtual space formed through the Associative Words Generator (AWG) using the SMB dimension. We do not fully use the SMB dimension as a measuring tool for spatial sensation in AWG applications. Instead, we use six SMB dimensions, namely, pleasantness, complexity, unity, enclosedness, affection, and originality. This choice is based on the relevance of the dimensions to the context of our research objectives. The output generated through the AWG is projected using VR as a tool for sensing the manipulated scene. A virtual environment (VE) experience generated by VR can manipulate the experience of space (scene), and manipulating space will make people who use VR feel like they are in a simulated environment. When we move in a 3D environmental space, cognitive relevance will unite with our interactions with objects (Draschkow and Võ, 2016). Objects here play an important role when we can remember what objects there are and how our attention changes when manipulated objects are associated with design elements and design principles to form a different scene. The scene contains supporting elements that are related to associative word stimuli spoken during design consultations between clients and designers/architects as well as studio lecturers and students.

3. Methodology

This study examines the validity of the spatial visualization of the AWG© application with user impression responses. The validity test of the three-dimensional spatial visualization in the AWG© application is designed to find individual perceptual preferences for the space based on a set of associative words that have an in-depth impression. Experimental respondents formed four groups according to the target user segment, namely, students, studio lecturers, clients, and designers/architects. The classification of respondent groups based on the required target segmentation in utilizing AWG© serves the purpose of aligning abstract perceptions in both design critique processes (students and studio lecturers) and brainstorming interaction processes (clients and designers/architects).

Thirty-six Indonesians were recruited for this study, and informed consent was obtained from all respondents. The respondents included 9 interior and architecture undergraduate students (mean age = 20.15) (S), 9 interior and architecture studio lecturers (mean age = 48.30) (L), 9 professional designers/architects (mean age = 48.44) (D/A), and 9 community/clients (mean age = 44.12) (C).

The selection of students for this experiment is based on their level of experience in spatial design, which is minimal and at an early stage of their academic studies. Conversely, studio lecturers were chosen based on their teaching experience as faculty and their extensive background in critiquing the designs produced by these students. Clients, as one of the respondent groups, were selected based on their lack of fundamental understanding and knowledge regarding spatial design, along with their interest in utilizing the services of designers/architects. On the other hand, designers/architects were required to meet criteria related to experience, including a minimum of 5 years of real project experience and a portfolio that has been utilized by clients.

The rationale behind recruiting each group—students (S), studio lecturers (L), clients (C), and designers/architects (D/A)—was driven by the significance of equalizing perception, particularly for individuals whose professions heavily depend on visual perception, creativity, and collaboration, specifically within the fields of interior design and architecture. Studio lecturers, designers, and architects are anticipated to grasp and standardize the visual perception of both students and clients. Design, being a cognitive activity, necessitates the visual communication of abstract ideas, where each respondent must comprehend the meaning conveyed through spoken words. If interpretations and perceptions differ among studio lecturers and students or between designers, architects, and clients, achieving visual consensus in design decisions becomes challenging. We anticipate that lessening the visual discrepancy gap during design critique and consultation can narrow the spatial mental imagery gap between pairs of groups, such as student and lecturer groups, as well as client and designer/architect groups.

Experiments were conducted using the AWG© application through several data collection and validation sessions within 20 minutes. In the data collection session, respondents were asked to visualise the space with a theme based on predetermined keywords and describe them simultaneously. In the initial session, the respondents were instructed to mentally envision and verbally describe a 4x4 residential room, incorporating keywords representing neutral perception dimensions and a positive perception dimension ("natural" and "homey"). These keywords served as motivational cues for the ensuing experiments. A five-minute interval was allocated for respondents to articulate the interior environment, emphasizing "natural" and "homey" attributes (Adharamadinka et. al., 2023).

Then, the respondents were asked to try the AWG© application facilitated by a set of VR instruments. The spatial visualization was derived from the word associations through the AWG© application. In this session, the words entered into the application were those chosen by the researchers. The researchers utilized the combination of same two words in this step to make dimensional virtual space visualizations embodying the "natural" and "homey" essence. These visualizations served as stimuli to guide respondents in responding to the corresponding perceptual attributes.

Afterwards, the procedure in the data collection session was repeated by selecting the spatial visualization keyword according to the respondent's wishes by typing through AWG© interface. When the AWG© application usage test was completed, the respondents were asked to rate the results of the room visualization generated through the AWG© application using a seven-scale Likert questionnaire. The questions were based on the aforementioned six SMB dimensions. This questionnaire was utilized to examine the spatial perceptions of the AWG© users of 3D virtual space visualizations.

Thereafter, in the validation session, data were processed using a quantitative approach. Specifically, the distribution of the average and the correlation of dimensions in each group of respondents were analysed through comparisons of the assessments between groups of respondents, to reveal the pattern of assessment of each respondent on the visualization of interior spaces. This comparison helped us find gaps or deficiencies in the AWG© application so that it can be customized according to the target user. A consistent client–designer/architect or design student–studio lecturer perception at the time of brainstorming or design critique is necessary to simplify the process and save time. Designers/architects can save time in responding to space preference requests from clients and interior design students to understand directions from their studio lecturers.

4. Results and discussion

The experiment involved a total of 36 respondents, comprising nine respondents each for the student (S), studio lecturer (L), client (C), and designer/architect (D/A) groups. The classification of respondent groups based on the required target segmentation in utilizing AWG© serves the purpose of aligning abstract perceptions in both design critique processes (students and studio lecturers) and brainstorming interaction processes (clients and designers/architects). The selection of students for this experiment is based on their level of experience in spatial design, which is minimal and at an early stage of their academic studies. Conversely, studio lecturers were chosen based on their teaching experience as faculty and their extensive background in critiquing the designs produced by these students. Clients, as one of the respondent groups, were selected based on their lack of fundamental understanding and knowledge regarding spatial design, along with their interest in utilizing the services of designers/architects. On the other hand, designers/architects were required to meet criteria related to experience, including a minimum of 5 years of real project experience and a portfolio that has been utilized by clients.

Each respondent was asked to use a VR device that was connected to the AWG© application. In the first session, the 3D visualization generated by the AWG© application was the result of processing natural and homey keywords. In the second session, the respondents had the freedom to choose the keywords they wanted to process and generate in 3D visualizations through the AWG© application. After that, the respondents assessed the AWG© application by filling out a seven-scale Likert questionnaire based on the SMB dimensions. The data processing results consist of an analysis of the mean distribution; dimensional correlation analysis of the assessments of groups of students, studio lecturers, clients, and designers/architects; and comparison of student–studio lecturer and client–designer/architect correlations.

Prior to conducting a comprehensive analysis, the reliability test of data collection was conducted with reference to the dimensional variables that were determined as data requirements. Each dimensional variable included three questions from the questionnaire. The acceptable limit for reliability testing is a Cronbach's alpha of 0.70 or higher for a set of items to be considered a scale. In the collected study data, the Cronbach's alpha was 0.775, indicating validity and reliability of the questions.

4. 1. Comparison of assessments between groups of virtual reality–Associative Words Generator©

Analysis of the average distribution of the completed questionnaires was conducted to determine the respondents' assessments based on the SMB dimensions. The questionnaire raised the following six SMB dimensions. Of the 36 research respondents, the average values of the dimension sorted from highest to lowest are originality (6.24), affection (5.38), pleasantness (5.10), unity (4.66), enclosedness (4.39), and complexity (4.21).

Table 2 Distribution of the questionnaire average score based on the respondent groups and the six SMB dimensions

SMB Dimension	Mean				Overall Mean	Standard Deviation
	Students	Studio Lecturers	Clients	Designers/ Architects		
Pleasantness	5.55	4.85	5.15	4.85	5.10	1.01
Complexity	4.67	3.78	4.40	4.00	4.21	0.77
Unity	4.78	4.63	5.04	4.18	4.66	0.95
Enclosedness	4.18	4.41	4.26	4.70	4.39	0.80
Affection	5.51	4.92	6.04	4.92	5.38	0.84
Originality	6.37	5.81	6.37	6.40	6.24	0.75

In Table 2, the originality dimension has the lowest deviation (0.75), meaning that its perception in each group has almost the same proportion (average of 6.24 for all groups). Meanwhile, the highest deviation is found in the pleasantness dimension, with the student group rating this dimension the highest (5.55).

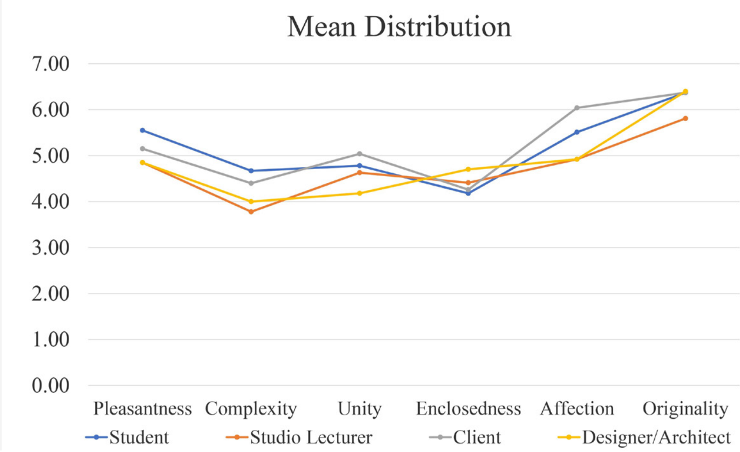

Figure 2 Comparison of the questionnaire average score based on the respondent groups and the six SMB dimensions

Figure 2 shows that the pleasantness and affection dimensions in the designer/architect and studio lecturer groups have overlapping means, meaning that these groups have similar abilities in assessing aspects of beauty and familiarity in the interior design. The similarity of these assessments indicates that both groups have similar assessments of the suitability of the keywords with the respondents' image and liking for the AWG© application. In the enclosedness dimension, all groups have means that are close to each other, meaning that all groups rate the impression of enclosedness at almost the same level as the experience obtained when using the AWG© application. This indicates that all groups similarly assess the completeness of interior elements and have a strong and rigid impression of the AWG© application. This happens because of the uniform arrangement of space in the virtual simulation of the AWG© application. On the originality dimension, the student, client, and designer/architect groups have overlapping means, while the mean of the studio lecturer group does not approach the mean of the other groups. This indicates that the students, clients, and designer/architect groups have similar assessment abilities of authentic elements. The similarity of these assessments suggests that these groups have similar assessments of the development motivation and curiosity towards AWG© applications.

Meanwhile, the studio lecturer group has a higher critique of the exploration of spatial elements, meaning they think that the spatial visualization of the AWG© application tends to be normative or ordinary. It is necessary to visualise an AWG© application that is more relevant to the perception dimension keyword to make the studio lecturer group rate the originality dimension with a higher value. For example, the keyword perception dimension 'shady' should be visualised with associations such as 'shadows', 'cool', and the like by using Associative Concept Network Analysis (ACNA) method. The means of the student and client groups are higher than those of the studio lecturer and designer/architect groups on most dimensions, suggesting that the student and client groups are more easily impressed by the virtual space stimulus of the AWG© application. The Associative Concept Network Analysis (ACNA) proves valuable for extracting profound insights from collected verbal inputs (verbalizations). This process involves generating word associations using The University of South Florida Word Association (USF Dictionary) Rhyme and Word Fragment Norms (Nelson, McEvoy, and Schreiber, 2004). This technique offers significant advantages as it enhances comprehension of the underlying meaning in verbal expressions (Nagai et al., 2011; Georgiev et al., 2012; Junaidy & Nagai, 2013; Junaidy et al., 2020).

Referring to the line graph of the comparison of word associations resulting from the Associative Concept Network Analysis (ACNA) data processing of student–studio lecturer on the use of the VR-AWG© application (see Figure 3) that was examined in the previous study (Adharamadinka et al., 2023), the student group produced associative words with Out-Degree Centrality (ODC) score of: (0,18) house; (0,11) tree, door; (0,10) color, window, hard; (0,08) hot, green, blue, red, wall; (0,07) room, white, light, work, flower; (0,06) metal, square, open, soft, floor, top, up, art, bright, food, good, picture, see, clothing, smell, paper, cold, chair, sun; (0,05) water, straight, space, sex, beautiful, black, tile, high, desk, table, wood, thing, pretty, look, back, face, grass, play, nature, feel. Meanwhile, the studio-lecturer group produced associative words with ODC score of: (0,12) house; (0,10) paper; (0,08) room, tree, love, light; (0,07) open, hard, school, door; (0,06) square, up, flower, window, good, dog, nature, place, close, air, star, wood, money, green, sun, fly, life, sky, water, smell, space, black, wall, color, timeless, work, bright, nice, length, big, grass, play, yard, shine, fun, car. It indicates a visual gap or discrepancy in comparing the responses of the two groups. Students generated more associative words than studio lecturers when using the VR-AWG© application.

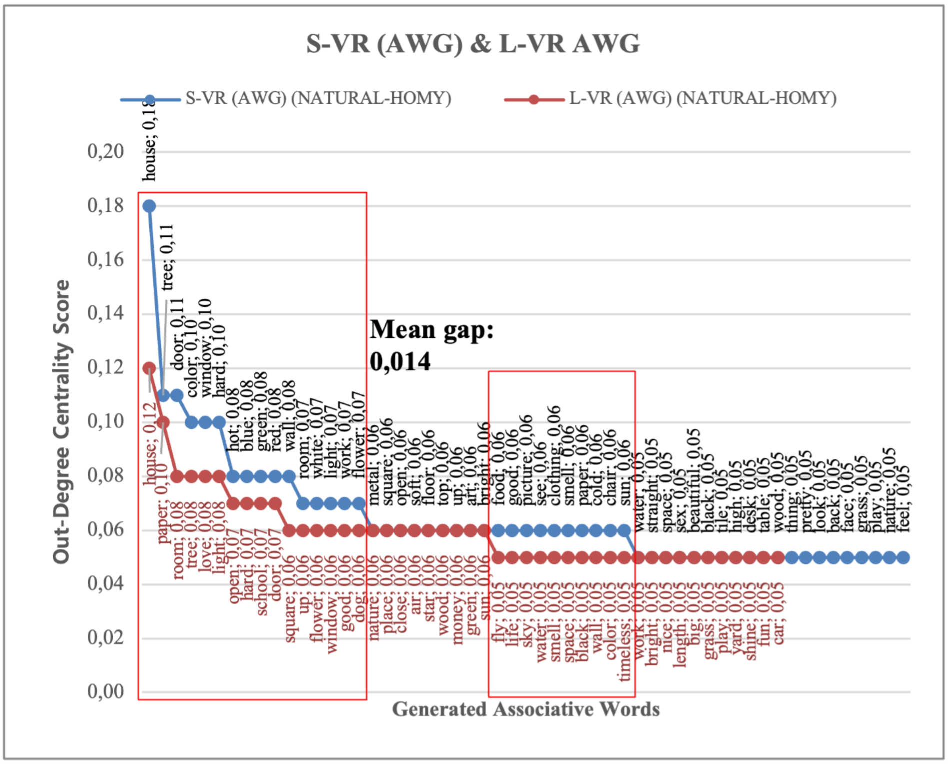

Figure 3 Comparison line graph of word association results from ACNA data processing of student–studio lecturer groups on the use of VR technology through the AWG© application (Adharamadinka et. al., 2023)

Adharamadinka et al. (2023) also examined a comparison line graph of the word association data processing of ACNA client–designer/architect on the use of VR-AWG© application (see Figure 4). Similar to student–studio lecturer on the use of the VR-AWG© application, the designer/architect group also produced fewer associative words than the client group when using VR-AWG© application. The client group produced associative words with (ODC) score of: (0,22) house; (0,14) tree; (0,12) green; (0,11) color; (0,10) black, red, blue; (0,09) hard, white, wall, flower, room, money, water; (0,06) life, light, forest, paper, dog, art, glass, shade, window, home, nature, good, door, chair, picture. Meanwhile, the designer/architect group produced associative words with ODC score of: (0,14) house; (0,08) green, light, tree, room, good, paper, wall, door; (0,07) work, clothes, space, color, red, money; (0,06) hard; (0,05) friend, water, open, square, area, blue, sun, flower, food, car, people.

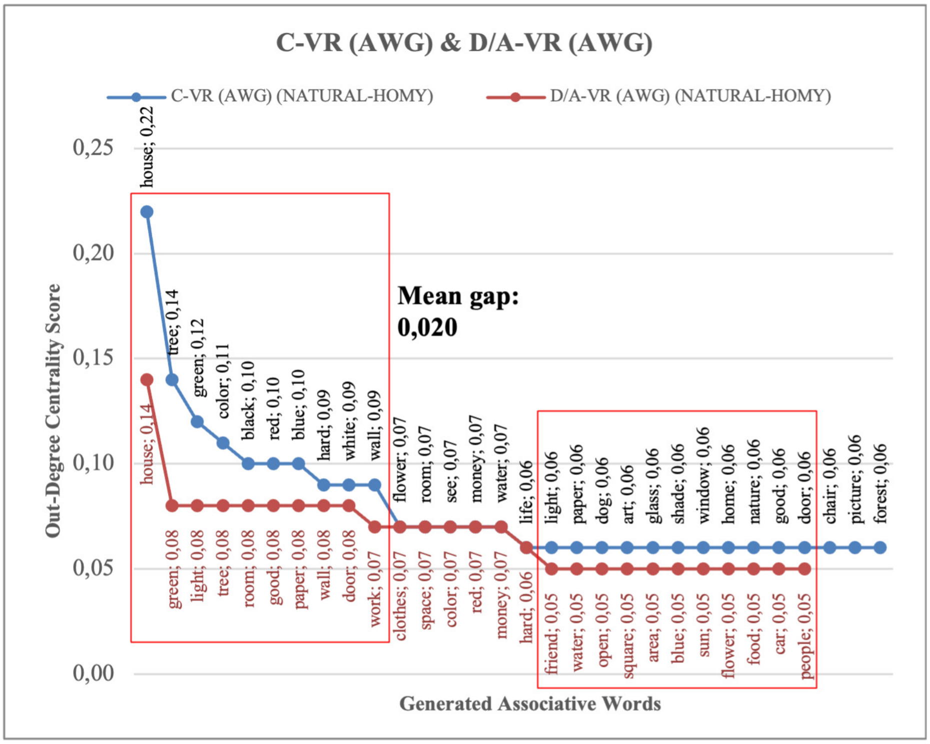

Figure 4 Comparison line graph of word association results from ACNA data processing of client–designer/architect groups on the use of VR technology through the AWG© application (Adharamadinka et. al., 2023))

The distribution of the average assessment of all groups of respondents through the questionnaire shows that for most of the dimensions of the questionnaire, the studio lecturer and the designer/architect groups have means below those of the student and client groups. This indicates an alignment of data in the comparison of responses between the student–studio lecturer and client–designer/architect groups from both association word generation and assessment through the questionnaire. In other words, the data analysed through the ACNA method, where the results are latent data, are aligned with the data obtained through subjective assessments given by the respondents through the questionnaire. The alignment of the data shows a response pattern whereby the student and client groups feel more stimulated by the AWG© application than the studio lecturer and designer/architect groups.

4. 2. Correlation of assessments between groups towards virtual reality–Associative Words Generator©

Correlation analysis was conducted to see the relationship in the assessment patterns between the groups, namely, S and L and C and D/A group pairs. Prior to this analysis, a correlation analysis was performed for each group on the six selected SMB dimensions and then, we connected pairs of groups by looking at the similarity of the correlation significance of each respondent. This way, the dimensions that bridge each pair of respondent groups can be seen.

4. 2. 1. Student group (S)

Of the nine respondents from the student group (S), the correlation ordered from the highest to the lowest values are affection–pleasantness (0.686), unity–pleasantness (0.529), unity–enclosedness (0.467), pleasantness–complexity (0.387), affection–complexity (0.357), pleasantness–enclosedness (0.216), affection–unity (0.191), unity–complexity (0.186), and affection–enclosedness (0.053). Moreover, the negative correlations are originality–complexity (-0.109), enclosedness–complexity (-0.262), originality–affection (-0.316), originality–enclosedness (-0.454), originality–unity (-0.541), and originality–pleasantness (-0.585). Table 3 presents the results of the correlation test of the six SMB dimensions in the S group.

Table 3 Correlation of the six SMB dimensions in the student group

		Pleasantness	Complexity	Unity	Enclosedness	Affection	Originality
Pleasantness	Pearson Correlation	1					
	Sig (2–tailed)						
Complexity	Pearson Correlation	0.387	1				
	Sig (2–tailed)	0.303					
Unity	Pearson Correlation	0.529	0.186	1			
	Sig (2–tailed)	0.143	0.631				
Enclosedness	Pearson Correlation	0.216	−0.262	0.467	1		
	Sig (2–tailed)	0.577	0.496	0.206			
Affection	Pearson Correlation	.686*	0.357	0.191	0.053	1	
	Sig (2–tailed)	0.041	0.345	0.622	0.892		
Originality	Pearson Correlation	−0.585	−0.109	−0.541	−0.454	−0.316	1
	Sig (2–tailed)	0.098	0.780	0.133	0.220	0.408	

* denotes significance at the 0.05 level (2–tailed).

The Pearson correlation test indicates that the affection dimension has a significant correlation with the pleasantness dimension (0.686). This shows that the average architecture/interior design student feels more familiar with their environment when the environment is more beautiful. Using the AWG© application, the student group prefers spatial visualization when the visualization is more in line with the image or the selected keywords.

The results of the correlation calculations in Table 3 indicate that the student group has an insignificant overall assessment of the use of the AWG© application, indicated by the significance of the correlation that only exists on the pleasantness and affection dimensions, whereas no significant correlation is found in other dimensions. This suggests that the student group is at the exploratory stage of design assessment such that variations exist in evaluation with high diversity.

4. 2. 2. Studio lecturer group (L)

Of the nine respondents in the studio lecturer group (L), the correlation ordered from the highest to the lowest values are unity–complexity (0.925), unity–affection (0.919), affection–complexity (0.885), originality–unity (0.850), affection–pleasantness (0.779), affection–originality (0.768), originality–complexity (0.744), unity–pleasantness (0.715), complexity-pleasantness (0.564), originality-pleasantness (0.539), enclosedness–originality (0.155), and complexity–enclosedness (0.132). Moreover, those with negative correlations are unity–enclosedness (-0.027), enclosedness–affection (-0.102), and enclosedness–pleasantness (-0.396). Table 4 presents the results of the correlation test of the six SMB dimensions in the L group.

Table 4 Correlation of the six SMB dimensions in the studio lecturer group

		Pleasantness	Complexity	Unity	Enclosedness	Affection	Originality
Pleasantness	Pearson Correlation	1					
	Sig (2-tailed)						
Complexity	Pearson Correlation	0.564	1				
	Sig (2-tailed)	0.114					
Unity	Pearson Correlation	.715*	.925**	1			
	Sig (2-tailed)	0.030	0.000				
Enclosedness	Pearson Correlation	−0.396	0.132	−0.027	1		
	Sig (2-tailed)	0.292	0.735	0.944			
Affection	Pearson Correlation	.779*	.885**	.919**	−0.102	1	
	Sig (2-tailed)	0.013	0.001	0.000	0.795		
Originality	Pearson Correlation	0.539	.744*	.850**	0.155	.768*	1
	Sig (2-tailed)	0.134	0.022	0.004	0.691	0.016	

** (*) denotes significance at the 0.01 (0.05) level (2-tailed).

Based on the Pearson correlation test in the student group, it is indicated that the unity dimension has a significant correlation with the pleasantness (0.715) dimension and a strongly significant correlation with the complexity (0.925) dimension. This shows that the average studio lecturer in the field of architecture/interior design feels that the environment has a more unified impression when the environment is more beautiful or has a variety of contrasting elements in it. Using the AWG© application, the studio lecturer group assesses that the quality of spatial visualization is more consistent when the spatial visualization is more in line with the imagination of the respondents or is easier to understand despite the complexity of the variations in interior elements.

The affection dimension has a significant correlation with the pleasantness (0.779) dimension and a strongly significant correlation with the complexity (0.885) and unity (0.919) dimensions. This indicates that the average studio lecturer in the field of architecture/interior design feels that the environment is more familiar when the environment is more beautiful, has a variety of contrasting elements, or has the impression of being united in the elements in it. Using the AWG© application, the studio lecturer group prefers spatial visualization when the visualization is more in line with the respondents' imagination and is easier to understand even though it has complexity in the variation of interior elements or has a more consistent quality.

The originality dimension has a significant correlation with the complexity (0.744) and affection (0.768) dimensions and a strongly significant correlation with the unity (0.850) dimension. This means that the average studio lecturer in the field of architecture/interior design feels an authentic impression of their environment when the environment is familiar, has a variety of contrasting elements, or if its elements have a unified impression. Using the AWG© application, the studio lecturer group is more curious about variations in spatial visualization when they like the spatial visualization more and it is easier to understand despite the complexity of the variations in interior elements or if the spatial visualization has a more consistent quality.

The results of the correlation calculations in Table 4 indicate that the studio lecturer group has the most significant assessment of the use of the AWG© application, indicated by a significant correlation in nine of the 15 correlation dimensions. This includes significant correlations on the unity–pleasantness, affection–pleasantness, originality–complexity, and originality–affection dimensions as well as strong significant correlations on the unity–complexity, affection–complexity, affection–unity, and originality–unity dimensions. Meanwhile, there are no significant correlations on the complexity–pleasantness, originality–pleasantness, and all enclosedness dimensions. This indicates that the studio lecturer group has design assessment skills with a perspective that focuses on the unity–complexity–originality–affection dimensions, which is indicated by a significantly strong correlation, such that the studio lecturer group can assess the application of AWG© in a way of thinking that focuses on a particular viewpoint. The unity–complexity–originality–affection dimensions, which are identical to the criteria of unity, contrast, authenticity, and familiarity, are elements that are often considered in design assessment for a group of studio lecturers.

4. 2. 3. Client group (C)

Of the nine respondents in the client group (C), the correlation ordered from the highest to the lowest values are affection–originality (0.815), complexity–pleasantness (0.792), affection–unity (0.751), pleasantness–unity (0.576), unity–complexity (0.521), unity–originality (0.378), enclosedness–pleasantness (0.321), affection–pleasantness (0.301), complexity–affection (0.128), and complexity–enclosedness (0.118). Moreover, those with negative correlations are originality–pleasantness (-0.251), enclosedness–affection (-0.307), enclosedness–unity (-0.340), originality–complexity (-0.376), and enclosedness–originality (-0.497). Table 5 presents the results of the correlation test of the six SMB dimensions in the C group.

Table 5 Correlation of the six SMB dimensions in the client group

		Pleasantness	Complexity	Unity	Enclosedness	Affection	Originality
Pleasantness	Pearson Correlation	1					
	Sig (2-tailed)						
Complexity	Pearson Correlation	.792*	1				
	Sig (2-tailed)	0.011					
Unity	Pearson Correlation	0.576	0.521	1			
	Sig (2-tailed)	0.104	0.150				
Enclosedness	Pearson Correlation	0.321	0.118	−0.340	1		
	Sig (2-tailed)	0.400	0.762	0.371			
Affection	Pearson Correlation	0.301	0.128	.751*	−0.307	1	
	Sig (2-tailed)	0.432	0.742	0.020	0.422		
Originality	Pearson Correlation	−0.251	−0.376	0.378	−0.497	.815**	1
	Sig (2-tailed)	0.515	0.318	0.316	0.173	0.007	

**(*) denotes significance at the 0.01 (0.05) level (2-tailed).

The Pearson correlation test on the client group indicates that the pleasantness dimension has a significant correlation with the complexity dimension (0.792). This shows that the average client feels that the environment is more beautiful when the impression of contrasting elements in the environment is higher. Using the AWG© application, the client group assesses that the spatial visualization is more in line with the imagination of the respondents when the visualization of the space is easier to understand despite the complexity of the variations in interior elements.

The affection dimension has a significant correlation with the unity dimension (0.751). This indicates that the average client feels more familiar with their environment when the elements in their environment are more integrated. Using the AWG© application, the client group prefers the spatial visualization more when the visualization has a more consistent quality.

The originality dimension has a strong significant correlation with the affection dimension (0.815). This suggests the average client feels an authentic impression of their environment when the environment is familiar. Using the AWG© application, the client group is more curious about the variety of spatial visualization when they like the visualization more.
The results of the correlation calculations in Table 5 indicate that the client group has a slightly significant assessment of the use of the AWG© application, marked by a significant correlation in three of the 15 correlation dimensions. A significant correlation is seen on the complexity–pleasantness and affection–unity dimensions, and a strong correlation significance is observed on the originality–affection dimension. No significant correlation is found on the other dimensions. This means that the client respondents have design assessment skills with a perspective that focuses on certain dimensions such as the originality–affection dimension, which is indicated by a significantly strong correlation. The originality–affection dimension, which is identical to the criteria of authenticity and familiarity, can be an element that attracts the attention of the general public.

4. 2. 4. Designer/architect group (D/A)

Of the nine respondents in the designer/architect group (C), the correlation ordered from the highest to the lowest values are complexity–enclosedness (0.888), originality–pleasantness (0.852), originality–complexity (0.830), pleasantness–complexity (0.810), affection–unity (0.796), unity–originality (0.761), enclosedness–unity (0.761), unity–complexity (0.725), pleasantness–enclosedness (0.723), originality–enclosedness (0.699), unity–pleasantness (0.602), originality–affection (0.542), complexity–affection (0.498), enclosedness–affection (0.465), and pleasantness–affection (0.477). Table 6 presents the results of the correlation test of the six SMB dimensions in the D/A group.

Table 6 Correlation of the six SMB dimensions in the designer/architect group

		Pleasantness	Complexity	Unity	Enclosedness	Affection	Originality
Pleasantness	Pearson Correlation	1					
	Sig (2-tailed)						
Complexity	Pearson Correlation	810**	1				
	Sig (2-tailed)	0.008					
Unity	Pearson Correlation	0.602	.725*	1			
	Sig (2-tailed)	0.087	0.027				
Enclosedness	Pearson Correlation	.723*	.888**	.761*	1		
	Sig (2-tailed)	0.028	0.001	0.017			
Affection	Pearson Correlation	0.447	0.498	.796*	0.465	1	
	Sig (2-tailed)	0.227	0.172	0.010	0.207		
Originality	Pearson Correlation	.852**	.830**	.761*	.699*	0.542	1
	Sig (2-tailed)	0.004	0.006	0.017	0.036	0.132	

**(*) denotes significance at the 0.01(0.05) level (2-tailed).

The Pearson correlation test in the designer/architect group indicates that the complexity dimension has a strong significant correlation with the pleasantness dimension (0.810). This suggests that the average designer/architect in the field of architecture/interior design feels that the environment is more beautiful when the variation or contrast of elements in the environment is higher. Using the AWG© application, the designer/architect group assesses that the spatial visualization is more in line with the imagination of the respondents when the visualization is easier to understand, despite the complexity of the variations in interior elements.

The complexity dimension has a significant correlation with the unity dimension (0.725). This indicates that the average designer/architect in the field of architecture or interior design feels that their environment has a higher sense of unity when the variation or contrast of elements in their environment is also higher. Using the AWG© application, the designer/architect group assesses that the spatial visualization has a more consistent quality when the spatial visualization is easier to understand despite the complexity of the variations in interior elements.

The enclosedness dimension has a correlation with the pleasantness (0.723) and unity (0.761) dimensions, and a strong correlation with the complexity (0.888) dimension. This indicates that the average designer/architect in the field of architecture or interior design feels that the environment is spatially closed when the environment feels beautiful, has a unified impression, or has a variety of contrasting elements in it. Using the AWG© application, the assessment of the designer/architect group on the completeness of the spatial visualization is higher when the spatial visualization is more in line with their imagination, has more consistent quality, or is easier to understand despite the complexity of the variations in interior elements.

The affection dimension has a correlation with the unity dimension (0.796). This means that the average designer/architect in the field of architecture/interior design feels more familiar with their environment when the environment has a more unified impression. Using the AWG© application, the group of designers/architects prefers spatial visualization more when the consistency of the quality of spatial visualization is higher.

The originality dimension has a correlation with the unity (0.761) and enclosedness (0.699) dimensions and a strong correlation with the pleasantness (0.852) and complexity (0.830) dimensions. This suggests that the average designer/architect in the field of architecture/interior design feels an authentic impression of their environment when the environment is more integrated, enclosed, beautiful, or has a variety of contrasting elements in it.

The results of the correlation calculation in Table 6 indicate that the designer/architect group has a significant assessment of the use of the AWG© application, indicated by a significant correlation in most of the AWG© evaluation dimensions, namely, unity–complexity, enclosedness–pleasantness, enclosedness–unity, affection–unity, originality–unity, and originality–enclosedness, as well as a strong significant correlation on the dimensions of pleasantness–complexity, enclosedness–complexity, originality–pleasantness, and originality–complexity. No significant correlation is found on the unity–pleasantness, affection–pleasantness, affection–complexity, affection–enclosedness, and originality–affection dimensions. This means that designer/architect respondents have design assessment skills with a comprehensive perspective such that they can assess AWG© applications with correlated parameters.

4. 3. Comparison of assessment correlations between pairs of groups toward virtual reality–Associative Words Generator©

Table 7 Comparison of the correlation significance of the six SMB dimensions in all groups Correlation of Dimensions Respondent Group

Correlation of Dimensions	Respondent Group			
	Student	Studio lecturer	Client	Designer/ Architect
Pleasantness–Complexity	Non	Non	**Significant**	**Significant (strong)**
Pleasantness–Unity	Non	Significant	Non	Non
Pleasantness–Enclosedness	Non	Non	Non	Significant
Pleasantness–Affection	**Significant**	**Significant**	Non	Non
Pleasantness–Originality	Non	Non	Non	Significant (strong)
Complexity–Unity	Non	Significant (strong)	Non	Significant
Complexity–Enclosedness	Non	Non	Non	Significant (strong)
Complexity–Affection	Non	Significant (strong)	Non	Non
Complexity–Originality	Non	Significant	Non	Significant (strong)
Unity–Enclosedness	Non	Non	Non	Significant
Unity–Affection	Non	Significant (strong)	Significant	Non
Unity–Originality	Non	Significant (strong)	Non	Significant
Enclosedness–Affection	Non	Non	Non	Non
Enclosedness–Originality	Non	Non	Non	Significant
Affection–Originality	Non	Significant	Significant (strong)	Non

Table 7 shows a comparison of the results of the SMB dimension correlation analysis from the questionnaires that were filled out after the respondents used the AWG© application. By pairing the student and studio lecturer groups, and the client and designer/architect groups as parameters for assessing the relevance of the usability of the AWG© application, we find that:

a. The student and studio lecturer groups have a similar tendency towards the pleasantness–affection dimension, as indicated by a significant correlation. Both the student and studio lecturer groups tend to judge an environment or room to be more beautiful when the environment or room feels more familiar. Using the AWG© application, the student and studio lecturer groups like the spatial visualization more when the spatial visualization is more in line with their imagination. This suggests that both student and studio lecturer groups prefer rooms with similar characteristics because they both have developed a similar understanding of the definition of beauty and familiarity. This can happen because the student group has been exposed to the knowledge of the studio lecturer group in their studio classes/ sessions.

b. The client and designer/architect groups have a similar tendency to rate the pleasantness–complexity dimension, indicated by a significant correlation. Both the client and designer/architect groups tend to judge an environment or room to be more beautiful when the contrast or variation of elements in the environment or room is higher. Using the AWG© application, the client and designer/architect groups assess that the spatial visualization is more in line with their imagination when the spatial visualization is easier to understand despite the complexity of the variations in interior elements. This indicates that the client and designer/architect groups have similar assessments of the beauty of the room because both have built an understanding of the effect of contrasting variations of space elements on beauty. This can happen because of the influence of design trends and media that introduce contrasts to a wide audience such that the client and designer/architect groups have been influenced by similar views.

5. Conclusions

By measuring the depth of associative words and identifying the SMB dimensions with the highest significance, this study gauges the sensation of respondents when responding to the visualization of virtual space. Through correlation analysis, the researchers conclude that the six SMB dimensions in this experiment have an effect on each other. Specifically, how the dimensions affect each other are described below (Table 8):

a. The average distribution of assessments across groups of respondents shows that the studio lecturer and designer/architecture groups have means below those of the student and client groups on most of the SMB dimensions. This indicates an alignment of data in the comparison of responses between the student–studio lecturer and client–designer/architect groups from both the associated word generation and assessment through questionnaires. Referring to the results of previous studies, the results of the data analysed through the ACNA method are latent and in line with the data obtained from the subjective assessments given by the respondents through the questionnaire. This alignment indicates a response pattern that the student and client groups feel more stimulated by the AWG application than the studio lecturer and designer/architect groups.

b. The student and studio lecturer groups have a similar tendency to assess the pleasantness–affection dimension, which is characterised by a significant correlation. Both the student and studio lecturer groups tend to judge an environment or room to be more beautiful when the environment or room feels more familiar. Using the AWG© application, the student and studio lecturer groups like the spatial visualization more when the visualization is more in line with their imagination. This shows that the student and studio lecturer groups have room preferences with similar characteristics because both groups have developed a similar understanding of the definition of beauty and familiarity. This can happen because the student group has been exposed to the knowledge of the studio lecturer group in their studio classes/sessions.

c. The client and designer/architect groups have a similar tendency to assess the pleasantness–complexity dimension, which is characterised by a significant correlation. Both client and designer/architect groups assess an environment or room to be more beautiful when the contrast or variation of elements in the environment or room is higher. Using the AWG© application, the client and designer/architect groups assess that the spatial visualization is more in line with their imagination when the spatial visualization is easier to understand despite the complexity of the variations in interior elements. This shows that the client and designer/architect groups have similar assessments of the beauty of the room because both have built an understanding of the effect of contrasting variations of spatial elements on beauty. This can happen because of the influence of design trends and media that introduce contrasts to a wide audience such that the client and designer/architect groups have been influenced by similar views.

d. The use of the SMB theory as a basis for determining the dimensions when responding to the sensation of interior space can also apply to the concept of the outside or exterior environment. The difference lies in the SMB dimensions used as a variable such that researchers can adjust the needs of the study based on the purpose of using SMB theory and on certain groups of respondents.

Table 8 Summary of the Research

Respondent	Summary			
	Correlated SMB	Using AWG	Using Imagination	Agree if room
Student	Pleasantness – Affection	More Stimulated	Based on Basic Knowledge	**More familiar, more beautiful**
Studio lecturer	Pleasantness – Affection	–	Based on Higher knowledge and real references	**More familiar, more beautiful**
Client	Pleasantness – Complexity	More Stimulated	Based on references and trends	**More variations and contrast, more beautiful**
Designer/Architect	Pleasantness – Complexity	–	Based on Higher knowledge and real implementations	**More variations and contrast, more beautiful**

The presented Table 8 provides evidence that the most impactful SMB dimension on all respondents is the 'Pleasantness' dimension, of comfort and aesthetics. It is noteworthy that the design critique interaction process between students and studio lecturers is influenced by discussions focusing on the familiarity and aesthetic aspects of a given space. Conversely, the brainstorming process involving clients and designers/architects requires considerations of how a spatially complex environment with diverse alternatives can be deemed acceptable.

6. Future work

Until now, the beauty and aesthetic value of the generated three-dimensional model have not been the main focus in the development of the AWG application. To improve the application of the 3D AWG© spatial visualization generator, the algorithm and the resulting virtual spatial visualization can be further developed. According to the respondents, spatial visualization is needed for spatial immersive sensations to understand better the quality of space. In addition, the respondents suspect that spatial visualization can help equalise the perception and impression of the room between two parties such as studio lecturers and students or designers and their clients because the spatial visualization can help them convey more concrete expressions of room design imagery. The respondents also agree that 3D visualizations that are generated in real-time can save time. In conclusion, the alignment of keywords with more interactive and livelier visualizations and features can improve the quality of the AWG application. Therefore, the development of algorithms, suitability of keywords with visualization, and aesthetic quality of spatial visualization in the AWG application can be an opportunity for researchers to conduct further research.

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