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The Effect of Interior Design Elements and Lighting Layouts on Prospective Occupants' Perceptions of Amenity and Efficiency in Living Rooms

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Abstract: This study examines the effect of interior design elements on prospective occupants' perceptions of amenity and efficiency in a residential space. Thirty-one prospective occupants participated in a survey using virtual reality environments that consist of various combinations of interior design elements. In this study, occupants' perceptions were discussed in terms of affordance and satisfaction, and the relationship between them is interpreted statistically. The spatial factors affecting overall satisfaction at a detailed level were discussed. The causal relationship between the interior design elements and space were determined under the elaboration of perception processing. Multiple linear relationships between a limited number of spatial factors and virtually created space were analyzed. The perceived affordance of interior design elements was influenced by priming and concrete behaviors in a space. The materials, surfaces, and colors were weak contributors to clear perceptions about space. The occupants' evaluative perception processing elaborations were not effectively activated in the assessment of spatial design adequacy (SDA) in terms of materials, surfaces, and colors in a space.

Keywords: interior design elements; occupants' perception; amenity; efficiency; causal relationship; residential space; virtual reality environment; spatial design adequacy

1. Introduction

The analysis of spatial factors is fundamental to determining appropriate conditions for the satisfaction of occupants' needs in actual space in terms of self-reported examined procedures in spatial design adequacy (SDA). In 1964, the World Health Organization (WHO) established the primary categories of residential satisfaction as safety, health, efficiency, and amenity. During an early design phase, the needs of occupancy have been examined for the SDA of safety and health using simulations based on data obtained from experiments in actual space [1,2].

However, SDA has not been reviewed for amenity and efficiency because occupants have not clearly reported whether their spaces are able to satisfy their lifestyles considering their subjective residency values such as social, cultural, and personal background, and experiences. Consequently, the deficiency of amenity and efficiency in a real space and economic loss after the completion of building construction hardly decreased [3].

Spatial design adequacy (SDA) means the spatial design qualities that can satisfactorily fulfill occupants' goal in an actual space [4]. Amenity, or comfort, is subjective satisfaction; occupants feel agreeable in spatial conditions that align with their lifestyles and social, cultural, and personal background, and their own experiences [4]. Efficiency, or convenience, refers to the subjective satisfaction of occupants when they are not stressed because of spatial conditions that agree with certain behaviors and activities [5–8].

The SDA of amenity and efficiency in early design phases were discussed in previous studies based on the comparison between current spatial designs and previous post-occupancy evaluation (POE) results [9,10]. However, the comparative evaluation in the previous studies showed several unavoidable shortcomings to examine the design quality and its suitability for the needs of the current occupants.

A virtual reality environment (VRE) was employed to evaluate the SDA in terms of amenity and efficiency [11]. However, the predictive evaluations of SDA using VRE for occupants' self-evaluative responses in previous studies have not clearly described SDA to ensure the best choice of housing in an actual space.

In previous studies, various defects in occupants' responses were reported, including the following: (1) the relationship between spatial elements and space was not clearly represented [12,13]; (2) the actuality was not fully investigated in actual space [14]; and (3) redundancies existed between amenity and efficiency [4].

Ambiguities in previous studies relate to occupants' perception processes [15]. That is, insufficient activation of perception processing occurred due to obscure examinations of SDA during the entire self-evaluation procedure [3,16,17]. Furthermore, the evaluation process was insufficiently directed to explain the relationships between spatial elements [18].

These problems are identified with a lack of experiential integration during the occupants' instant examination of current VRE space. For example, the VRE immersive condition could be insufficient for occupants to create homogeneity in the current virtual space based on their prospective behaviors regarding amenity and efficiency. The future occupant would create a prospective memory with experiential heterogeneity to the current alternative based on previous personal experience. New approaches to improve occupants' experiences in the schematic design stage should be required.

A new approach was considered in the perspective of behavior settings theory and related previous studies. In the initial behavior settings theory, the human–environment relationship was explained in a relation with behavior. Human, environment and behavior were organized in a system that is totally interrelated [19]. In particular, physical environments were analyzed in terms of functionality as a device that supports or restricts certain behaviors. In this sense, SDA can be considered as a relationship in which the spatial element supports the future occupants' specific behaviors converging into overall satisfaction with the space [20].

Wicker et al. have extended the concept of early behavior settings. Wicker understood the behavior settings as four components: temporal stages, resources, internal dynamics, and context [21]. The shortcomings of existing SDA evaluation method revealed a defect of prospective perception activation in terms of internal dynamics. Improvement of SDA clarity should be considered under the evaluation process elaboration.

In human–environment interaction perspectives, occupants' evaluative perceptions are sufficiently elaborated to show how spatial elements and space related each other. For example, a certain type of psychological approach such as a reinforcement of intentional systems and improvements of the evaluative participatory procedure in the VRE are effective to improve the shortcomings mentioned above [22].

The improvement of new SDA evaluation approach focuses on allowing residents to accurately generate their unique prospective perception of amenity and efficiency activities according to their own experience, values, and knowledge. This study divides behaviors into strongly purpose-oriented (or purpose) behavior and weakly purpose-oriented (or non-purpose) behavior in order to analyze the future occupants' unconscious and conscious experiences. Furthermore, the concepts of affordance and satisfaction are used to describe the occupants' perceptions of SDA in terms of time-sequential causality.

The objective of this study is to examine the effect of interior design elements on prospective occupants' perceptions of amenity and efficiency in a residential space. This study examines the causal relationship between the interior design element (e.g., finish and furniture arrangement) and space under the elaboration of perception processing, which activates the actual prediction to verify SDA during the early architectural design phase using VRE extraction of BIM data.

In this study, amenity was considered as a perception of purpose-free action compared with preexisting experience in interior space. Satisfaction in terms of amenity is influenced by spatial aspects (e.g., finish factors) that affect emotional satisfaction. In contrast, efficiency was considered as a perception of purpose-oriented action for serving guests.

2. Research Method

2.1. Design of Experiments

2.1.1. Two Steps for Review of Early Design

Verifying SDA in the early design phase is a two-step process of selecting the best spatial conditions. The first step is aimed at determining the best shape of a space by comparing the potential alternatives. In this step, each alternative contains a variation in the combination of spatial shape factors such as width, depth, and height, as well as their respective ratios.

In the first step, findings of a previous study demonstrated that the causal relationship between the spatial size and shape factors (e.g., spatial size, shape, and configuration of spatial elements and space) was clearly presented in occupants' perceptions, which reflected the time-sequential characteristics of an actual experience according to amenity and efficiency [4].

Results of the study indicated that the correlation between spatial factors (size and shape) and SDA based on the elaboration of occupants' perception processing can be a useful guide to determining spatial size and shape and predicting occupants' satisfaction regarding amenity and efficiency in real spaces [4].

The second step is aimed at ascertaining the best finish factors of a selected finished shape of space by comparing the likely alternatives. Each alternative is addressed by a variation in the combination of factors such as material, color, and lighting conditions. In this step, the arrangement of furniture is generally suggested to increase occupants' perceptions of actuality.

As a second step, the best spatial designs for housing in association with the previous first experiment were investigated in this study [4]. The influence of spatial factors (e.g., color, materials, and lighting fixtures) on occupants' perceptions regarding amenity and efficiency has not been fully discussed, since the effect of environmental factors on occupants of a space was limited to certain interactions between them.

2.1.2. Improvement of Occupants' Prospective Experience

The improvement of occupants' prospective experience considered in this study is as follows. First, for activation of an intentional system, occupants' evaluative perception processing during the evaluation is elaborated by two priming—that is, the introduction of categorical knowledge for amenity and efficiency and pre-accommodation in VRE. Priming activates working memory to increase the accessibility to long-term memory in association with amenity and efficiency. It activates a new experience (prospective memory) regarding current spatial design compared with previous amenity and efficiency experiences.

Amenity could be an emotional reaction to emotional background attention, requiring an involuntary withdrawing of the implicit memory. In contrast, efficiency could be an attitude toward certain actions in goal-oriented attention, requiring voluntary intensive withdrawing of the explicit memory, such as categorical knowledge [6–8]. Efficiency requires more attention than amenity in the elaboration of perception processing.

In this study, satisfaction in terms of efficiency is affected by such spatial aspects as furniture arrangement, which influences movement for hosting guests. The effect of indoor environmental factors on occupants' perceptions of amenity and efficiency was excluded due to the limitations of occupants' responses under VRE test conditions.

Second, the participatory evaluation process of occupants is guided so that they will enlarge the integration of direct perception (affordance of spatial factors) and indirect perception (satisfaction with a space) during instant evaluations.

This approach would improve the clarity of occupants' responses in time-sequential situations for distinguishing between perception (instant evaluation for spatial elements) and cognition (holistic evaluation of a space by recall) [15].

In the psychological view, evaluation of perception is both unconscious and conscious with tacit knowledge. For example, evaluation of satisfaction could be determined as a continuous cognitive process in terms of amenity and efficiency through the withdrawing of sophisticated knowledge in the long-term memory. Additionally, evaluation of affordance could be regarded as a construction integration process to create a new experience through the priming of episodic memory [23].

Accordingly, top-down perception and bottom-up perception are integrated with intentionality aimed at amenity and efficiency in association with time-sequential causality [24]. Concepts of affordance and satisfaction are used to describe the structure of the causal relationship between the space design factors and space in occupants' perceptions [25–28].

2.1.3. Approach for Examination Spatial Design Adequacy

The experiments were designed to examine the aspect of causal relationships between interior design elements of a space and occupants' perceptions in terms of amenity and efficiency needs. In the experiments, the dependent variables were designated as perceptions of satisfaction, and independent variables were designated as perceptions of affordance in terms of amenity and efficiency. Experimental conditions employed in this study were expanded from Barker's and Wieker's behavior setting model [29–31].

Figure 1 shows a comprehensive understanding of the temporal stage of behavior settings and the control of SDA variables in occupants' responses used in this study. The structure of SDA in this study was organized according to the following procedures. The temporal stage of behavior setting for SDA in terms of amenity and efficiency was organized according to affordance (direct perception) and satisfaction (indirect perception) [32].

Detailed procedures of the analytical framework are as follows. (1) The affordance of each different interior design element was evaluated. (2) Overall satisfaction with a space was evaluated and the implications of the results were observed in association with the cognitive psychological perspectives and human–environment interaction theories [33,34]. The relationship between affordance and satisfaction was examined statistically and the implication of the results were reviewed in practical use and discussed in line with previous studies. Finally, the scope and limitations of SDA verification in the early design phase were discussed using building information modeling data.

For an analysis of occupants' responses, human–environment interaction theories were applied to determine characteristics of actual experiences. The experiential aspects of amenity and efficiency on occupants were analyzed based on the pleasure arousal hypothesis and the social learning theory [15]. The pleasure arousal hypothesis demonstrates that occupants are most attracted to settings that are moderately arousing and maximally pleasurable. Agreeable spatial conditions appeal to occupants because of openness, such as harmonious materials, colors, shapes, and styles of lighting fixtures on the spatial finishes of walls, floors, and ceilings.

According to the social learning theory, occupants observed, processed, and imitated behaviors, attitudes, and emotional reactions for desirable behaviors [15]. Occupants did not feel stress in agreeable spatial settings where they engaged in certain behaviors, including displaying artwork as they served guests in a living room.

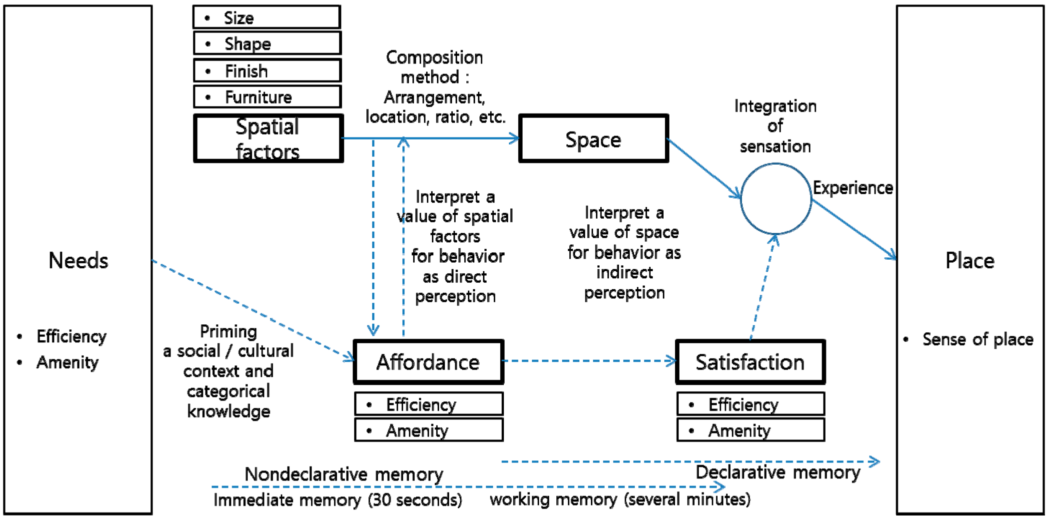


Figure 1. Comprehensive understanding of temporal stage behavior setting.

2.2. Space Selection, Interior Design Elements and Lighting Layouts

In this study, experimental processes were applied according to general decision-making processes for space design. In various schematic design phases, selecting the best alternative for spatial factors and arrangements is a decision made by designers and clients as they determine the shape of a space and its height, width, and depth. Then, they assess the condition of interior design elements for the pre-determined spatial shape because these factors reduce unnecessary repetition of design consents.

To determine appropriate spatial conditions and dimensions of space for the experiments in this study, the results of a previous study were examined. It was reported that a rectangular shaped space was selected as the most favorable for living rooms in terms of overall satisfaction regarding amenity and efficiency [4]. Specifically, a space 7.33 m wide, 4.55 m deep, and 2.6 m high was preferred by occupants in terms of overall satisfaction with amenity.

The dimensions for space, which were mentioned above and used in the previous study, were applied in this study to secure logical validity for experiments and determine the best factor for interior conditions according to verification of SDA.

A detailed layout of the space is shown in Figure 2. The east wall was finished with wood, and a wall-mounted television was installed on it. The area where the TV was installed was finished with marble. The north wall was finished with light brown wood; it featured an entrance door, with no additional objects installed on it.

The south and west walls had three and two windows, respectively. Two windows measuring 1.8 m wide by 1.6 m high were installed on the west wall. Three windows were installed on the south wall. The height of each of those windows was 2.3 m. The ratio of window to wall was 40.33% for the east wall and 52.88% for the south wall. All windows were covered with clear glaze. The rest of the wall area was finished with paper.

A five-seat sofa finished with gray fabric was placed in the northwest area of the room. A steel-framed coffee table with dimensions of 1.2 m by 0.9 m was placed in front of the sofa. The top area of the table was covered with tempered glass. A light purple rug was placed on the floor underneath the sofa and coffee table. The remaining space was reserved for personal use.

For the space layout in Figure 2, eight design alternatives for the interior design elements—including lighting layout—were prepared for experiments in this study. Tables 1 and 2 summarize detailed conditions for the interior design elements of the eight spaces. The eight cases contain various compositions in term of finishing material, surface brightness, and lighting layout. These different conditions were employed to examine the influential factors affecting spatial perceptions. Among the eight cases, the first case was used as a base case for interior design.

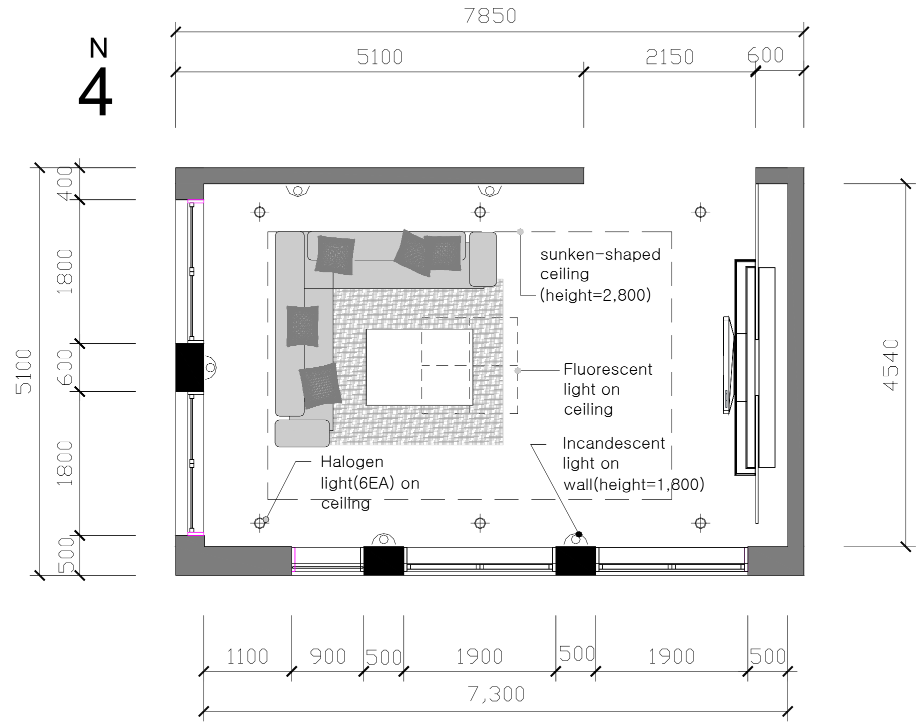


Figure 2. Layout of space and fixture (unit: mm).

The color of the east and north walls, which were finished with wood, was light brown. The color of the ceiling, which was also finished with wood, was a light gray. These combinations were equally applied to all eight alternatives. The south and west walls, which were finished with paper, were light ivory for cases 1–4 and dark ivory for cases 5–8. The color of the floor, which was covered with marble, was light ivory. As shown in Tables 1 and 2, different brightness levels were applied to the floor and south and west walls to generate the eight alternatives in this study.

For the space with different finishes, a lighting combination was applied to give reality to the model. Figure 2 shows the layout of lighting fixtures in the space. Six recessed halogen fixtures were installed on the ceiling, with a linear fluorescent fixture measuring 1.8 m by 1.2 m installed at the center of the ceiling. A cove lighting system with fluorescent lamps was installed along the perimeter. Two wall-mounted lighting fixtures with incandescent bulbs were installed on the north and south walls.

As shown in Table 2, the eight space alternatives contained different types of lighting layouts for the experiments conducted in this study. The lighting system did not provide light but contributed to form interior design elements in the space. Perspective views of the eight spaces are illustrated in Figure 3.

All spaces in the experiment were created virtually using ArchiCAD Version 12 (Graphisoft: Budapest, Hungary). Then, these spaces were exported to the Virtual Building Explorer (VBE) format, which provides easy navigation for virtual environments because this navigation environment is more user-friendly [35,36].

The display conditions of the VBE format used the render mode with a headlight, a background mode with the sky, and a 0.98° view cone. The navigation speed and mouse sensitivity were 0.59 s and 22, respectively. A camera was installed at a height of 1.6 m above the floor; it was used for the navigator's visual fields. All spaces were projected on a 17-inch TFT computer screen in sequence. The screen resolution was 1600 × 900, and the conditions for brightness, color quality, and images did not cause visual problems for navigation.

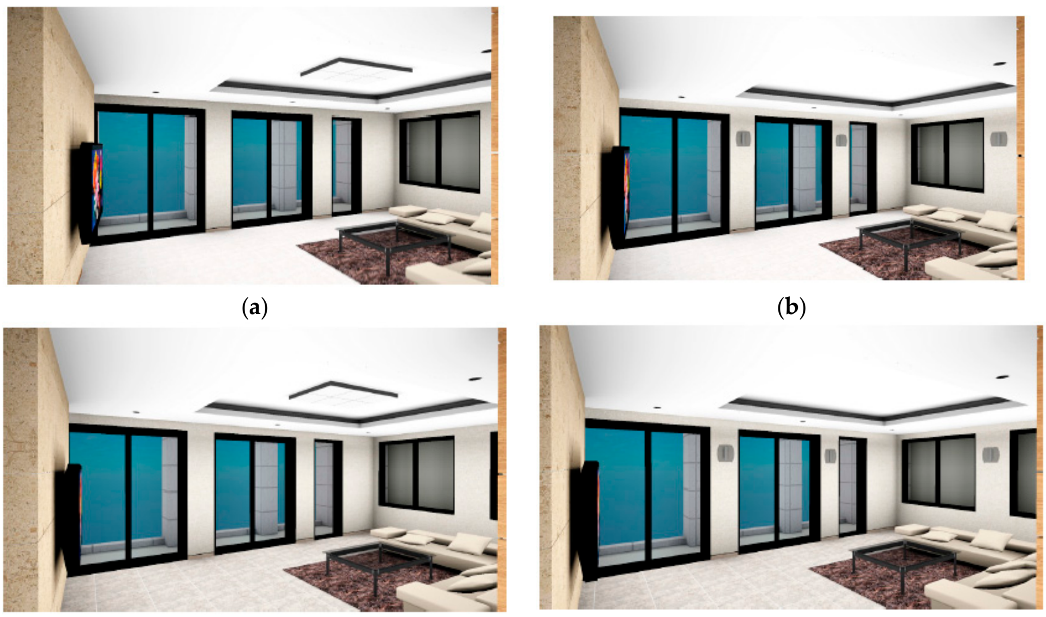
Table 1. Det1ailed conditions of materials assigned for walls.

Case	North		East		South, West		
	Material	Color	Material	Color	Material	Color	Brightness [%]
1	Wood	Light Brown	Wood	Light Brown	Paper	Light ivory	87
2	Wood	Light Brown	Wood	Light Brown	Paper	Light ivory	87
3	Wood	Light Brown	Wood	Light Brown	Paper	Light ivory	87
4	Wood	Light Brown	Wood	Light Brown	Paper	Light ivory	87
5	Wood	Light Brown	Wood	Light Brown	Paper	Dark ivory	73
6	Wood	Light Brown	Wood	Light Brown	Paper	Dark ivory	73
7	Wood	Light Brown	Wood	Light Brown	Paper	Dark ivory	73
8	Wood	Light Brown	Wood	Light Brown	Paper	Dark ivory	73

Table 2. Detailed conditions of materials assigned for floor, ceiling, and lighting layout.

Case	Floor			Ceiling		Lighting Installation			
	Material	Color	Brightness	Material	Color	Ceiling Halogen	Ceiling Fluorescent	Ceiling Cove	Wall-Mounted
1	Marble	Light Ivory	87 %	Wood	Light Gray	O	O	O	X
2	Marble	Light Ivory	87 %	Wood	Light Gray	O	X	O	O
3	Marble	Light Ivory	73 %	Wood	Light Gray	O	O	O	X
4	Marble	Light Ivory	73 %	Wood	Light Gray	O	X	O	O
5	Marble	Light Ivory	87 %	Wood	Light Gray	O	O	O	X
6	Marble	Light Ivory	87 %	Wood	Light Gray	O	X	O	O
7	Marble	Light Ivory	73 %	Wood	Light Gray	O	O	O	X
8	Marble	Light Ivory	73 %	Wood	Light Gray	O	X	O	O

The eye height of participants for the navigations using computers in this study was 1.6 m. Individual differences were not considered when collecting responses. The Korean Statistical Information Service reported that the average eye height of a 25-year old Korean is 1.62 m for a man and 1.49 m for a woman (http://kosis.kr, 2010). Further, in the testing procedure used in this study, pre-accommodations in VRE were conducted so that participants could control their expectations or bias error according to height differences.



(a) (b) (c) (d)

Figure 3. *Cont.*

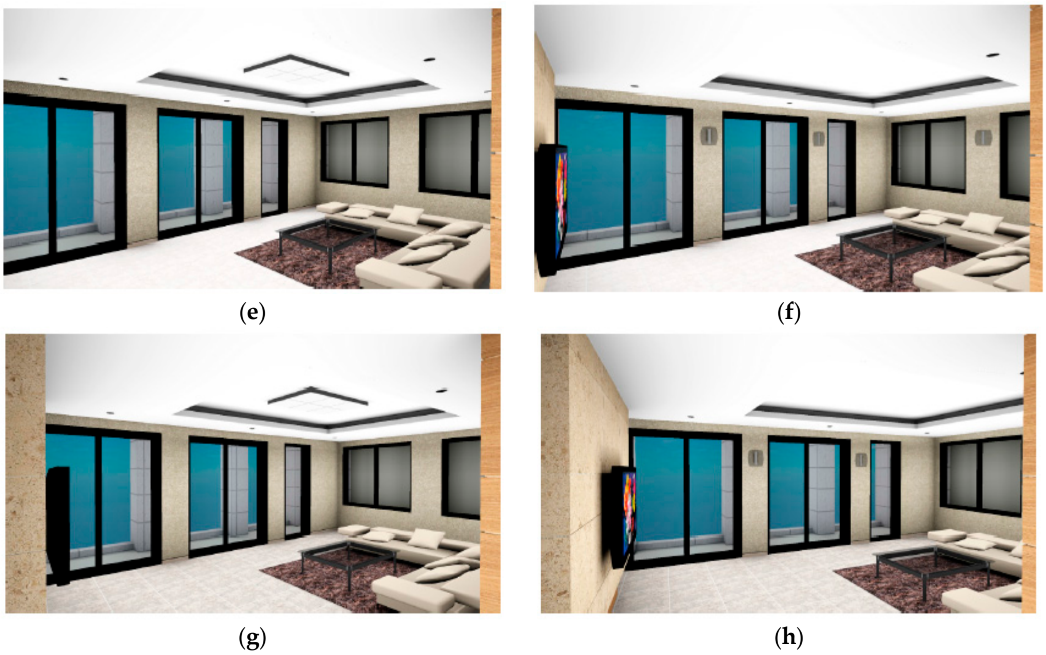


Figure 3. Perspective view of space (case 1–8): (**a**) Case 1; (**b**) Case 2; (**c**) Case 3; (**d**) Case 4; (**e**) Case 5; (**f**) Case 6; (**g**) Case 7; (**h**) Case 8.

2.3. Participants and Questionnaires

Overall, 31 healthy young people expecting to buy houses in the future participated in the experiments conducted in this study to examine occupants' SDA for various factors associated with interior design. Twenty-two participants were female and nine participants were male. Participants' ages ranged from 20 to 29 years, with a mean of 23.2 years. All participants had work experience using computers. Their work experience ranged from one to six years.

All participants were familiar with computer tasks using virtual reality navigations. To screen for the capability of using a computer, pre-experiments were performed. All participants had the appropriate ability to navigate space using virtual reality based on given scenarios. In addition, participants' health conditions were prescreened to satisfy the general standards required (e.g., normal vision and the ability to identify colors and variations of spatial configurations in virtual worlds).

The questionnaires used for experiments in this study consisted of two parts. One part included questions about participants' general characteristics. The other included questions regarding spatial perceptions of each given space.

The questions about general characteristics were designed to capture mostly demographic information about the participants, such as gender, age, and spatial sense regarding changes in space configurations. The questions were used to analyze participants' general characteristics for spatial perception under given conditions.

The questions for spatial perception are summarized in Tables 3 and 4. The questionnaires contain 15 questions about amenity and 15 questions about efficiency. The organization of the questions about spatial perception for the main survey was established logically to appropriately interpret the relationship in time-sequential feedback. The questions provided a time-sequential structure for the correlation between the affordance of the spatial factors and overall satisfaction in terms of participants' spatial perceptions.

The questions in this study were newly solidified based on considerations of the limitations of previous POE studies [37]. For example, the previous literature reviews examining the issue of comfort for building occupants in indoor environments were focused mostly on the effects of a single environmental condition on humans (e.g., visual environment). Furthermore, the relationship between spatial factors and space has not been examined in detail. Frontczak et al. pointed out that comfort is defined as satisfaction with purely indoor environmental quality and does not include satisfaction with other aspects of a building, such as furniture and colors [38].

Table 3. Questions for the perception of amenity.

Number	Question Contents
A1	Is the material of wall conducive to feeling amenity?
A2	Is the color of wall conducive to feeling amenity?
A3	Is the location of wall exhibiting paintings conducive to feeling amenity?
A4	Is the area of wall exhibiting paintings conducive to feeling amenity?
A5	Is the material of floor conducive to feeling amenity?
A6	Is the color of floor conducive to feeling amenity?
A7	Is the shape of ceiling conducive to feeling amenity?
A8	Is the color of ceiling conducive to feeling amenity?
A9	Is the arrangement of lighting fixtures conducive to feeling amenity?
A10	Is the style of lighting fixtures conducive to feeling amenity?
A11	Is the location of TV conducive to feeling amenity?
A12	Is the arrangement of sofa conducive to feeling amenity?
A13	Is the sofa style conducive to feeling amenity?
A14	Is the location of vacant space conducive to feeling amenity?
A15	How well is your sense of amenity satisfied while walking through this space?

Table 4. Questions for the perception of efficiency.

Number	Question Contents
E1	Is the material of wall sufficient for serving guests?
E2	Is the color of wall sufficient for serving guests?
E3	Is the location of wall exhibiting paintings sufficient for serving guests?
E4	Is the area of wall exhibiting paintings sufficient for serving guests?
E5	Is the material of floor sufficient for serving guests?
E6	Is the color of floor sufficient for serving guests?
E7	Is the shape of ceiling sufficient for serving guests?
E8	Is the color of ceiling sufficient for serving guests?
E9	Is the arrangement of lighting fixtures sufficient for serving guests?
E10	Is the style of lighting fixtures sufficient for serving guests?
E11	Is the location of TV sufficient for serving guests?
E12	Is the arrangement of sofa sufficient for serving guests?
E13	Is the sofa style sufficient for serving guests?
E14	Is the location of vacant space sufficient for serving guests?
E15	How well is your sense of efficiency satisfied while walking through this space?

In this study, the questions regarding occupants' perceptions of changes in interior design elements were organized under the concept of SDA. Questions used for the experiments consisted of overall satisfaction with the space, the effect of surface finishes and lighting fixtures, and the influence of furniture arrangement in terms of amenity and efficiency. The participants' responses for these conditions were evaluated as low-level perceptions (i.e., intervention of reasoning through activating the emotional experiences in virtual space regarding previous experiences in real spaces).

The questions regarding occupants' perceptions of space (overall satisfaction) were organized with reference to the previous POE [39–41] and neuroscience research [18,23,42]. Yasushi argued that satisfaction in terms of efficiency is affected by the spatial aspects for increasing usage for everyday life activities, utilization of facilities, transportation, and service, among others. Furthermore, satisfaction in terms of amenity is affected by spatial aspects that increase emotional pleasure, such as high-quality aesthetics, openness, easiness of community formation, separation from unpleasant facilities, and nature [43,44].

In this study, efficiency was evaluated for everyday life activities and usage of facilities to support serving guests. Amenity was evaluated for aesthetics, openness to nature, and subsequent emotional pleasure. The participants' responses for amenity and efficiency were evaluated as high-level perceptions (i.e., reason-based perception through priming of categorical knowledge to obtain expectations regarding satisfaction in the current context).

2.4. Participants' Evaluation Procedures

A series of experiments were conducted to examine the SDA of amenity and efficiency for given spatial conditions. In each experiment, instructions, tests, and a final survey were conducted using virtually created space in a computer laboratory. The experimental procedures follow:

(1) Step 1: Introduction (15 min)
Prior to the main tests, an introduction lasting 15 min was given to provide information about the background of the tests and survey procedures.

(2) Step 2: Priming (15 min)
Two types of framings were conducted during this 15-min session to elaborate on potential occupants' perceptions. One was to provide categorical knowledge about the terminology of amenity and efficiency. The other was to allow participants to navigate in advance to virtual environments in order to become familiar with the environment. For example, during the priming period, participants adapted themselves to the given virtual spatial environments in which the behavior settings were framed according to amenity and efficiency. The participants were ready to respond immediately with their judgments using both subconscious and conscious episodic memory activation according to the suggestion in a previous study [14].

(3) Step 3: Evaluation of affordance of amenity (40 min)
Evaluations of the spatial conditions of given spaces were performed over 40 min. During the allotted time, all participants navigated through eight spaces. Completing the navigation for each room consisted of the conditions outlined in Tables 1 and 2; participants were asked to answer questions 1 to 14 in Table 3 about the affordance of the amenity. They navigated to the next assigned space in sequence and answered the applicable questions. According to the sequence, participants navigated through the eight spaces and answered the questions for all of them. A seven-point Likert scale summarized in Table 5 was used to answer the questions.

(4) Step 4: Evaluation of overall satisfaction regarding amenity (5 min)
Overall satisfaction for the space was evaluated within 5 min. After the participants completed the navigation and answered the questions for each space's condition, they were asked to answer question 15 in Table 3.

(5) Step 5: Evaluation of efficiency (40 min)
The procedure outlined in Step 3 was iterated equally for the evaluation of efficiency using the contents and questions in Table 4 about the affordance of efficiency.

(6) Step 6: Evaluation of overall satisfaction regarding efficiency (5 min)

Table 5. Voting scale for questionnaires.

Answer	Scale
Strongly agree	3
Moderately agree	2
Slightly agree	1
Neither agree nor disagree	0
Slightly disagree	−1
Moderately disagree	−2
Strongly disagree	−3

As in Step 5, overall satisfaction for the space was evaluated within 5 min. After participants completed the navigation and answered the questions for each space's condition, they were asked to answer question 15 in Table 4.

In these experiments, participants were not made aware of the changes in the spatial factors before entering the next space using navigation software; it was intended that they should identify the changes in the space independently without prior information. This procedure prevented the "guinea pig effect." The participants could concentrate on articulating their perceived affordance and satisfaction without bias because they could maintain the evaluation direction for amenity according to the framing and seamless evaluation during the walk-through in the virtual space.

3. Results

3.1. Participants' General Characteristics

The general characteristics of the participants, which explain their sensitivity to perceived spatial conditions, are presented in Figure 4 and Table 6. A seven-point Likert scale summarized in Table 5 was used to answer all questions. Overall, the participants easily perceived the changes in spatial components that influence spatial perceptions. Whereas 54.8% of the participants easily recognized these changes (GQ1, M = 0.55, SD = 1.26), 9.7% of the participants were not sensitive to them.

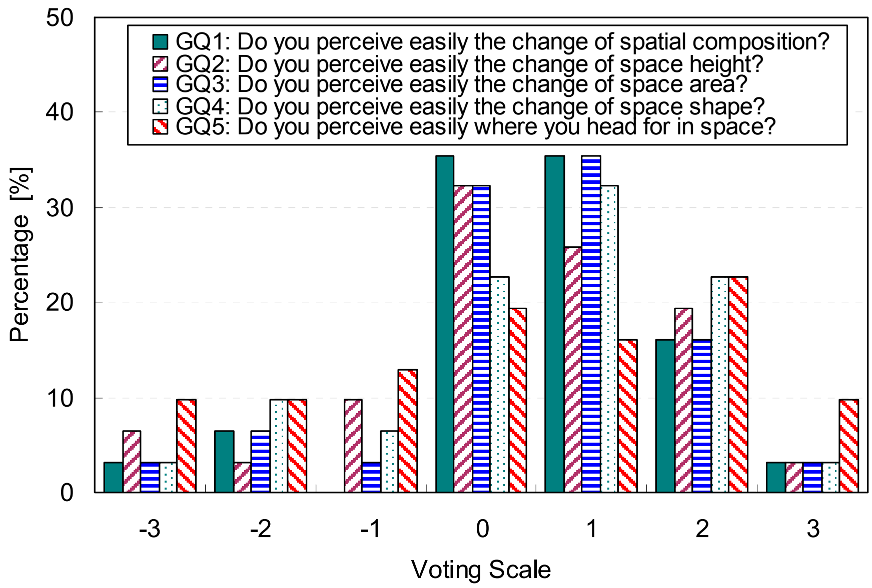


Figure 4. Participants' general characteristics.

Table 6. Statistic for participants' general characteristics.

Question Number	N	Mean	Std. Deviation	Skewness		Kurtosis	
				Statistic	Std. Error	Statistic	Std. Error
GQ.1	31	0.55	1.26	−0.86	0.42	1.56	0.82
GQ.2	31	0.39	1.43	−0.67	0.42	0.52	0.82
GQ.3	31	0.52	1.29	−0.79	0.42	1.15	0.82
GQ.4	31	0.52	1.43	−0.72	0.42	0.10	0.82
GQ.5	31	0.29	1.83	−0.32	0.42	−0.90	0.82

Specifically, 48.4% of the participants answered that they could easily perceive the changes in ceiling height, but 19.4% of participants could not (GQ2, M = 0.39, SD = 1.43). The participants also perceived area changes less sensitively than they perceived the changes in ceiling height (GQ3, M = 0.52, SD = 1.29).

The participants also perceived shape change less sensitively (GQ4, M = 0.52, SD = 1.43). The participants appropriately perceived changes in spatial shapes (M = 0.52, SD = 1.43). However, when the participants navigated through the given spaces, their ability to perceive direction clearly was not excellent (GQ5, M = 0.29, SD = 1.83).

The skewness for the participants' general characteristics in Figure 4 is summarized in Table 6. Overall, five characteristics presented in Figure 4 showed a little negative skewness with a range from −0.86 to −0.32. The Kurtosis that presents the measure of tailedness of participants' general characteristics for the change of spatial elements explained in Figure 4 is summarized in Table 6.

In summary, the distribution of participants' general characteristics was not skewed significantly, although it was not perfectly normal. This finding indicates that the survey results about the participants' general characteristics were unbiased; thus, the results from their responses could be used reliably for this study.

3.2. Perception of Amenity

3.2.1. Effect of Surface Properties and Lighting Layout on Perception of Amenity

The influence of surface properties and lighting layout on the perception of amenity was analyzed. The statistical analysis results for each question are presented in Figures 5–9. The data points on the graphs indicate the mean responses regarding perception reported by all participants who took part in the experiments conducted for this study.

As shown in Figures 5 and 6, the wall material was not insufficient for creating a positive perception of amenity (A1) for cases 1 to 6, for which the brightness of the wall material varied. The worst perceptions were reported for low brightness levels in case 7 (M = −0.32, SD = 1.38) and case 8 (M = −0.29, SD = 1.24). In contrast, the high brightness levels in cases 1 to 4 were perceived positively. The wall color was marginally sufficient to earn a positive impression of amenity (A2) for the higher brightness of walls in cases 1, 2, 3, 4, and 7. The color with a lower brightness level in case 8 had the worst spatial composition for perceptions of amenity (M = −0.29, SD = 1.24).

The location of the exhibition wall was a significant contributor to spatial perception in terms of amenity (A3). When all lighting fixtures remained on the ceiling in cases 1, 3, 5, and 7, the exhibition wall area was a strong contributor to improved amenity, and spatial perception as it related to amenity (A4). In cases 1, 3, 5, and 7, recessed halogen and fluorescent lighting were installed on ceilings, and the exhibition wall area was a strong contributor to improved amenity in these scenarios. The detailed findings about the effect of wall surfaces on the perception of amenity are summarized in Table 7.

As shown in Figures 7 and 8, the floor material was a positive and meaningful factor in perceptions of amenity (A5). The high level of brightness of floor material in case 5 created the most preferred condition for spatial perceptions of amenity (M = 0.71, SD = 1.07). The floor color was also a positively effective factor in perceptions of amenity (A6).

When the lighting fixtures varied, the ceiling shape was perceived as a significant factor in providing differences in perceptions of amenity (A7). The ceiling shape in cases 1, 3, 5, and 7 with direct lighting on the ceiling was perceived as a more acceptable condition than the ceiling shapes in cases 2, 4, 6, and 8 with cove and wall-mounted lighting.

When the lighting fixtures and layouts were changed, the ceiling color was an effective contributor to differences in perceptions of amenity (A8). The ceiling colors in cases 1, 3, 5, and 7 were perceived as more agreeable than those in cases 2, 4, 6, and 8, even though the color was not changed. The findings about the effect of floor and ceiling surfaces on the perception of amenity are summarized in Table 7.

As shown in Figure 9, the layout of the lighting fixtures functioned as a strong contributor to perceptions of amenity (A9). For cases 1, 3, 5, and 7, which had fluorescent and halogen fixtures on the ceilings, the arrangement of the lighting fixtures was perceived as an agreeable condition in terms of amenity. However, for cases 2, 4, 6, and 8, which featured recessed halogen and wall-mounted lighting fixtures, the arrangement of the lighting fixtures worsened spatial perception in terms of amenity. In particular, case 2 was regarded as the worst for spatial perceptions of amenity (M = –0.74, SD = 1.65).

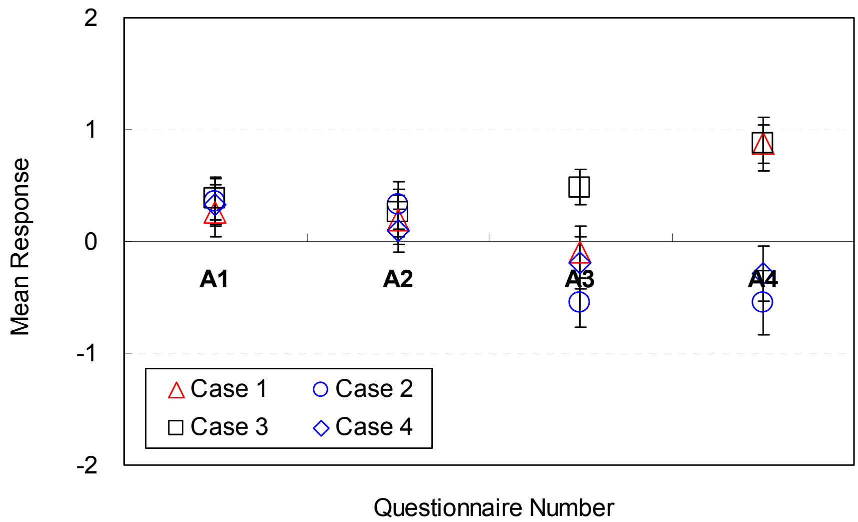


Figure 5. Effect of wall finish on perception of amenity (Cases 1–4).

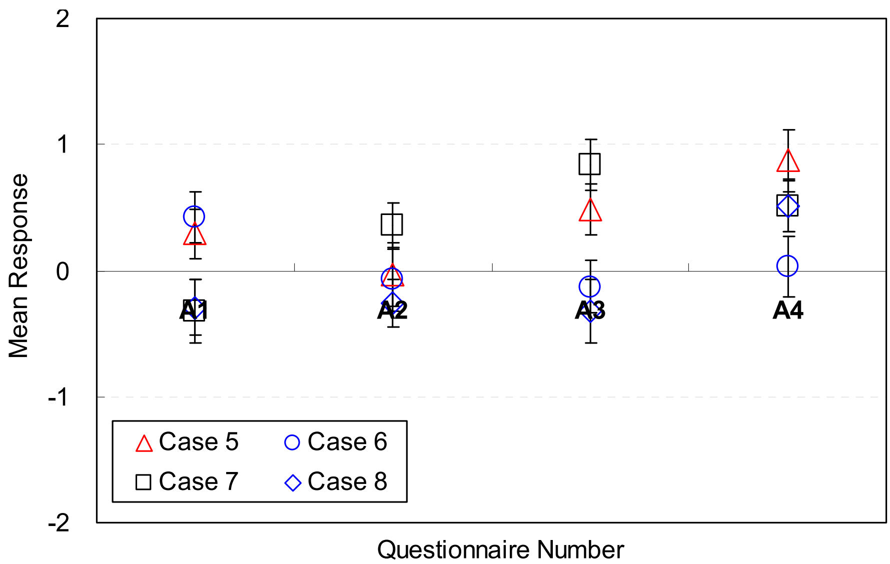


Figure 6. Effect of wall finish on perception of amenity (Cases 5–8).

The style of lighting fixtures strongly contributes to amenity (A10). For cases 1, 3, 5, and 7, the style of lighting fixtures was generally perceived as an agreeable condition in terms of amenity. For cases 2, 4, 6, and 8, the style of the lighting fixtures caused a more negative spatial perception in terms of amenity. The findings about the effects of lighting layout and fixtures on the perception of amenity are summarized in Table 7.

In summary, brighter wall colors were perceived positively and the vacant wall areas without lighting fixtures were perceived as agreeable conditions for exhibiting artwork and paintings. Floor materials were perceived as meaningful, and the affordance level was not clearly distinguishable based on the higher and lower brightness levels used for floor materials. Ceiling shape, color, and direct lighting may be more affordable for improving perceptions of amenity. Furthermore, the layout of lighting fixtures and direct lighting style were perceived as agreeable.

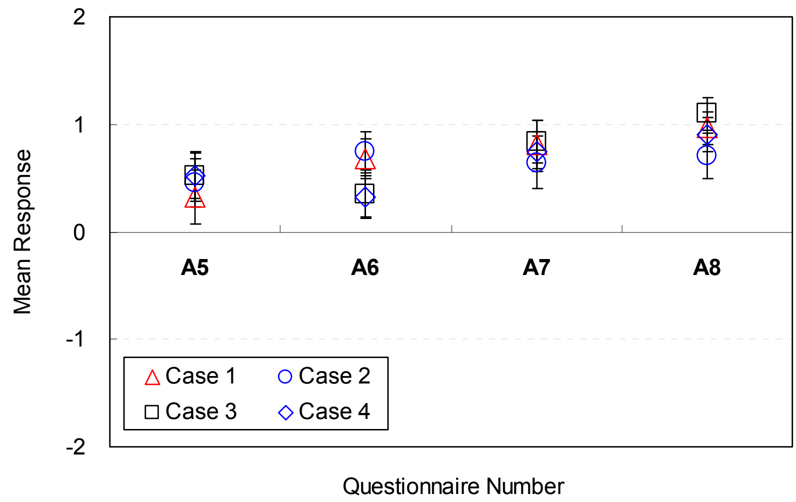


Figure 7. Effect of floor and ceiling finish on perception of amenity (Cases 1–4).

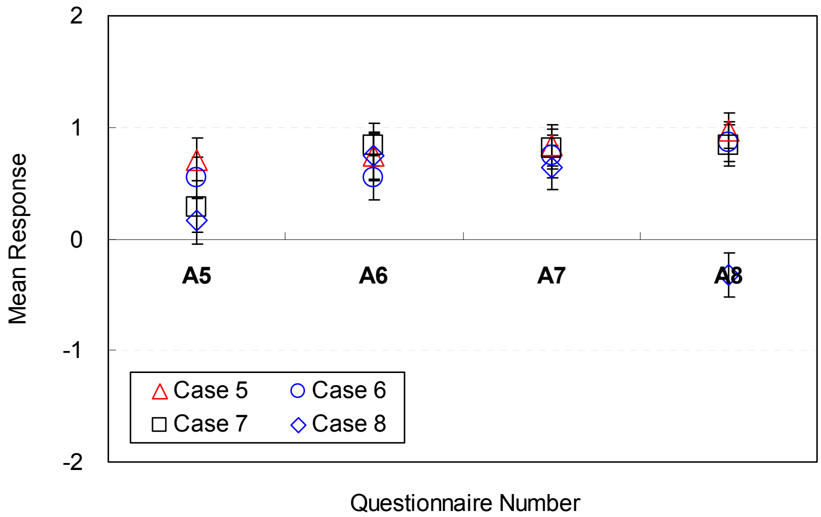


Figure 8. Effect of floor and ceiling finish on perception of amenity (Cases 5–8).

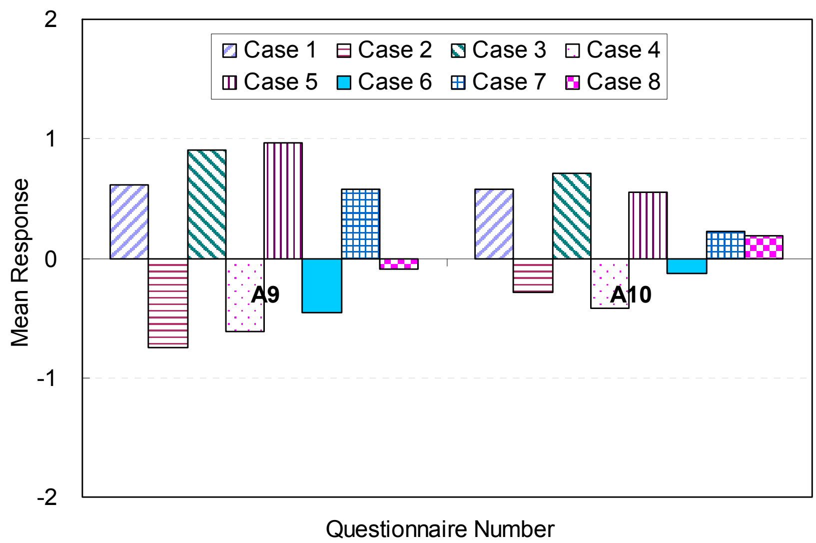


Figure 9. Effect of lighting layout and fixtures on perception of amenity (Cases 1–8).

Table 7. Response for amenity perception.

Category	Number	Question Content	Findings in Response for Amenity Perception
Surface finish of wall	A1	wall material	Lower brightness levels of the wall materials were not the ideal conditions, although the bright color effectively generated feelings of pleasure in the participants.
	A2	wall color	Higher brightness of a wall is perceived positively.
	A3	location of the exhibition wall	- Vacant area without lighting fixtures on the wall was an agreeable condition. - Vacant space is perceived as a more affordable way to exhibit artwork or paintings.
	A4	area of the exhibition wall	- Vacant area without lighting fixtures on the wall is an agreeable condition in which to exhibit artwork and paintings. - Vacant area without lighting fixtures was perceived as better for exhibiting artwork and paintings.
Surface finish of floor and ceiling	A5	floor material	- Higher brightness of the floor material functioned as a meaningful factor. - The brighter color could promote participants' feelings of pleasure.
	A6	floor color	High brightness of the floor material is perceived as a meaningful factor.
	A7	ceiling shape	Ceiling shape with direct lighting might be a more affordable way of improving the perceptions of amenity.
	A8	ceiling color	Ceiling color with direct lighting may be better for improving the perceptions of amenity.
Lighting	A9	lighting fixtures arrangement	Arrangement of the lighting fixtures with direct lighting is perceived to be better.
	A10	lighting fixtures style	Style of lighting fixtures with direct lighting may be more agreeable.
furniture arrangement	A11	TV location	TV location is directly perceived as a useful factor in affording the amenity in accordance with their lifestyle.
	A12	sofa arrangement	Sofa arrangement is perceived to be a useful factor to afford amenity.
	A13	sofa style	Sofa style was not perceived to be a significant factor that affects amenity
	A14	vacant space location	Space 5 was perceived to be the favorite condition for improving amenity
Overall space	A15	sense of amenity	the overall satisfaction level of amenity was influenced by the perceived perception of the wall material (A2), the exhibiting wall location (A4), floor color (A7), lighting fixture arrangement (A10), lighting fixture style (A11), sofa arrangement (A13), and sofa style (A14). The results indicate that the wall material, lighting fixture arrangement, and sofa arrangement may strongly contribute to the overall satisfaction level in terms of amenity.

3.2.2. Effect of Furniture Arrangements on Perception of Amenity

Perceptions of amenity for furniture arrangements are shown in Figures 10 and 11. The findings about the effect of furniture arrangement on the perception of amenity are summarized in Table 7.

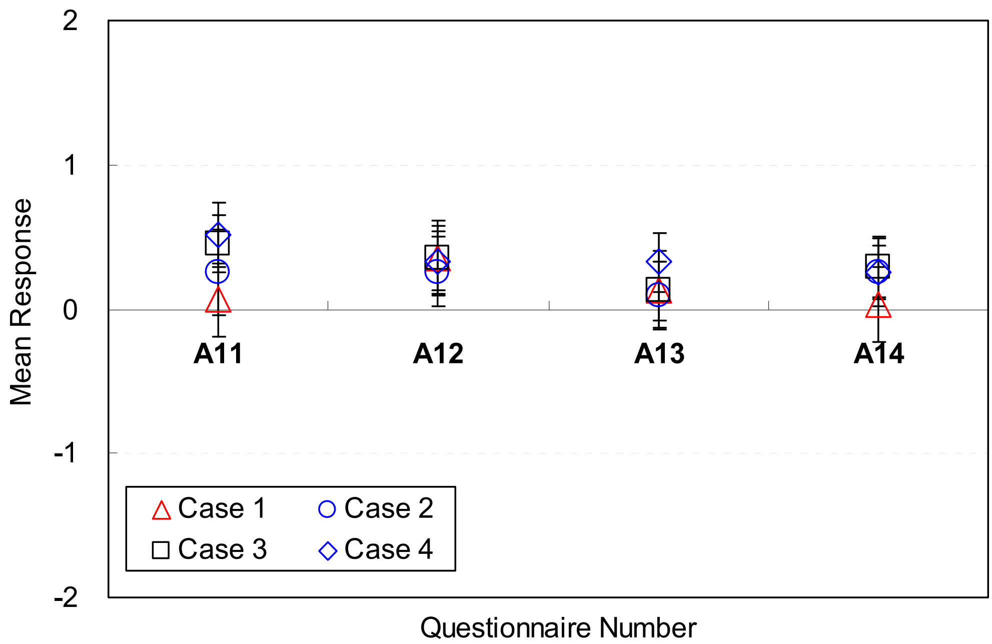


Figure 10. Effect of furniture arrangement on perception of amenity (Cases 1–4).

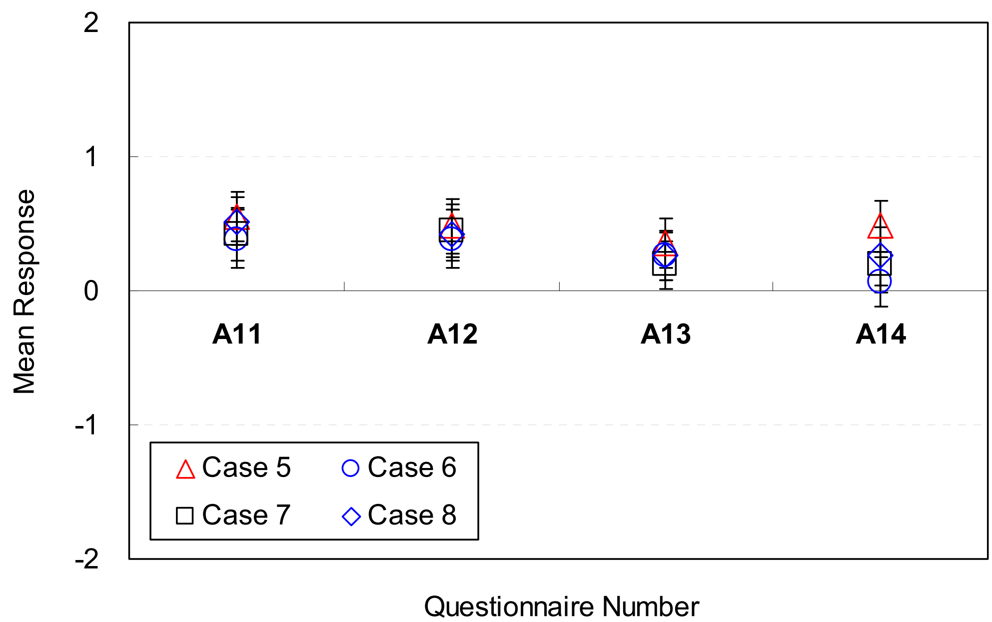


Figure 11. Effect of furniture arrangement on perception of amenity (Cases 5–8).

The TV location was an effective factor for the user of a space in terms of affordance of amenity (A11). The mean responses of amenity ranged from 0.06 to 0.55. Case 5 showed the best condition for improving amenity (M = 0.61, SD = 0.99). The sofa arrangement was perceived as an effective factor for improving perceptions of amenity (A12). Case 5 provided appropriate spatial conditions to improve amenity of a space for users (M = 0.48, SD = 1.00). The findings demonstrate that the sofa arrangement is useful for affordance of amenity in a space.

However, it does not seem that the sofa style functions as an affordable factor for spatial perceptions of amenity (A13). In this study, the mean response for the eight spaces did not exceed 0.35 on the voting scale. Case 5 was perceived as the best condition for improving amenity (M = 0.35, SD = 0.15). Since the results demonstrate that the sofa style was not perceived to be a significant factor affecting amenity, furniture styles do not need to be determined in the early phase of spatial design. The location of the vacant space positively affected spatial perception in all eight spaces (A14). Case 5 was perceived to be the favorite condition for improving amenity (M = 0.48, SD = 0.16).

In summary, the location of the TV, sofa arrangement, and location of vacant areas in a space play effective roles toward positive perceptions of amenity. However, the sofa style was not a significant factor for amenity.

3.2.3. Overall Satisfaction and Influential Factors for Amenity

The overall satisfaction levels with a space in terms of amenity are illustrated in Figure 12. The mean response regarding overall satisfaction varied according to the changes in the interior design elements used for the space (A15).

Among all conditions established for the eight spaces examined in this study, case 5 was selected as the favorite condition in terms of amenity (M = 0.61, SD = 1.12). It seems that the space in this case provided aesthetically harmonious conditions based on the composition of the interior design factors. The lower brightness level of walls, higher brightness of the floor, and recessed lighting fixtures were linked to favorable perceptions of amenity. Additionally, cases 1 and 3—featuring recessed halogen and florescent fixtures on the ceiling—provided favorable conditions for amenity (M = 0.39, SD = 0.84).

On the contrary, cases 2 and 4 failed to garner favorable perceptions of amenity for the given spaces (M = −0.16, SD = 1.00). The wall-mounted lighting fixture and cove lighting system on the ceiling were viewed as unfavorable elements for amenity perceptions.

The results indicate that recessed lighting fixtures on the ceilings functioned as effective contributors for improving favorable perceptions of amenity in the given spaces, compared to the contribution of surface brightness to perceptions of amenity.

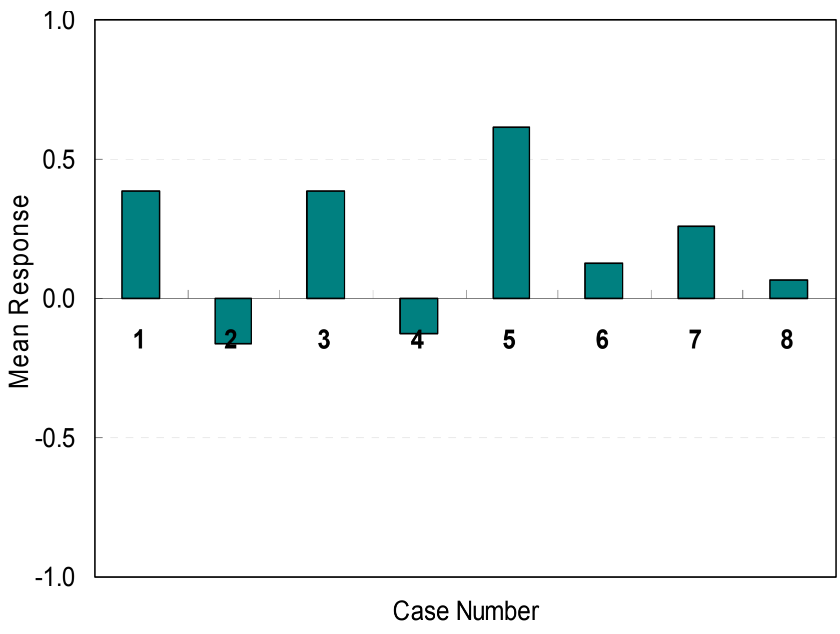


Figure 12. Overall satisfaction levels for amenity (Cases 1–8).

In this study, multiple linear prediction models that explain the influence of interior design factors on the perception of amenity were developed to examine relationships between them. The mean response for overall satisfaction in terms of amenity was considered a dependent variable, and all responses to the questionnaire were considered as independent variables.

Among them, independent variables that were acceptable within a significance level of 0.05 were included in final models. An analysis of variance (ANOVA) was employed to investigate linear relationships between independent and dependent variables. The multiple linear prediction models and ANOVA test results are summarized in Table 8.

Overall, the prediction model implies that perceptions of amenity (A15) regarding a space and interior design factors under given conditions are correlated linearly. Since the significance level was lower than 0.01, the model is strongly acceptable. The coefficient of determination (r^2) for the model was 0.5906, implying that the reduced error variance in the prediction of amenity was 59.06%, when the perceptions of interior design factors were used to predict the overall satisfaction in terms of amenity.

The overall satisfaction level regarding amenity was influenced by perceptions of the wall material (A1), location of the exhibition wall (A3), floor color (A6), lighting fixture arrangement (A9), lighting fixture style (A10), sofa arrangement (A12), and sofa style (A13).

Among the seven factors, the effects of wall material, lighting fixture arrangement, and sofa arrangement on the perception of amenity in a space were stronger than other factors. The influence of the location of the exhibition wall on amenity perceptions was very weak. Therefore, more attention should be paid to these three major factors to secure more favorable spaces for users, although the overall effects from the seven factors selected in the models are important for improving the satisfaction level for amenity. The findings about overall satisfaction in terms of the perception of amenity are presented in Table 7.

Table 8. Relationship between spatial factors and occupants' perception of amenity.

Variable	Unstandardized Coefficient		*t*	Sig.	ANOVA
	B	Std. Error			
(Constant)	−0.1054	0.05	−2.01	0.05	F(7240) = 49.46 Sig. = 0.00 r^2 = 0.5906
A1	0.2439	0.04	6.26	0.00	
A3	0.0765	0.04	1.98	0.05	
A6	0.1110	0.04	2.69	0.01	
A9	0.2398	0.04	5.46	0.00	
A10	0.1754	0.05	3.74	0.00	
A12	0.2421	0.04	5.97	0.00	
A13	0.1106	0.04	2.65	0.01	

Where, Variable: Question number in Table 3.

In summary, the results provide an effective equation for predicting the conditions of interior design factors when the space finishes are determined in the participatory design process for living rooms. The wall material, lighting fixture arrangement, and sofa arrangement are common factors that should be determined carefully to improve spatial satisfaction in terms of amenity. In addition, more design options for lighting style, floor color, sofa style, and location of the exhibition wall should be offered to improve prospective occupants' spatial perceptions of amenity.

3.3. Perception of Efficiency

3.3.1. Effects of Surface Finish and Lighting on Perceptions of Efficiency

The contribution of surface finish and lighting fixtures to the perceptions of efficiency was examined in this study. The statistical analysis results for each question are presented in Figures 13–17. The graphs show the mean response for perception of efficiency reported by all participants.

As shown in Figures 13 and 14, wall materials were generally acceptable for hosting guests in all cases (E1). Overall, the wall with a brightness level of 87% was slightly more affordable than the wall with a brightness level of 73%. Case 3, in which the brightness level of walls was 87%, viewed as most effective in terms of the efficiency of space for hosting guests (M = 0.77, SD = 0.80).

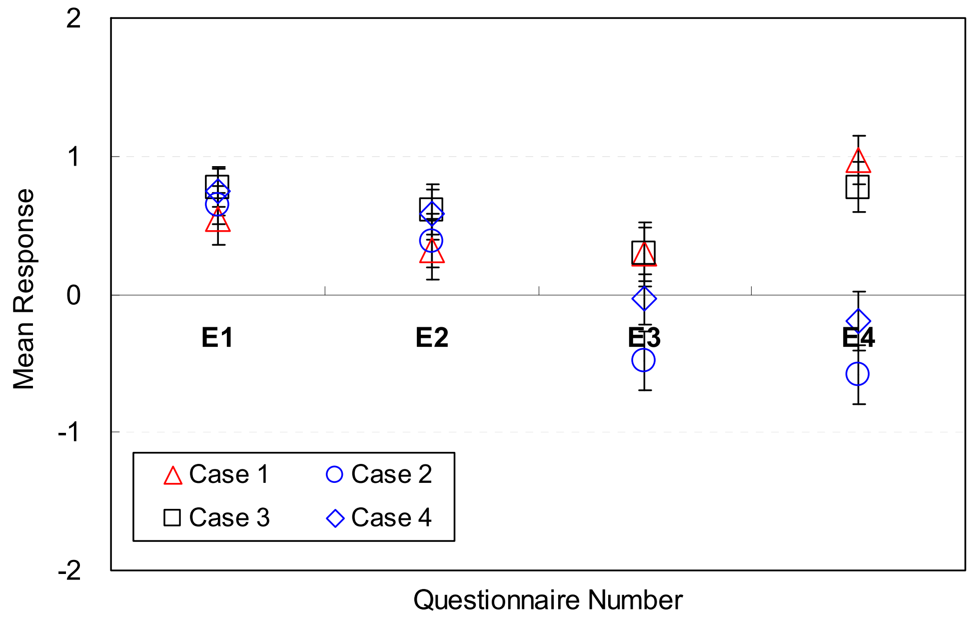


Figure 13. Effect of wall finish on perception of efficiency (Cases 1–4).

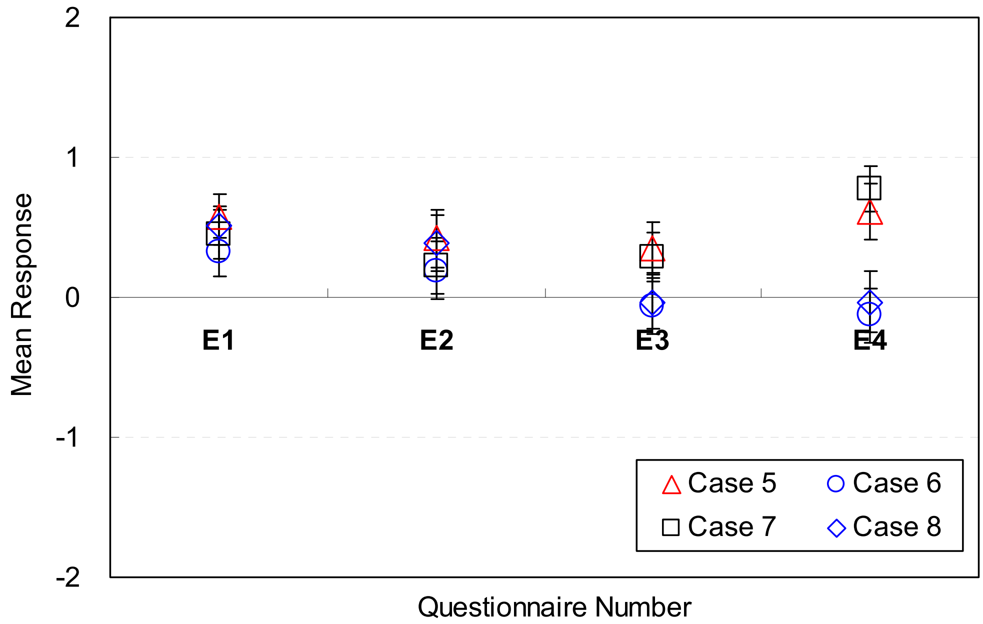


Figure 14. Effect of wall finish on perception of efficiency (Cases 5–8).

Wall color was marginally sufficient to afford positive perceptions of efficiency (E2) in all eight cases. The higher the brightness level of a wall, the more it tended to be perceived positively. The location of the exhibition wall was a contributor for spatial perception in terms of efficiency (E3), but the influence was not strong for all cases. Case 2 resulted in the least favorable perceptions of efficiency (M= −0.48, SD = 1.21). It seems that a vacant area without lighting fixtures on the wall was an agreeable condition for hosting guests because the vacant space was perceived as more affordable for exhibiting artwork or paintings.

The exhibition wall area also contributed to the level of brightness for the wall of efficiency (E4). Detailed findings about the effects of wall surfaces on perceptions of efficiency are summarized in Table 9.

As shown in Figures 15 and 16, the floor material contributed to favorable perceptions of efficiency (E5) in all eight spaces; further, the range of differences was narrow. The range for mean response was within 0.16 on the voting scale, implying that a variation in floor material was not a significant influential factor for the perception of efficiency.

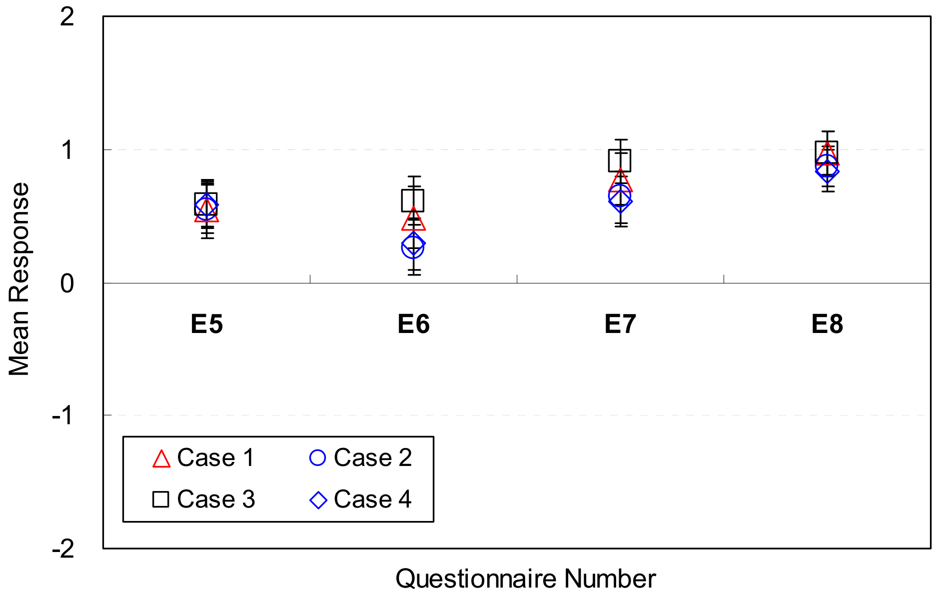


Figure 15. Effect of floor and ceiling finish on perception of efficiency (Cases 1–4).

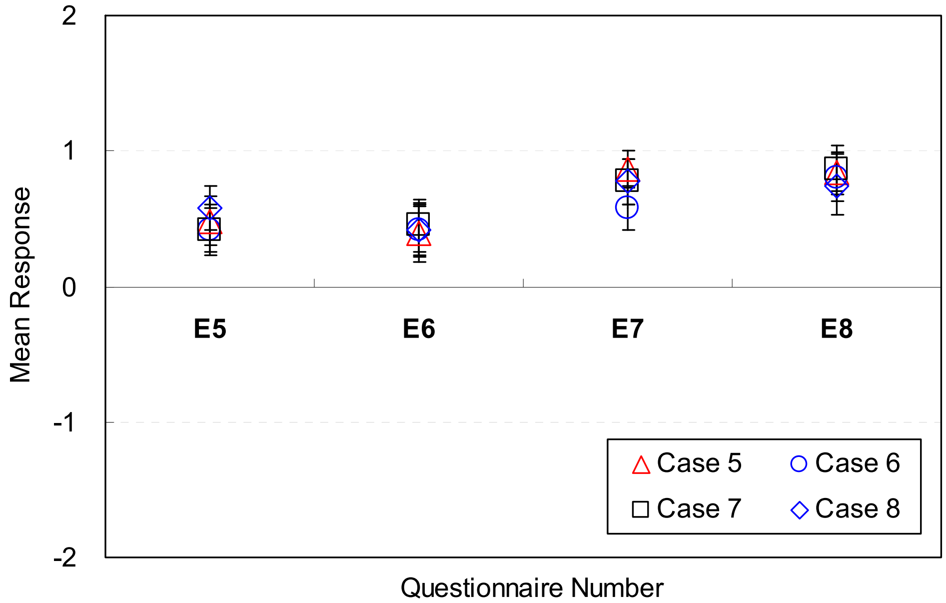


Figure 16. Effect of floor and ceiling finish on perception of efficiency (Cases 5–8).

The color of the floor material was a positive and effective factor in perceptions of efficiency (E6). The mean response range from 0.26 (M = 0.26, SD = 1.15) to 0.61 (M = 0.61, SD = 0.99) on the voting scale showed no negative perceptions caused by the color of the floor. Case 3 generated an agreeable condition for spatial perceptions of efficiency (M = 0.61, SD = 0.99). Although the brightness in cases 1, 2, 5, and 6 (87%) was relatively higher than that of the floor in cases 3, 4, 7, and 8 (73%), the mean response showed a narrow range of variation. It seems that the change in brightness was an insignificant contributor to perceptions of efficiency.

The ceiling shape was perceived as an influential factor in providing a small difference in perceptions of efficiency (E7). Overall, the ceiling shape was evaluated as a positive factor for serving guests in the space (M = 0.58, SD = 0.92 ~ M = 0.90, SD = 0.91). In general, ceilings containing recessed halogen and fluorescent lighting fixtures were evaluated favorably for efficiency. On the contrary, the ceiling with a cove lighting fixture was not preferred significantly.

Ceiling color also contributed to favorable perceptions of efficiency (E8), and the difference in mean responses for the eight spaces examined was narrow. The difference range of mean response was 0.23 on the voting scale (M = 0.74, SD = 1.21 ~ M = 0.97, SD = 0.91). Detailed findings about the effect of floor and ceiling surfaces on the perception of efficiency are provided in Table 9.

As shown in Figure 17, the arrangement of the lighting fixtures functioned as a strong contributor to the perception of efficiency (E9). Cases 1, 3, 5, and 7, which had fluorescent and halogen lighting fixtures on the ceiling, provided favorable conditions for better perceptions regarding efficiency of a space (M = 0.61, SD = 0.92 ~ M = 0.74, SD = 1.09). However, cases 2, 4, 6, and 8, which had wall-mounted lighting fixtures and no fluorescent lighting on the ceiling, failed to obtain favorable perceptions of efficiency (M = −0.55, SD = 1.09 ~ M = −0.23, SD = 1.12). For example, case 4 accrued the least favorable perceptions of efficiency (M = −0.55, SD = 1.65).

Moreover, the style of lighting fixtures strongly contributed to efficiency (E10). Its influence was similar to that of the arrangement of lighting fixtures. Cases 1, 3, 5, and 7 provided favorable conditions for better spatial perception in terms of efficiency (M = −0.58, SD = 1.06 ~ M = 0.71, SD = 0.82), but perception regarding efficiency was worse in cases 2, 4, 6, and 8 (M = −0.32, SD = 1.42 ~ M = −0.06, SD = 1.09).

Findings imply that the ceiling shape with no decoration will be preferred by prospective occupants of a space. Further, additional objects on the walls and ceiling should be avoided to improve the perception of efficiency in a space. The detailed implications about the effect of lighting layout and type on the perception of efficiency are provided in Table 9.

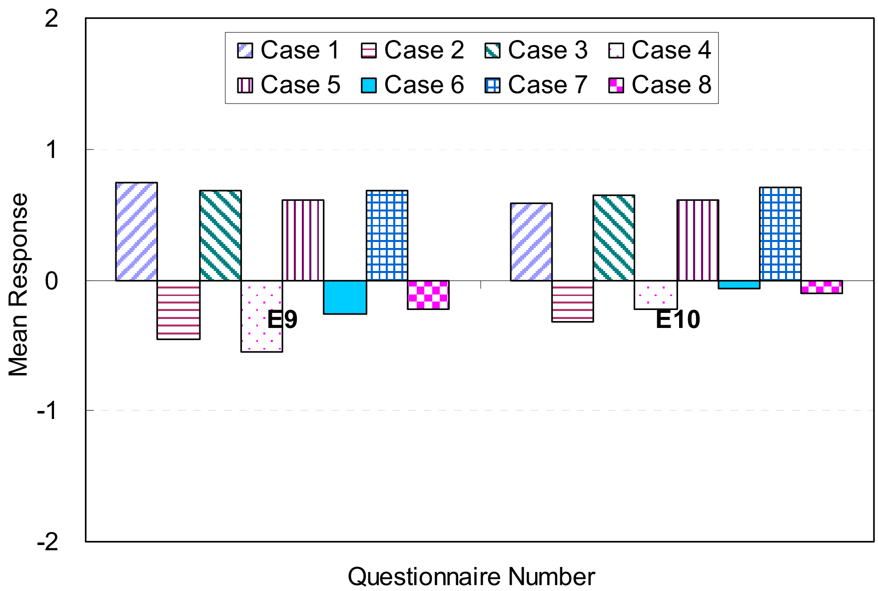


Figure 17. Effect of lighting layout and fixtures on perception of efficiency (Cases 1–8).

Table 9. Response for efficiency perception.

Category	Number	Question Content	Findings in Response for Efficiency Perception
Surface finish of wall	E1	wall material	Space 3, which had the highest brightness (87%), was the most effective in terms of efficiency for hosting guests in the space.
	E2	wall color	Higher brightness of a wall is perceived positively.
	E3	location of the exhibition wall	Vacant location without lighting fixtures on the wall was an ideal condition for hosting guests.
	E4	area of the exhibition wall	Vacant area without lighting fixtures on the wall is ideal for exhibiting artwork and paintings.
Surface finish of floor and ceiling	E5	floor material	Higher brightness of the floor material is perceived as a meaningful factor.
	E6	floor color	Spaces 1, 2, 5 and 6 was relatively higher than the color of floor in Spaces 3, 4, and 7 and 8.
	E7	ceiling shape	Ceiling shape with direct lighting might be more affordable and improve the perceptions of efficiency.
	E8	ceiling color	Ceiling color with direct lighting may improve the perceptions of efficiency.
Lighting	E9	lighting fixtures arrangement	In Spaces 1, 3, 5, and 7, which had direct lighting systems, the arrangement of the lighting fixtures was generally perceived as efficient.
	E10	lighting fixtures style	In Spaces 1, 3, 5, and 7, which had direct lighting systems, the style of lighting fixtures was generally perceived as efficient.
furniture arrangement	E11	TV location	Spatial factors were not varied for the eight spaces presented.
	E12	sofa arrangement	Spaces 2 and 5 were perceived to have agreeable conditions for improving efficiency.
	E13	sofa style	Sofa style was not an affordable factor for the spatial perception of efficiency.
	E14	vacant space location	Location of the vacant space positively affected the participants' spatial perception in all eight spaces.
Overall space	E15	sense of efficiency	Space 3 and Space 5 were selected as optimal in terms of efficiency. Space 3 was composed of the higher brightness wall, lower brightness floor, and direct lighting system. Space 5 was composed of the lower brightness wall, higher brightness floor, and direct lighting system.

In this study, higher levels of brightness for a wall tended to be perceived positively. The variety of floor materials was not a significant influential factor for perceptions of efficiency. The vacant area on a wall without lighting fixtures was considered an agreeable condition for exhibiting artwork and paintings. Additionally, a ceiling containing a mounted fluorescent lighting fixture was evaluated favorably for efficiency.

3.3.2. Effect of Furniture Arrangements on Perception of Efficiency

Occupants' perceptions of spatial elements sufficient for serving guests are described in Figures 18 and 19. The TV location in all spaces contributed to positive perceptions of efficiency (E11), although the variation range for mean response was not wide (M = 0.26, SD = 1.21 ~ M = 0.61, SD = 0.99).

The sofa arrangement was perceived to be effective for better perceptions of efficiency (E12). Cases 2 and 5 were perceived to reflect agreeable conditions for improving efficiency (M = 0.55, SD = 1.18). The findings imply that the sofa arrangement is perceived as a useful factor in terms of efficiency because the sofa location relates to serving guests.

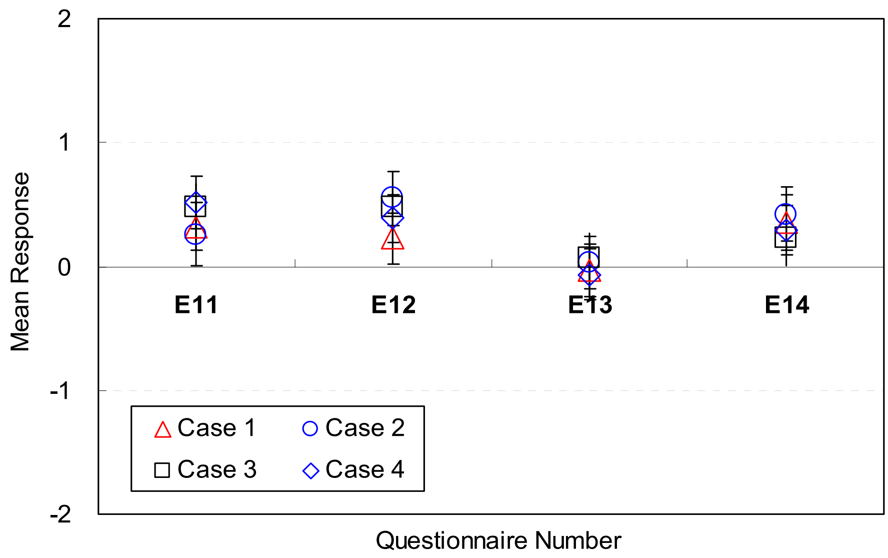


Figure 18. Effect of furniture arrangement on perception of efficiency (Cases 1–4).

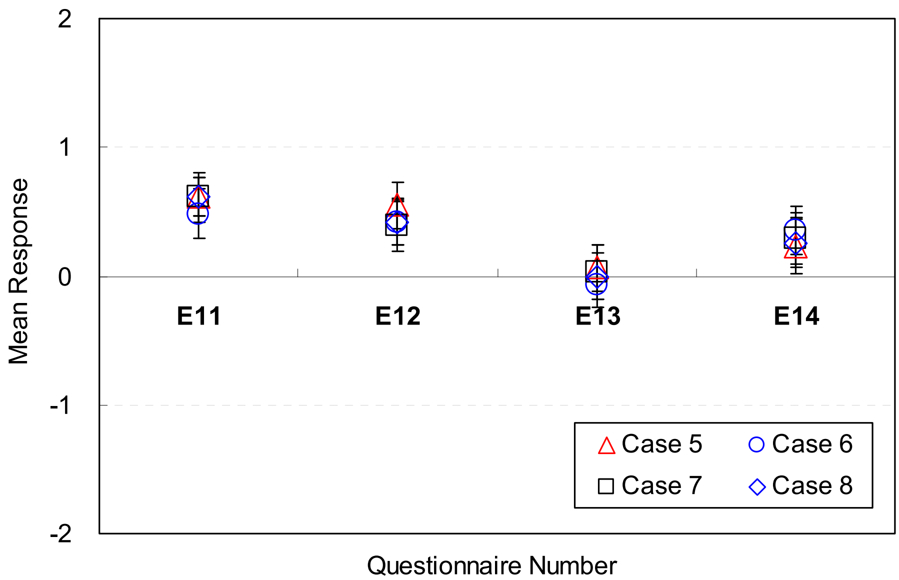


Figure 19. Effect of furniture arrangement on perception of efficiency (Cases 5–8).

The sofa style, however, was not perceived as an affordable factor for efficiency (E13). The mean response for all eight cases was close to neutral on the voting scale (M = −0.06, SD = 1.06 ~ M = 0.06, SD = 1.21). The results demonstrate that the sofa style was not perceived to be a significant factor affecting efficiency. Accordingly, sofa styles do not need to be determined in the early phase of spatial design.

The location of the vacant space positively affected participants' spatial perceptions in all eight spaces (E14). The findings indicate that the location of the sofa should be separated from the pathway so as not to disturb occupants' movements in the living room. The implication about the effect of furniture arrangement on the perception of efficiency is summarized in Table 9.

In summary, the TV location and sofa arrangement are useful factors and should be carefully determined to afford efficiency when hosting guests. Additionally, vacant space should be secured for better spatial perceptions of efficiency. As mentioned previously, sofa styles do not need to be determined in the early phase of spatial design.

3.3.3. Overall Satisfaction and Influential Factors for Efficiency

Overall satisfaction levels for efficiency of a space are illustrated in Figure 20. The mean responses for overall satisfaction varied according to changes in the interior design factors of the space (E15).

Among all conditions of the eight spaces investigated in this study, case 3 (M = 0.55, SD = 0.96) and case 5 (M = 0.55, SD = 0.77) illustrated the best conditions in terms of efficiency. This result was like that for overall spatial satisfaction in terms of amenity discussed in a previous section. It seems that lower brightness levels for walls, higher brightness levels for floors, and recessed lighting fixtures on ceilings contributed to favorable perceptions of a space's efficiency. No negative perceptions of efficiency were reported for the eight alternative spaces. The results indicate that recessed lighting fixtures on the ceiling contributed effectively to improved and favorable perceptions of efficiency. The findings about overall satisfaction in terms of the perception of efficiency are presented in Table 9.

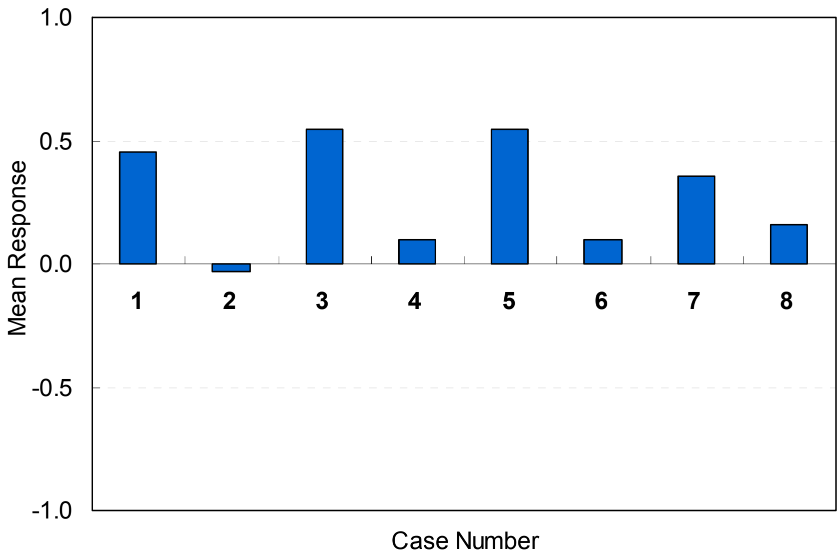


Figure 20. Overall satisfaction levels for efficiency (Cases 1–8).

Like the cases analyzed for perceptions of amenity, multiple linear regression analyses were employed to examine the effect of interior design elements on perceptions of spatial efficiency. A prediction model for the overall perception of efficiency was developed. The mean response for overall satisfaction in terms of efficiency was used as a dependent variable, and all responses to the questionnaire were considered as independent variables. The procedures for developing test statistics were equivalent to those used for the cases related to amenity. The multiple linear prediction models and ANOVA test results are summarized in Table 10.

Overall, the prediction model indicates that perceptions of efficiency (E15) correlated linearly with interior design elements under the given spatial conditions. The model is strongly acceptable since the significance level was lower than 0.01. The coefficient of determination (r^2) for the model was 0.510. This finding indicates that error variance can be reduced by 51% when the perceptions of interior design elements are utilized for the prediction of overall satisfaction regarding efficiency.

The overall satisfaction level for efficiency was influenced by wall material (E1), location of the exhibition wall (E3), floor color (E6), arrangement of lighting fixtures (E9), style of lighting fixtures (E10), and sofa arrangement (E12).

Among the six factors employed in the prediction models, the influence of lighting fixture style and sofa arrangement on the perception of efficiency was stronger than others. Wall material and location of the exhibition wall were slightly effective in terms of efficiency perceptions. The effect of floor color was the weakest. All factors included in the prediction are effective for improving overall spatial satisfaction in terms of efficiency, but more attention should be paid to the stronger elements.

Table 10. Relationship between spatial factors and occupants' perception of amenity.

Variable	Unstandardized Coefficient		t	Sig.	ANOVA
	B	Std. Error			
(Constant)	−0.0257	0.05	−0.49	0.62	
E1	0.1460	0.05	2.75	0.01	F(6241) = 41.8
E3	0.1424	0.04	3.49	0.00	
E6	0.0915	0.04	2.19	0.03	Sig. = 0.00
E9	0.0991	0.05	1.98	0.05	
E10	0.2938	0.05	5.73	0.00	r^2 = 0.510
E12	0.2074	0.04	4.93	0.00	

Where, Variable: Question number in Table 4.

In summary, the prediction model may be useful when designers determine the conditions of the spatial finishes in the design phase. The lighting fixture style and sofa arrangement are common factors that should be determined carefully to enhance spatial satisfaction for efficiency. More design options should be made available for wall material, location of the exhibition wall, floor color, and lighting fixture arrangement to improve prospective occupants' spatial perceptions regarding efficiency.

4. Discussion

In this study, the implication of findings summarized in Tables 7 and 9 is discussed to signify the elaboration of occupants' perceptions; additionally, the contributions to practical and theoretical expansion are addressed. The results indicate that the ambiguity about occupants' perceptions presented in previous studies has been diminished using the analytical approach suggested in this study.

Although various responses were collected and examined in this study, some meaningful aspects must be discussed in association with the cognitive psychological perspectives and human–environment interaction theories. A summary follows.

4.1. Perception of Interior Design Elements

The implications of findings in this study are classified into three categories. First, the perceptions of walls in terms of amenity and efficiency were meaningful. Affordance of wall material and color varied within a narrow range, but the affordance of area and location of the exhibition wall varied widely. This implies that favorable impressions of amenity and efficiency were strong when the stimuli of spatial elements were perceived intensively.

The wall finish in the selection of brighter colors can be explained by the social learning theory: people are intrinsically motivated to seek reinforcement, such as positive stimulation and avoidance of unpleasant stimulations [15]. Furthermore, the finding that brighter colors promoted participants' feelings of pleasure is associated with the pleasure arousal dominance hypothesis in cognitive psychology [15]. This relationship reflects actual experiences about spaces in real houses.

Second, the affordance of the floor and that of the ceiling were not equal. The effects of the ceiling on the perception of affordance were stronger than those of the floor, possibly because the ceiling area was predominantly exposed to the visual field of occupants.

Finally, perceptions of amenity were positive but perceptions of efficiency were negative. The perception of amenity was positive when detailed directions for certain behaviors in the space were not given. On the contrary, the perception of efficiency was negative in environments with guidelines for certain behaviors in the space.

The findings imply that perceptions of amenity and efficiency were influenced by the priming of detailed and concrete behaviors in space. As discussed in a previous study [24], occupants' evaluative perception processing is expanded based on the priming suggested in this study. The conditions of priming used in this study were the introduction of categorical knowledge about amenity and efficiency and pre-accommodation in VREs.

4.2. Correlation between Overall Satisfaction and Interior Design Elements

Occupants' direct and indirect perceptions were effectively presented in this study. The mean responses for overall satisfaction levels regarding amenity and efficiency were higher when a direct fluorescent lighting system was applied to a space. Findings are fairly consistent with previous studies suggesting that the direct lighting system generally used in Korea evokes positive pleasure and favorable perceptions from occupants in their spatial experiences [15].

It seems that the participants voted according to their accumulated experiences, since direct lighting is common in Korea and participants were familiar with the direct lighting system. Direct lighting provided feelings of pleasure when looking at artwork and paintings with participants. The direct lighting style and legible condition enhanced participants' abilities to look at the paintings, clearly increasing feelings of pleasure.

Further, satisfaction regarding efficiency may not be interpreted perfectly using the social learning theory [45]. However, the results are consistent with the implication of the theory since occupants did not feel stress in agreeable conditions resulting from engaging in certain behaviors, such as displaying artwork and serving guests in a living room.

The findings of this study demonstrated that wall material and location of the exhibition wall, floor color, and the arrangements and styles of lighting fixtures were effective contributors to overall satisfaction levels regarding amenity and efficiency.

The conditions of lighting fixtures significantly affected overall satisfaction levels. In this study, the mean responses in terms of the affordance of changes to the ceiling were stronger than those for changes in the floor. However, no contribution of the ceiling to overall satisfaction levels was observed. It seems that elements such as lighting layout and ceiling shape—easily distinguished in virtual space—strongly affected perceptions of amenity and efficiency.

A previous study showed that size and location factors were strong contributors to perceptions of amenity and efficiency [4]. However, the results of this study showed that materials, surfaces, and colors were weak contributors to clear perceptions about space. These results are consistent with those of a previous study that examined spatial perceptions about actual residential space in buildings [46]. The influence of size and location on perception was more important than materials, surfaces, and colors in space.

The results imply that the causal relationship between the spatial factors and space reflects actual experience, with divisions into for amenity and efficiency. The causal relationship of the study was limited to the operational interpretation projecting occupants' time-sequential experiences.

4.3. Comparison between the Perception of Amenity and Efficiency

Affordance of amenity and efficiency were not significantly distinguishable in this study. In addition, overall satisfaction levels for the two perceptions were distinguished weakly. In a previous study, the causal relationship between spatial shape factors and overall satisfaction with a space was clearly presented in occupants' perceptions, which reflected the time-sequential characteristics of the actual experience according to amenity and efficiency [4]. However, the results of the study indicated that the correlation between the spatial finish factors and space were not clearly presented in the occupants' perceptions of these characteristics.

Prediction models for satisfaction in this study show that influential factors for overall satisfaction regarding amenity and efficiency were equal, but their contributions to satisfaction levels were different. For example, the layout of lighting fixtures affected overall satisfaction in terms of amenity, and lighting styles affected overall satisfaction in terms of efficiency.

Especially, the findings of this study demonstrated that sofa arrangement contributes to overall satisfaction levels for amenity and efficiency. Participants perceived that the sofa location correlated with their lifestyles, or the spatial experience in real houses [15]. This result indicates that occupants did not feel stress in agreeable spatial conditions (ease of movement) when serving guests. The finding aligns with the social learning theory, which describes how occupants observed and imitated behaviors for serving guests [45]. In this study, occupants perceived sofa arrangement as an operant condition because they learned that this condition would be desirable [15].

The findings of this study imply that perception was not integrated with primed intentions for distinguishing between amenity and efficiency. Priming based on occupants' perceptions would not reinforce the evaluation of SDA in comparing previous experiences in real spaces with the distinction between amenity and efficiency.

The primed categorical concepts regarding satisfaction with amenity and efficiency did not increase accessibility to long-term memory in association with the control of top-down inference strategies. Furthermore, free association did not increase the activation of evaluative low-level perceptions in virtual spaces in association with the control of bottom-up perception processing.

In this study, the results potentially imply that occupants' evaluative perception processing elaborations were not activated effectively in the assessment of SDA for amenity and efficiency under the operating conditions. In summary, amenity and efficiency could hardly be evaluated on a separate basis using virtually created environments. Results of the analysis results may be used effectively for space evaluation in an early design phase.

5. Conclusions and Future Work

In this study, various conditions for interior designs that satisfy occupants' needs for amenity and efficiency were examined based on SDA. Especially, the causal relationship between the design elements and space were examined under perception processing elaboration for discussing actual predictive occupancy satisfaction evaluations. A summary of findings is as follows.

1. The findings of this study show the following: (1) the affordance of materials, surfaces, and colors were weak contributors to clear satisfaction of space; (2) the causal relationship of the study was limited to the operational interpretation projecting occupants' time-sequential experiences; (3) affordance of amenity and efficiency examined in this study were not significantly distinguished. Moreover, overall satisfaction with each was distinguished weakly. The findings of this study imply that the occupants' evaluative perception processing elaborations were not activated effectively in the assessment of SDA in terms of materials, surfaces, and colors in a space.
2. Occupants' perceptions are evaluated in terms of affordance and satisfaction, and the relationship between them is interpreted statistically. This study could be used to increase the prediction level at the early design phase and improve objectivity associated with selecting the best design based on experience. This study predicts the spatial factors affecting overall satisfaction at a detailed level and suggests the quantitative relationship between a limited number of spatial factors and virtually created space variations.
3. Occupancy experience was evaluated for its influence on occupants' prospective perceptions in association with working memory (POE examined the impact of occupancy experience on occupants' retrospective memory). In particular, perception of affordance for interior design elements was influenced by priming and concrete behaviors in a space;
4. The VRE approach has benefits for modifying the design when used for architectural purposes by identifying influential factors for satisfaction regarding amenity and efficiency. Quantification of the visual quality by future occupants is useful in reasonably selecting the best spatial design conditions because a common presentation of the causal relationship between spatial factors and space could improve design participants' objectivity in selecting the best design. For example, when a conflict in SDA arises between design participants and potential occupants, the result of this study can be effectively used to solve the conflict between them.

In this study, a limited number of alternatives of space layouts with limited number of interior design elements were investigated. Physical environmental factors of living room spaces that influenced occupants' perceptions were not examined for effectiveness. Also, all participants in this study could not report their perceptions in terms of individual eye height because of research limitations, and the reasons for unexpected results for finish factors could not be fully identified from participants' responses.

For future studies, it would be beneficial to conduct further evaluations under conditions for individual eye height and tests in real surroundings to examine the influence of physical environmental factors on occupants' perceptions. Further analysis is recommended in cases for which varied spatial factors are used to compare SDA indicators (e.g., spatial factors in green building cases), and further studies would also be necessary for spaces in commercial buildings.

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