

Perception of the Sense of Enclosure in Interior Spaces with Variations in Transparent and Opaque Surfaces

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This study was made to assess the effect on the occupant's "sense of enclosure" of different positions and amounts of transparent and opaque surfaces for both daytime and nighttime conditions. Subjects wearing a head-mounted display device permitting a high degree of head movement virtually "visited" a scale model space, whose enclosing surfaces were systematically varied with either transparent or opaque surfaces. The result of experiment in the daytime condition generally supported Thiel's hypothesis concerning the theoretical weights (10 for floor, 20 for wall, 30 for ceiling) in determining the degree of explicitness as a factor in the degree of enclosure, although the following findings indicated that some modifications would be required. (1) Judgements of "degree of enclosure" depend on the disposition of transparent surfaces: subjects feel less enclosed in a space with two adjacent transparent walls than with other arrangements of the same number of transparent and opaque walls. (2) Judgements of "degree of enclosure" vary according to daytime and nighttime conditions: (a) the variance of "degree of enclosure" between transparent and opaque surfaces was larger in the daytime than in the nighttime; (b) in the daytime, "degree of enclosure" increases more in a case where a transparent ceiling turns to an opaque ceiling than where a transparent wall turns to an opaque wall, but the opposite was true in the nighttime. (3) Judgments of "degree of enclosure" clearly differentiated between spaces with transparent ceiling and those with an opaque ceiling.

Keywords: Perception; Enclosure; Interiors; Transparent and opaque surfaces

Introduction

The ultimate objective of this study is to develop a tool for describing, and hence communicating, the experiential aspects of the physical environment. In the present study, the general question of how we can describe our experience in an environment was specified by asking how we can describe the perceived sense of spatial enclosure. As Norberg-Shultz (1971) noted, "the enclosure, in fact, may be considered man's first real attempt to take possession of the environment," it is one of the most fundamental concepts in environmental design. Architectural design in particular concerns the issue of the perception of a sense of enclosure, and it has received considerable research interest, since one of the primary functions of architecture is to enclose space (Ashihara, 1970; Inui & Miyata, 1973; Takei & Ohara, 1977).

Based on these attempts for the objective analysis of the sense of spatial enclosure, Thiel (1997) has proposed a scale of "degree of enclosure," in his comprehensive discussions on the "anatomy of space." He noted, "the degree of enclosure, associated with the presence or absence of a sense of confinement, is postulated as a function of three primary factors: the degree of

explicitness, the absolute volume of the space, and the proportions of the space." He described the establishment of local space by three types of "space establishing elements" or SEEs: objects, screens, and surfaces. He conducted an experimental study to test the hypothesis concerning the weights of the SEEs in determining the degree of explicitness as a factor in the degree of enclosure (Thiel et al., 1986).

Following Thiel's experimental study, the present study was made to re-examine his hypothesis and to clarify the effect of the disposition of transparent and opaque surfaces on the occupants' "sense of enclosure". In addition to this, the following questions were raised and examined: (1) Does the simulation method affect the experimental result? One of the purposes of this study was to test the performance of the newly developed scale-model simulation apparatus, which allowed subjects to "visit" a model space and look in any direction. In Thiel's experiment using such a conventional technique as showing one-point perspective drawings, subjects had to stay one fixed station point, while the scale-model simulation apparatus used in our experiment allowed subjects to have multiple station points.

(2) Does a window with transparent glass have the same visual effect as one without glass on the participant's perception of the openness or enclosure of the space? In order to test this effect, the mobility of station points was essential to perceive the reflected image in glass surfaces. This issue is particularly interesting because contemporary buildings often feature interiors with large areas of window glazing, and in these interior spaces the spatial separation from the outside is often ambiguous. (3) Does the participant's perception of the openness or enclosure of the space vary according to daytime and nighttime conditions?

Method

Subjects

Ten male and ten female university students, without an architectural education, were employed as subjects for this experiment.

An interactive simulation system

An interactive simulation system (Figure 1) was designed to allow subjects, wearing a head-mounted display device (HMD), to virtually "visit" a scale model space. The CCD colour TV camera inserted into the scale model space moves according to subjects head motion of "look around", "look down and up", and horizontal body motion. Subjects can look in any direction. A scale model (1/10) of a living room of typical dimension in Japan (width x depth x ceiling height = 4.5m x 4.5m x 2.4m) was made of an aluminum frame, and the finishes of four walls and one ceiling could be systematically varied with either transparent or opaque surfaces. The scale model was fixed to the apparatus upside down in order to insert the CCD camera through a hole made in the model floor, however, the display in the HMD was right side up.

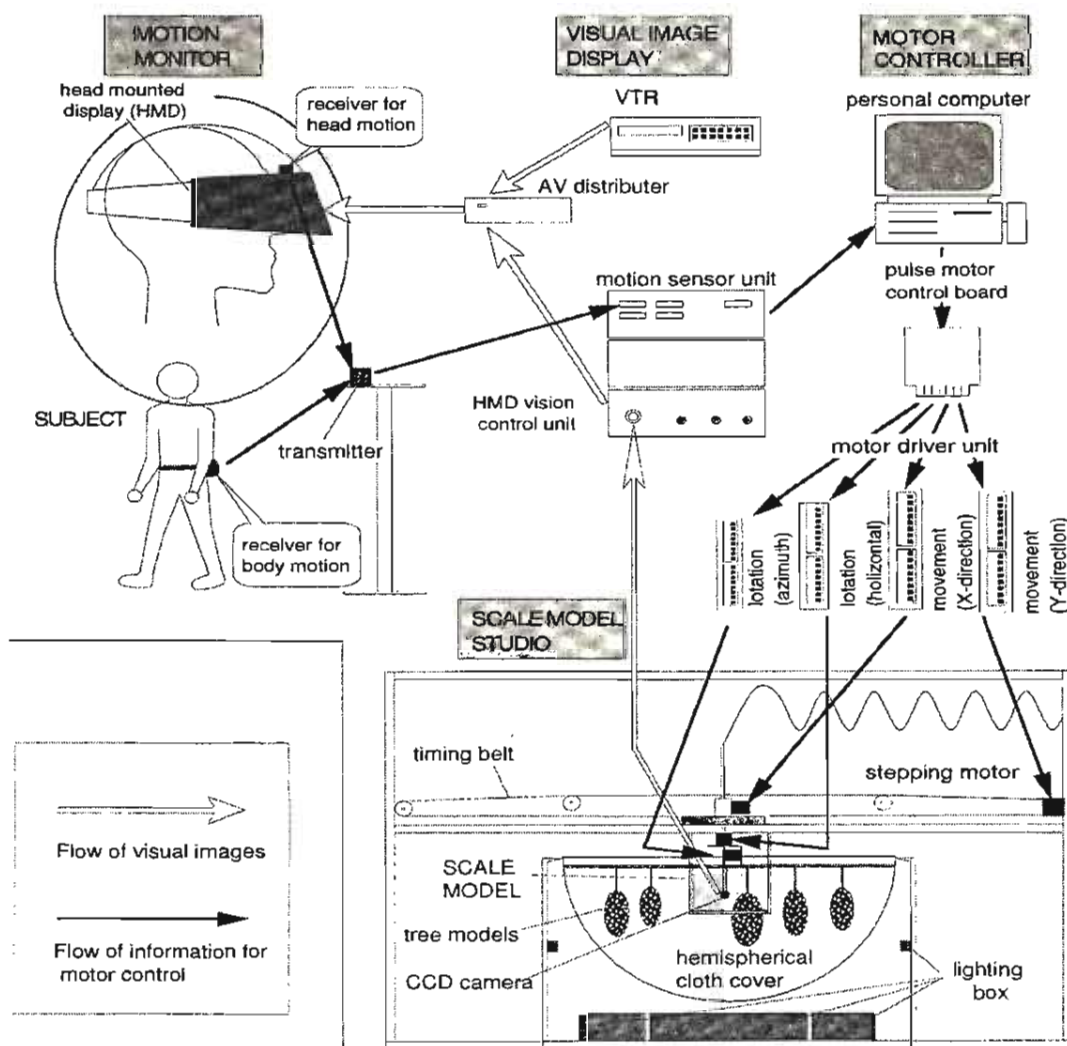


Figure 1. The interactive simulation system.

A hemispherical cloth sheet was illuminated by fluorescent light to provide the exterior space of the model room, representing the sky (Figure 2). Some trees were placed outside the room to give a sense of exterior space. The luminance of illumination was varied

according to day and night conditions. Such furniture as a tea table and chairs were installed to provide realistic cues as to the absolute size of the space, and some lighting fixtures were installed to make reflected images on the glass surfaces (Figure 3) for the night conditions.

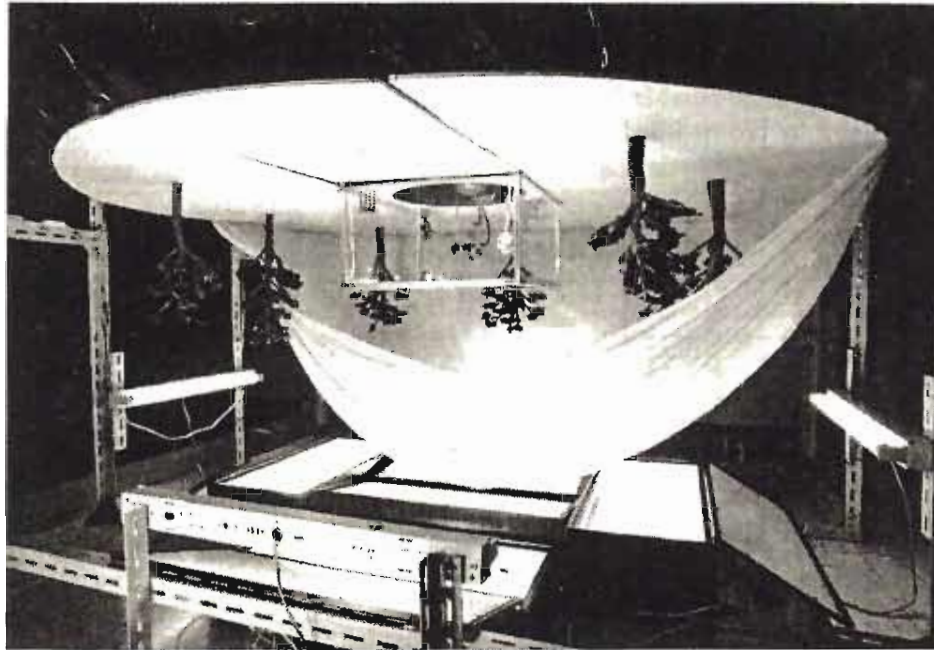


Figure 2. The simulation apparatus: a CCD colour TV camera is inserted into the model space.
(The hemispherical cloth sheet is partially removed to show the inside)



Figure 3. The subject wearing the HMD is looking around the interior space of the scale model.
(The TV monitor shows the same visual image as the HMD)

Procedure

Magnitude estimation was used to obtain subjects' judgments of "sense of enclosure". The method consisted of a series of twelve test stimuli (spaces), which were systematically varied with either transparent or opaque surfaces (Figure 4). Before the session, the following instructions concerning the definition of "sense of enclosure" were given to the subjects: "For the least enclosed condition, which we may experience in a large clear space with flat terrain, like a desert or a plain, we give the number '0'." Next, all test spaces were shown by pre-recorded videotape through the HMD. Then the standard stimulus (Space-

H, see Figure 4), whose number (magnitude) of enclosure was defined as "100", was visually presented to the subjects. The subjects were asked to view the space at will, with voluntary motions.

The task of the subjects was to compare each presented space with the standard stimuli and to render numerical estimates that were proportional to the magnitude of "sense of enclosure". The subjects were given as much time as they wished to complete the task. Every subject participated both sessions of daytime and nighttime conditions. Each session was completed in about 35 minutes.














| No. of Glass Surfaces | 5 | 4 | 3 | 2 | 1 | 0 |
|---|--|---|---|---|---|--|
| No. of Opaque Surfaces | 0 | 1 | 2 | 3 | 4 | 5 |
| Test Stimuli (Spaces) |  |  |  |  |  |  |
| H: Standard Stimulus | |  |  |  |  | |
|  Floor | | |  |  | | |
| Glass: Thick Line Frame Opaque: Gray Colour | | | | | | |

Figure 4. The twelve test stimuli.

Results and Discussion

Although the range of numbers rendered by the individual subject was different, the rank order of the stimuli was fairly consistent. The Kendall's coefficient of concordance was 0.90 in daytime condition and 0.87 in nighttime condition. This consistency of subjects' responses implied that the simulation system was usable for evaluation of interior spaces. For most subjects (80%), the variability of the numbers was larger in the daytime than in the nighttime. This indicated that the change of a "sense of enclosure" in

the daytime was larger than in the nighttime, when a transparent surface turns into an opaque surface. In the nighttime condition, the glass surfaces were considered to appear as "virtual" opaque surfaces due to reflection.

After the raw data of each subject was converted into z-scores (the standard deviation = 1, the mean = 0), the average score of the "sense of enclosure" (En) for each space was calculated.

As shown in Table 1 and Figure 5, the daytime average score increases as the number of transparent glass surfaces decreases. However, the rank order of the spaces with the same number of the glass surfaces was partially reversed for the nighttime. A careful examination of each case revealed that the ceiling surface in the daytime has a greater impact on the

"sense of enclosure" than a wall surface, while the opposite was true in the nighttime. For example, Space-B, which has a glass ceiling with three glass walls, was judged less enclosed in the daytime condition than Space-C, which has an opaque ceiling with four glass walls, but the opposite was true in the nighttime.

Table 1. The average score and rank order of "sense of enclosure" for day and night conditions

| Number of surfaces (glass / opaque) | | 5/0 | | | 4/1 | | | 3/2 | | | 2/3 | | | 1/4 | | 0/5 |
|-------------------------------------|--------------------|-------|-------|-------|-------|-------|-------|-------|------|------|------|------|------|-----|--|-----|
| space | | A | B | C | D | E | F | G | H | I | J | K | L | | | |
| Daytime | En (average score) | -1.66 | -1.27 | -0.94 | -0.67 | -0.57 | -0.43 | -0.13 | 0.12 | 0.45 | 0.67 | 0.92 | 1.79 | | | |
| | rank order | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | | |
| Nighttime | En (average score) | -1.34 | -0.77 | -0.99 | -0.15 | -0.12 | -0.25 | 0.48 | 0.33 | 0.54 | 1.17 | 1.03 | 1.79 | | | |
| | rank order | 1 | 3 | 2 | 5 | 6 | 4 | 8 | 7 | 9 | 11 | 10 | 12 | | | |

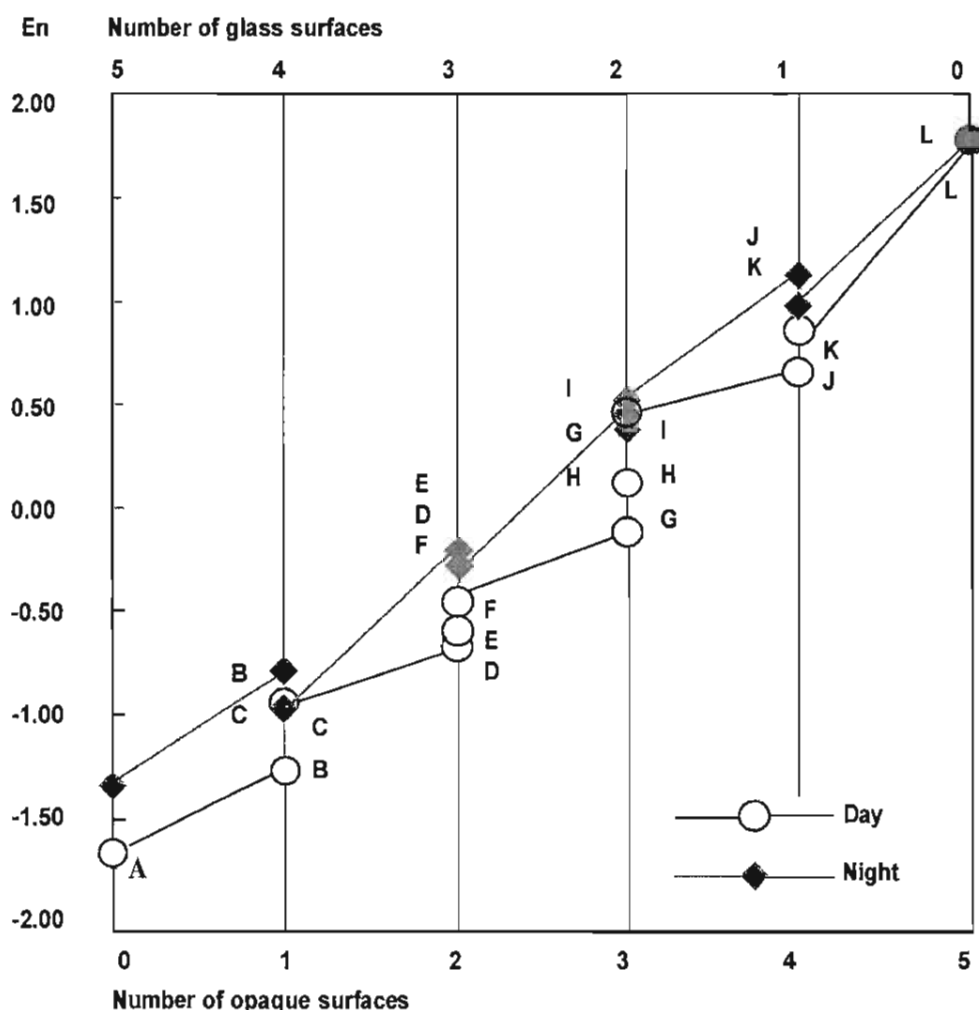


Figure 5. Relation between number of opaque surfaces and "sense of enclosure".

In both night and day conditions, it was noted that Space-H had lower score, i.e., was perceived as less enclosed, than Space-I, even though both of them had same number of glass walls. Comparing these spaces, we noticed that the glass walls in Space-H are adjacent, while in Space-I two glass walls are opposite each other (Figure 6). The difference of the scores between Space-D and Space-E can be also explained by the same reason.

As the above discussion indicates, the combination of the exterior conditions (day or night) and the position

of transparent glass surfaces (ceiling or wall) influenced the judgment of a "sense of enclosure". Therefore, a functional relationship between the "sense of enclosure" and the total area of opaque surfaces was examined separately for each of four different conditions. As shown Figure 7, a linear regression line for each condition fits well (the correlation coefficient was more than 0.99). This means that we need to treat these phenomena separately according to four conditions; and if we treat them separately, it is explained by a fairly simple relationship.

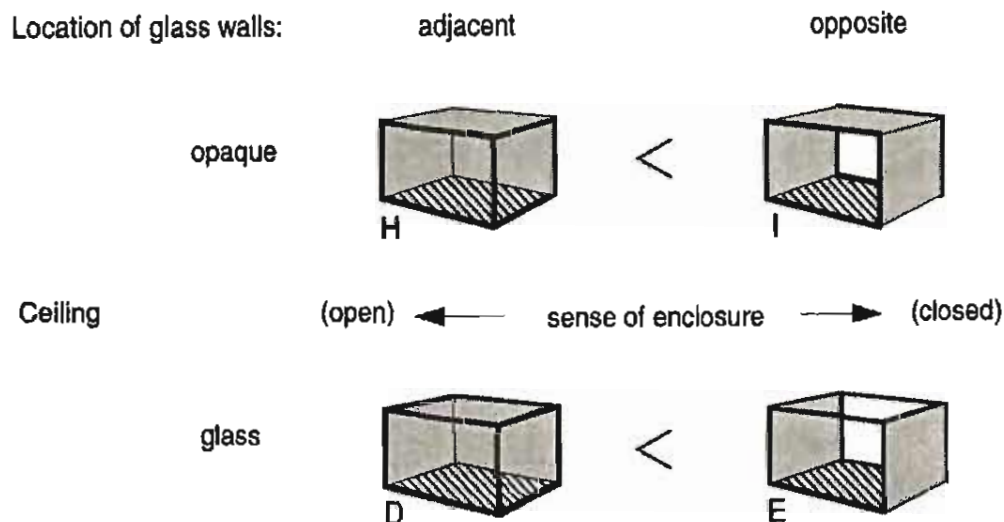


Figure 6. A space with adjacent glass walls was judged less enclosed.

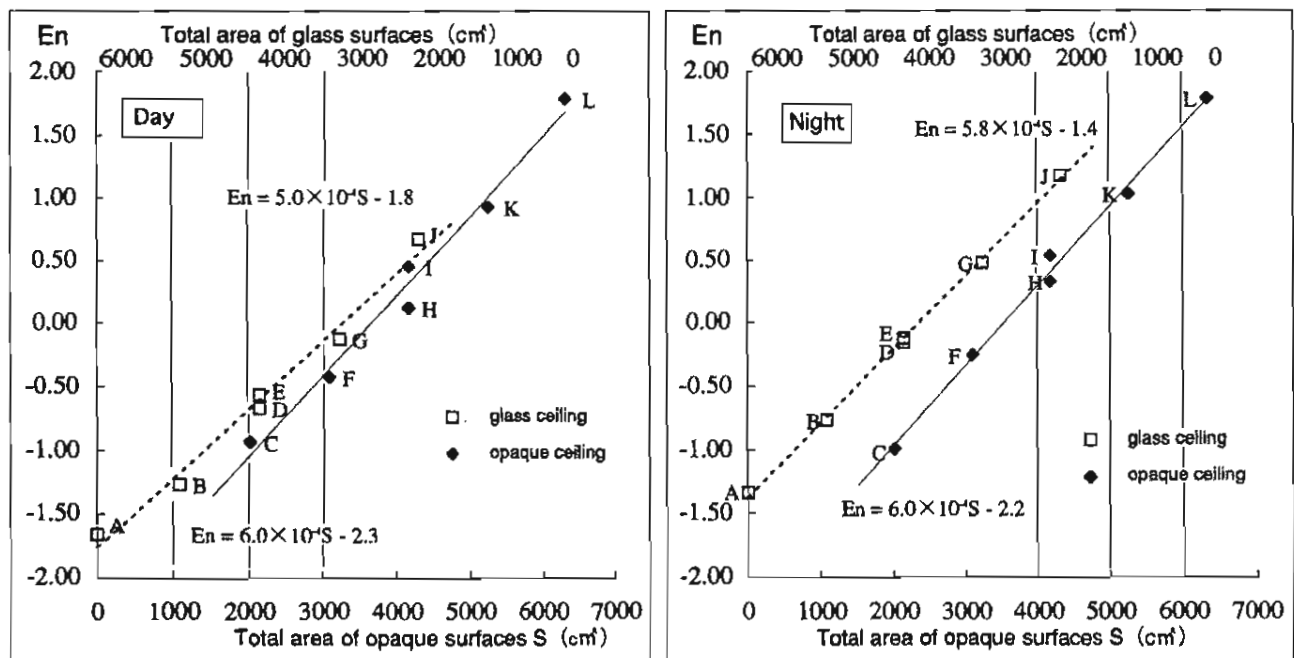


Figure 7. Relation between total area of opaque surfaces and "sense of enclosure".

Finally, our result was examined in the light of Thiel's hypothesis, which was our starting point. Although his hypothesis was not directly applicable to our test stimuli because our model had four walls instead of three, we simply borrowed his theoretical weights (10 for floor, 20 for wall, 30 for ceiling) to determine the degree of explicitness for each tested space. Figure 8 shows the relation between Thiel's scale and the results of the present study. In the daytime condition, a linear relation

indicates that our data generally support his hypothesis except for some dispersion in the cases of Space-H and Space-I, which we already discussed above. As for the night condition, Thiel's theoretical weights seems not be applicable. However, as shown in Figure 9, if we put the weight 10 for ceiling instead of 30, a linear relation was obtained between the revised score of explicitness and the judgment of "sense of enclosure" at night.

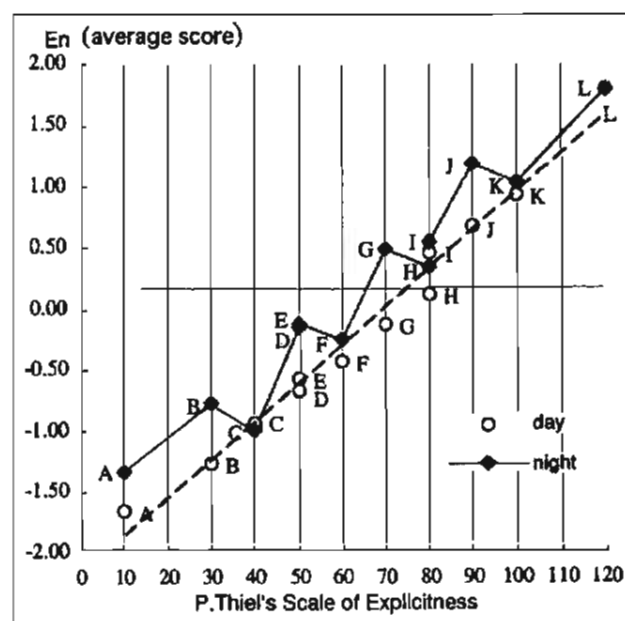


Figure 8. Relation between Thiel's scale of explicitness and "sense of enclosure".

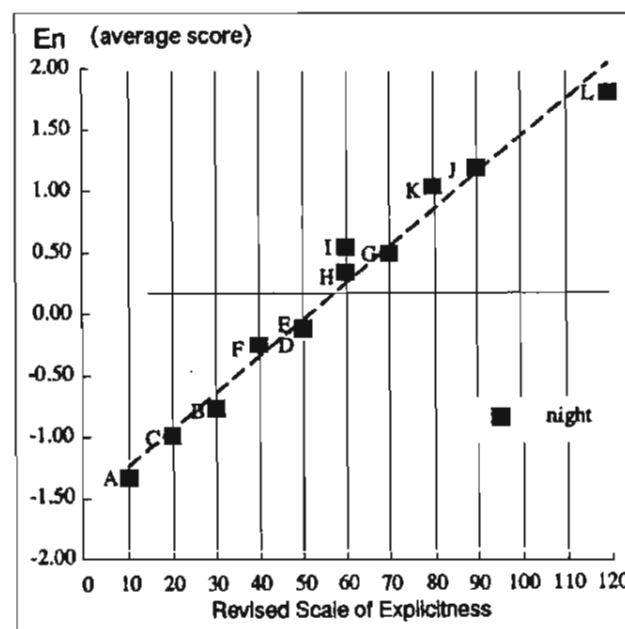


Figure 9. Relation between revised scale of explicitness and "sense of enclosure".

Conclusions and Implications

The result of experiment using the interactive simulation system generally supported Thiel's hypothesis in the daytime condition, although the following findings indicated that some modifications would be required. (1) Judgements of "degree of enclosure" depend on the disposition of transparent surfaces: subjects feel less enclosed in a space with two adjacent transparent walls than with other arrangements of the same number of transparent and opaque walls. (2) Judgements of "degree of enclosure" vary according to daytime and nighttime conditions: (a) the variance of "degree of enclosure" between transparent and opaque surfaces was larger in the daytime than in the nighttime; (b) in the daytime, "degree of enclosure" increases more in case that a transparent ceiling turns to an opaque ceiling than a transparent wall turns to an opaque wall, but the opposite was true in the nighttime. (3) Judgments of "degree of enclosure" clearly differentiated between spaces with transparent ceiling and those with an opaque ceiling.

Since the stimuli used in the experiment were a limited number of scale models of identical size and proportion, further research is needed to determine the validity of

the numerical relations obtained in this study, and to explicate Thiel's primary factors of absolute volume and space proportions; as well as Thiel's secondary factors of colour and texture of the surfaces, level and type of illumination, temperature and humidity, space furnishings, and human activity in the space.

The present effort provides one step to establish a quantitative explanatory system for predicting human perception of their environment. If the system is established and its computer program is developed, it would be a useful tool for environmental designers and planners in order to assess unbuilt environments. For example, if the designer were interested in the sequential experience of people as they move through the proposed rooms he/she would input the data into a computer and consult the program to know the perceptual impact of the changes. The feasibility of such program has been questioned because there are too many related variables to be handled and it requires much effort to generate the data. However, since computer aided drafting (CAD) has become quite popular among the environmental designers, the data is obtained without extra effort. Therefore, the program can be easily and interactively used in the design process.

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