An Experimental Study on the Change of Spatial Perception During Passing Through Spaces of Two Different Volumes

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Abstract

Inside the architectural space, we see a space of changing volume, differing in ceiling height or floor area. These volume changes are considered to affect human perception. The purpose of this study is to experimentally grasp and quantify such influences. Model experiments are performed for vertical perception (a feeling of an overhead opening by wellhole) and horizontal perception (easiness feeling of staying in alcove-shaped space appurtenant to fluidal space, such as an aisle). Consequently, it was found more effective to make the post-well higher than to make the pre-well space lower. In addition, it was found to be difficult to stay in alcove-shaped space too deep.

Keywords: Model experiment, volume change, spatial perception

1. PURPOSE OF STUDY

Inside the architectural space, we see a space of changing volume, differing in ceiling height or floor area. These volume changes are considered to affect the perception by a human moving in this space. In this study, volume changes are roughly classified into vertical and horizontal changes. The purpose of this study is to experimentally grasp and quantify the influences of these volume changes on human perception.

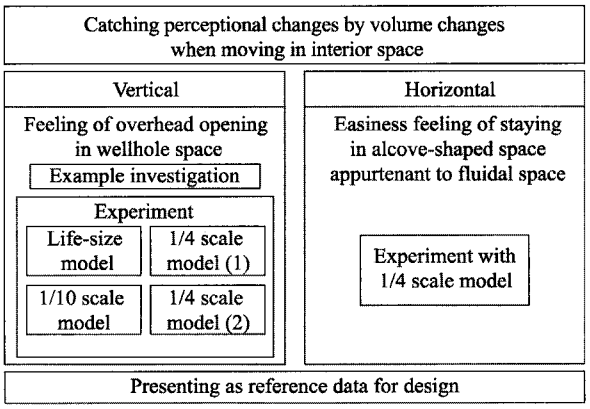


Figure 1. Organization of this study

More specifically, this study deals with an overhead opening that causes a human to feel a vertical change of spatial volume when entering a wellhole space. This study also deals with the easiness feeling of staying in an alcove-shaped space (staying space) appurtenant to the fluidal space such as an aisle as a horizontal volume change, such as an aisle.

For experimentation on the feeling of an overhead opening, we use three sizes of models (life-size, 1/4, and 1/10) to discuss the influences of model sizes on the results (Figure 1).

2. EXPERIMENT ON VERTICAL VOLUME

2.1. Example Investigation

We investigated 97 architectural design materials from "Kenchiku Shiryo Kenkyusha". Since this investigation was not statistically accurate, the results should be taken for reference only. Of

2587 articles, 1304 showed wellhole space. Figure 2 shows a summary of the investigation results. We saw differences of ceiling height from 2500 to 4500 mm.

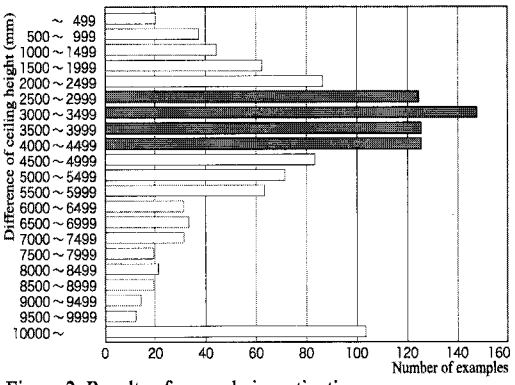


Figure 2. Results of example investigation

2.2. Experimental Settings and Method

This experiment was targeted at the continuous space of two different ceiling heights, and the uses and plane dimensions were not limited. The space of the low ceiling height was called the reference space and that of the high ceiling height was called the wellhole space. The ceiling height of the reference space was called Variable A and the difference of the ceiling heights between the reference space and wellhole space was Variable B. And the ceiling height of the wellhole space was called Variable C. By considering the results of an example investigation and the limits of experimentation, the variables were set as specified in Table 1.

For the experiment, the paired comparison method was used with two models of internal space, which linked different ceiling heights. After describing the purpose of the experiment and other information, we instructed the subjects to compare the two models and select the one producing a greater change in the feeling of an overhead opening. Figure 3 shows the experimental method, subjects, and content of the instruction. By evaluation, one point was given to the model with the stronger feeling of an overhead opening and no points to the other model. Then the evaluation average was calculated.

Table1. Settings of experimental variables (Vertical) (mm)

Ceiling height of reference space (Variable A) \ Difference of ceiling heights (Variable B)	+500	+1000	+1500	+2000	+2500	+3000	+4000
2400	Ceiling height of wellhole space (Variable C) C=2900	C=3400	C=3900	C=4400	C=4900	C=5400	C=6400
2700	C=3200	C=3700	C=4200	C=4700	C=5200	C=5700	C=6700
3000	C=3500	C=4000	C=4500	C=5000	C=5500	C=6000	C=7000

※ ■ : Setting range for the life-size, 1/4 scale (1), and 1/10 scale experiments
□ : Setting range for the 1/4 scale (2) experiment

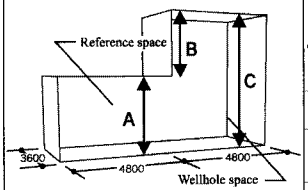
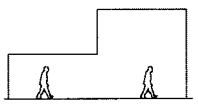
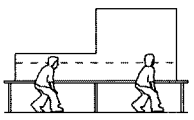
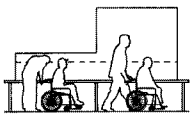
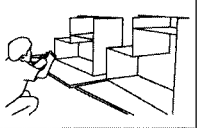
Dimensions of experimental models		Life-size model	1/4 scale model (1)	1/4 scale model (2)	1/10 scale model
	View of experiment				
	Gazing point	By subject	Secured at 400 mm from the floor		View from outside
	Test subject	10 students from our Architectural Department (Same for life-size, 1/4 scale (1), and 1/10 scale models)			
	Content of instructions	• Select either model that you think will give a greater change in the feeling of the overhead opening to a reference space user passing through the corresponding real space. • Do not consider the horizonal shape of the space or model material as judgment criteria.			

Figure 3. Experimental models and method

2.3. Experimental Results and Discussion

(1) Relationship between variables and evaluation averages

Figure 4 shows graphs of the relationship between the variables and the evaluation average. Regarding the relationship between Variable A and Variable B, the evaluation average becomes higher as Variable B becomes greater in all graphs. For the life-size model and 1/10 scale model, the evaluation average also becomes higher as Variable A becomes greater. The 1/4 scale model (1) is not as influenced by Variable A as were the other models. The 1/4 scale model (2) can only be compared roughly because the subjects and settings are different from those of other models.

However, the model shows a slightly different tendency from (1) of the same scale. The 1/4 scale model (1) does not show a difference of the evaluation average from the ceiling height of the reference space. Like the life-size model and 1/10 scale model, the 1/4 scale model (2) shows a greater evaluation average when the ceiling height of the reference space is higher. However, the evaluation is opposite when the ceiling height of the wellhole space is low. In the case of (1), the subjects were only instructed to fix their gazing points on the tape inside the model. In the case of (2), the subjects sat in wheelchairs to fix their gazing points.

For the relationship between Variable A and Variable C, we see that the evaluation average becomes naturally higher as Variable C becomes greater. As Variable A becomes greater, however, the evaluation average becomes lower. Thus, the evaluation becomes higher as the difference of the ceiling height becomes greater between the reference space and the wellhole space. If the difference of the ceiling height is constant, the ceiling of the wellhole space consequently becomes higher in proportion to that of the reference space, and the feeling of the overhead opening changes.

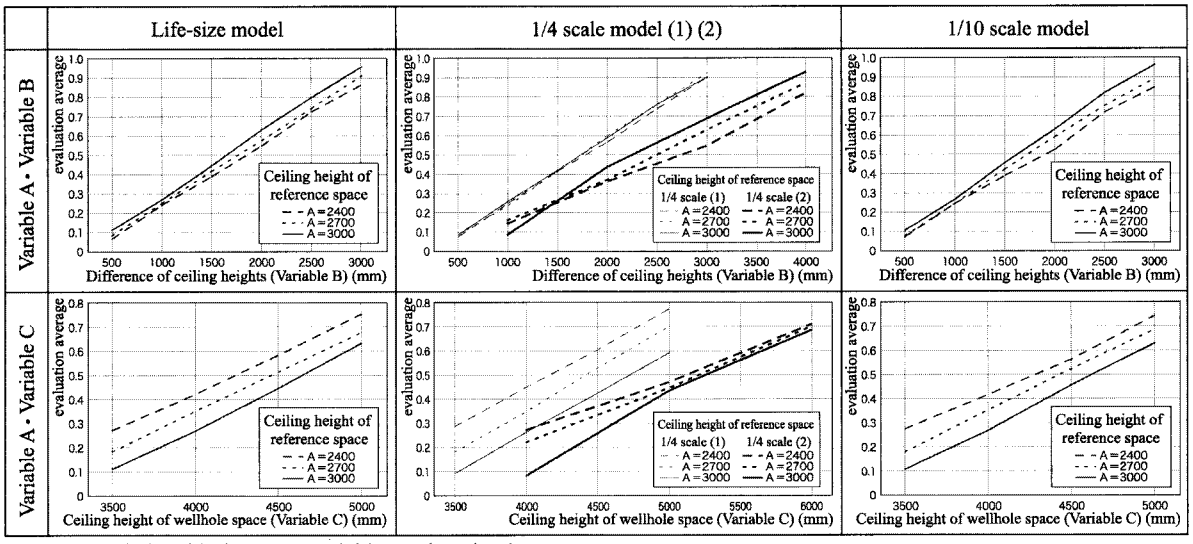
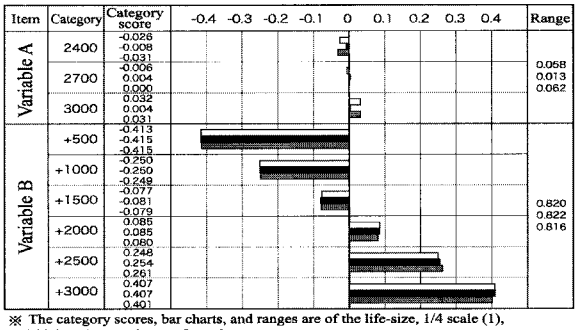


Figure 4. Relationship between variables and evaluation averages

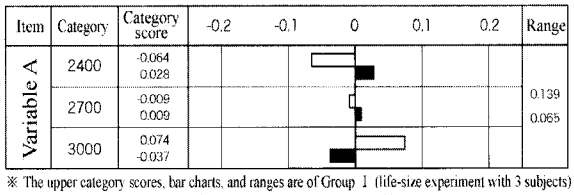
(2) The evaluation tendency by subject

To check the influences of Variable A and Variable B on the evaluation, Quantification method I was used for analysis (Figure 5). In all models, the influence of Variable B is greater than that of Variable A. Variable B shows a similar tendency for all subjects but the influence of Variable A varies among the subjects. Therefore, the subjects were grouped by the evaluation tendency of Variable A. Here, the subjects were grouped for three models, excluding the 1/4 scale model (2) of the different subjects. Consequently, the subjects formed two groups. Figure 6 shows a typical example of the evaluation tendency for Variable A. Group 1 gives a higher evaluation to the reference



※ The category scores, bar charts, and ranges are of the life-size, 1/4 scale (1), and 1/10 scale experiments from the top.

Figure 5. Results of analysis by Quantification method I



※ The upper category scores, bar charts, and ranges are of Group 1 (life-size experiment with 3 subjects) and the lower ones are from Group 2 (1/10 scale experiment with 7 subjects).

Figure 6. Example results of Quantification method I by group

space of the higher ceiling and is the majority for all models. Meanwhile, Group 2 gives a higher evaluation to the reference space of the lower ceiling. Group 2 gives a higher priority to the difference of ceiling heights than does Group. However, we should note that the tendencies of this experiment are the results of a paired comparison and do not directly indicate the degrees of perception against the stimuli.

(3) The differences of scale and evaluation tendency

Table 2 summarizes the relationship between the model scales and subjects. Judging from this, the subjects showed the same evaluation tendencies, irrespective of the model scale.

Table 2. Relationship between model scales and subjects

\Test subject / Reduced scale	01	02	03	04	05	06	07	08	09	10
Life-size	1	2	1	1	1	1	2	1	1	1
1/4(1)	1	2	1	1	×	2	2	1	1	1
1/10	1	2	1	1	1	1	2	1	1	1

※ 1 is a subject group which gives a higher evaluation to the reference space of the higher ceiling
2 is a subject group which gives a higher evaluation to the reference space of the lower ceiling

2.4. Conclusion of Experiment on Vertical Volume Change

From this experiment, we obtained the following results:

1) When the difference of ceiling heights was greater between the reference space and wellhole space, the feeling of an overhead opening changed more.

2) The ceiling height of the wellhole space affected the evaluation more than that of the reference space.

3) The paired comparison method gave almost similar results for the scale models and the life-size model.

4) The subjects could be divided into a majority showing the average tendency and a minority not showing the average tendency.

5) The subjects showed almost the same evaluation tendencies, irrespective of the model scale.

The result of 5) may indicate that models reduced to the scale of about 1/10 will give almost the same results as the life-size scale if the evaluation method is limited to a paired comparison.

3. EXPERIMENT OF HORIZONTAL VOLUME CHANGE

3.1. Experimental Settings and Method

The objects of this experiment were fluidal spaces of unlimited lengths with staying spaces on the left. With the ceiling height fixed at 2700 mm, the width of the fluidal space and the frontage and depth of the staying space were set as variables. Table 3 gives the values set for the variables.

staying space was appurtenant. After describing the purpose of the experiment and other information, we instructed the subjects to go through the two models and select the one where they felt more like staying in the staying space appurtenant to the fluidal space. Figure 7 shows the experimental method, subjects, and content of the instruction. In the evaluation, one point was given

Table 3. Settings of experimental variables (Horizontal) (mm)

		Width of fluidal space					
		1800			2700		
		Depth of staying space					
		900	1800	3600	900	1800	3600
Frontage of staying space	1800						
	3600						

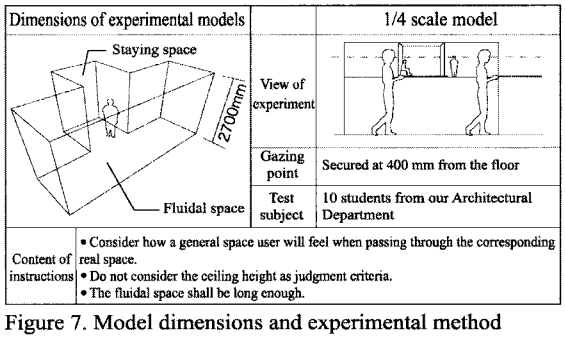


Figure 7. Model dimensions and experimental method

to a model of producing the stronger easiness feeling of staying and no points to the other model. Then the evaluation averages were calculated by a round robin for the 12 types of models.

3.2. Experimental Results and Discussion

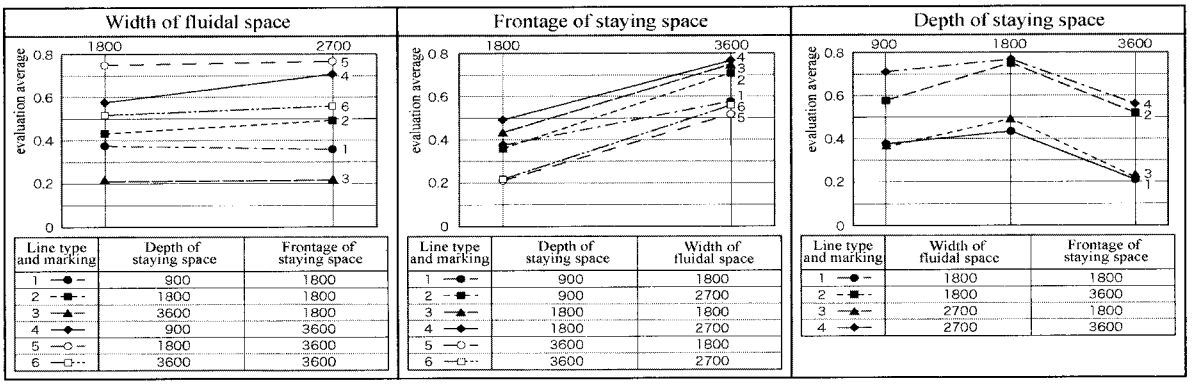
(1) Relationship between variables and the evaluation average

Figure 8 shows the relationship between each variable and the evaluation average. From the viewpoint of the width of the fluidal space, the evaluation average is slightly higher where the fluidal space is wider. In Pattern 1, however, the evaluation average becomes higher as the fluidal space becomes narrower. This is probably because the small staying space is difficult to recognize in a wide fluidal space.

Regarding the relationship between the frontage of the staying space and the evaluation average, the evaluation average becomes higher as the frontage becomes wider in all patterns. In Pattern 1, however, the difference of the evaluation average is slightly smaller than in the other patterns.

From the viewpoint of the depth of the staying space, the evaluation average is highest at the depth of 1800 mm and the lowest at the depth of 3600mm in all patterns. The evaluation tendency at the depth of 900 mm is different from those at the other two depths.

In general, the dimensions of the staying space affect the psychological easiness of staying more than the width of the fluidal space does. When the depth is 900 mm, the tendency is different from those in the other cases. This depends on whether the shallow staying space is recognized as a staying space.



Line type and marking	Depth of staying space	Frontage of staying space
1	900	1800
2	1800	1800
3	3600	1800
4	900	3600
5	1800	3600
6	3600	3600

Line type and marking	Depth of staying space	Width of fluidal space
1	900	1800
2	900	2700
3	1800	1800
4	1800	2700
5	3600	1800
6	3600	2700

Line type and marking	Width of fluidal space	Frontage of staying space
1	1800	1800
2	1800	3600
3	2700	1800
4	2700	3600

Figure 8. Relationship between variables and evaluation average

(2) Difference of evaluation tendency by subject

Because of the dispersion of the evaluation among subjects, the subjects were grouped by cluster analysis to clarify the evaluation tendencies. The subjects were divided into two groups (Figure 9). By comparing the evaluation tendencies, we could consider classification factors (Figure 10). The evaluation tendency is almost the same between Groups 1 and 2 for the width of the fluidal space and the frontage of the staying space, but different for the depth of the staying space. In Group 1, the evaluation becomes lower as the staying space becomes deeper. In Group 2,

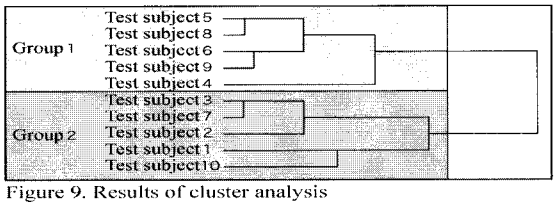


Figure 9. Results of cluster analysis

Item	Category	Category score	-0.2 -0.1 0 0.1 0.2	Range
Width of fluidal space	1800	-0.015 -0.025		0.050 0.031
	2700	0.015 0.025		
Depth of staying space	900	0.153 -0.138		0.271 0.400
	1800	0.094 0.133		
	3600	-0.247 0.004		
Frontage of staying space	1800	-0.135 -0.164		0.269 0.328
	3600	0.135 0.164		

※ The category scores, bar charts, and ranges are of subject Group 1 and 2 from the top

Figure 10. Results of Quantification method I by group

however, the evaluation is highest at the depth of 1800 mm and lowest at the depth of 900 mm. The depth of 3600 mm does not affect the evaluation so significantly.

3.3. Conclusion of Experiment about Horizontal Volume Change

From this experiment, we obtained the following results:

1) As the frontage of the staying space becomes wider, it becomes easier to stay.
2) The width of the fluidal space does not significantly affect the easiness feeling of staying.
3) As the staying space becomes too deep, it becomes difficult to stay.
4) From the viewpoint of the evaluation tendency depending on the depth of the staying space, thesubjects can be divided into two groups.

4. COMPARISON OF EXPERIMENTAL RESULTS BETWEEN THE VERTICAL AND HORIZONTAL PERCEPTION

Since this study deals with the feeling of an overhead opening and the easiness feeling of staying, which are different perceptions, the comparison between the vertical and horizontal directions is not the intended purpose. By rough comparison, however, we see that the evaluation goes up as the vertical volume change perpendicular to the moving line becomes greater, but the evaluation goes down as the horizontal volume change perpendicular to the moving line becomes too great. In both the vertical and horizontal directions, the subjects were divided by the evaluation tendency of one variable into two groups.

5. CONCLUSION OF THIS STUDY

Through the two experiments in this study, we could roughly quantify the influences of spatial volume changes on human perception:

1) In the vertical direction, the wellhole space affects the evaluation more than the reference space does.
2) In the horizontal direction, it becomes difficult to stay as the staying space becomes too deep.
3) From the viewpoint of the evaluation tendency, the subjects can roughly be divided into two groups.
4) Irrespective of the model scale, the subjects showed almost the same evaluation tendency in the paired comparison method for scale models up to 1/10.

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