Evaluation of
Spatial Imagination Ability in Reading

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Abstract. Words or paragraphs often create a concrete image in our minds. When reading a book, we can relive in our minds the same experiences the heroines or heroes have gone through. However, the imagined scenery of the reader and the author may not always be the same. In this paper, we define "spatial imagination ability" as the ability to imagine concrete scenery that corresponds to a written description in a book, and we developed the Spatial Imagination Test (SIT) to examine this ability. The results are as follows;
1) Approximately half of the subjects who read the paragraph obtained a similar image for the spatial layout of the house. However, their designs had different styles.
2) Drawings of over 35% contained rooms that were not described in the paragraph.
3) The average scores of the MCT were higher for students who drew undescribed rooms than for those who did not. However, statistical analysis showed that there was no significant difference (5% level) between the groups.
Key Words: Spatial ability, Spatial Imagination Test (SIT), Mental Cutting Test (MCT)
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1. Introduction

Words or paragraphs often create a concrete image in our minds. When reading a book, we can relive in our minds the same experiences the heroines or heroes have gone through. However, the scenery that the reader and the author imagine may not always be the same. Moreover, the imagined scenery of different readers may not be always the same. In contrast, excellent foreign literature and poetry can give us a common impression and allow us to

empathize with the author, even if the text is not written in the language of the author's home country. The reader does not misunderstand either scenery or the space described in a book.

ALEXANDER [1] proposed a way to design towns and buildings by using words in his book. He wrote, *'this book provides a language of this kind. It will enable a person to make a design for almost any kind of building, or any part of the built environment.'* and he proposed *'a way of using a pattern language to make buildings which are poems.'* This suggests that the combination of several words (a pattern) gives us an important clue for designing buildings. It also suggests that the ability to imagine a space from words or paragraphs is important for designing buildings. Regarding the ability to imagine spaces from words, OHYANAGI [2] examined stories for the relationship between the viewpoint of the hero and that of another character in the book. He analyzed the characteristics of the spatial images, but he did not examine the readers' ability to imagine a space. SHIINA [3] used a spatial orientation problem to examine the ability to imagine a space. In this study, the subject reads a series of statements about walking and turning in specified directions, and then was asked to identify the direction in which the imagined person was walking at a certain point in the sequence. In this test, the subject was only asked to identify the direction, not to imagine the space.

In the underlying paper, we define spatial imagination ability as the ability to imagine concrete scenery that corresponds to a written description in a book, and we developed the *Spatial Imagination Test* (SIT) to examine this ability. The SIT is a cognitive mapping test, so instead of a score, it provides information about the readers' cognition. The test asks the subject to read a paragraph that describes a house, and then to either draw the floor plan and a sketch of the house or to choose the corresponding photograph. By testing university students with the SIT, we were able to identify the characteristics of spatial imagination ability and to examine the relationship between spatial imagination ability and other spatial abilities. We presented the results of this test at the 14th and 15th International Conferences on Geometry and Graphics (ICGG) [4, 5]. The findings of these previous papers are combined in this paper.

2. Methodology

2.1. Contents of SIT

The SIT consists of four sections: reading, drawing, selecting photographs, and making relevant queries. Figure 1 shows an example of the SIT. The reading section of the SIT presents texts that describes a house. The texts consists of approximately 900 characters in Japanese. In the drawing section of the SIT, subjects are asked to draw a floor plan and a sketch of the house, based upon the texts they have just read. In the photograph-selection section, they are asked to choose one of 24 various interior photographs that best corresponds to the paragraph they have just read. In the final section, the subjects were asked to provide relevant personal information, such as their gender, age and favorite book etc..

2.2. MCT

The MCT (Mental Cutting Test) [6] is commonly used in graphic science to assess spatial ability. It is an objective test in which the participant is asked to imagine that a test solid is cut along the indicated plane, and is then asked to choose the correct cross-section from among

Figure 1: Example of SIT

five alternatives. The MCT is administered along with the SIT to identify the relationship between spatial ability and spatial imagination ability.

2.3. Subjects

The SIT was administered to 363 students taking a descriptive geometry course at a university during the years 2008 to 2010. They were freshmen and sophomores, and had not received any professional architectural education at the time of the test. The number of subjects who took part in the tests is shown in Table 1. The number of valid subjects (those who took both the SIT and the MCT) was 288.

Table 1: Number of subjects

			2008	2009	2010	number of subjects total
Year			2008	2009	2010	total
All subjects			125	125	113	363
valid subjects			79	99	110	288
Test A	Naomi	914 texts*	79	99	—	178
Test B	The Metamorphosis	799 texts*	—	—	33	33
Test C	Blade	629 texts*	—	—	39	39
Test D	A Wild Sheep Chase	1150 texts*	—	—	38	38

* number of texts (Japanese)

3. Results and discussion

3.1. Drawing examination

We consider Test A in the following analysis. The students' drawings of the floor plan of the ground floor were divided into the following four types based on the position of the entrance and the atelier: center, corner, convex, and nothing. Moreover, they were further divided into 17 types based on the position of the kitchen (Fig. 2). The percentage for each type for the ground floor is shown in Fig. 3. The figure shows that the highest percentages were for the corner type (70%) for the position of the entrance and atelier, and Type H (36%) for the position of the kitchen.
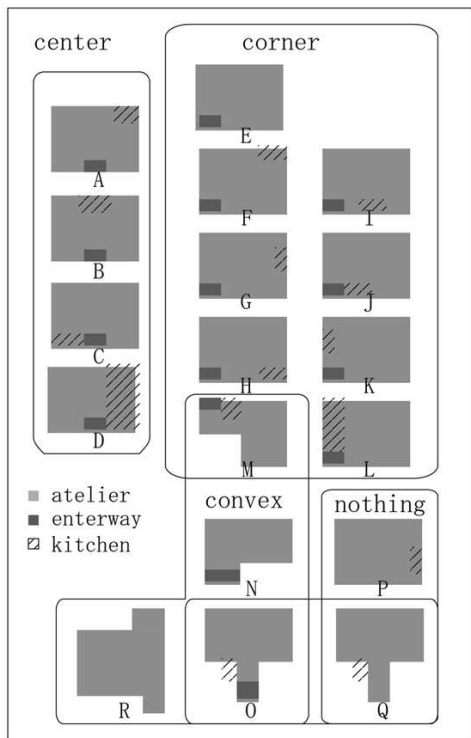
Figure 2: Type of layout (ground floor)
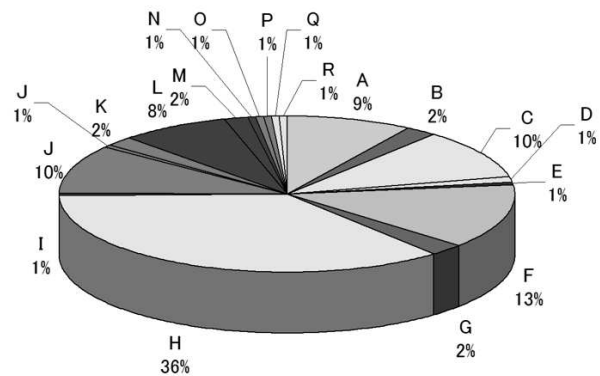
Figure 3: Percentage for each type (ground floor)

The drawings of the upstairs floor plan were divided into 13 types according to the position of the two rooms, stairs, and corridor (Fig. 4). The percentage for each type of upstairs plan is shown in Fig. 5. The figure shows that the highest percentage of students is for Type a (45%), which suggests that approximately half the subjects imagined the floor plan in the same way. We also note that the combined percentage of the top three types is greater than 75%, showing strong consistency.

3.2. Photograph selection

Figure 3.2 shows the percentage for each photograph chosen by the subjects. The highest percentages were for photographs No. 3 and No. 17 (Fig. 6), with a combined percentage of more than 50%, which suggests that approximately half of the subjects who read the paragraph obtained a similar image of the spatial layout of the house. Both photographs
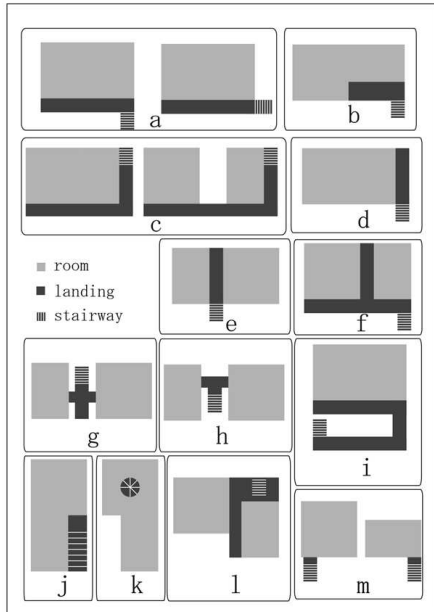
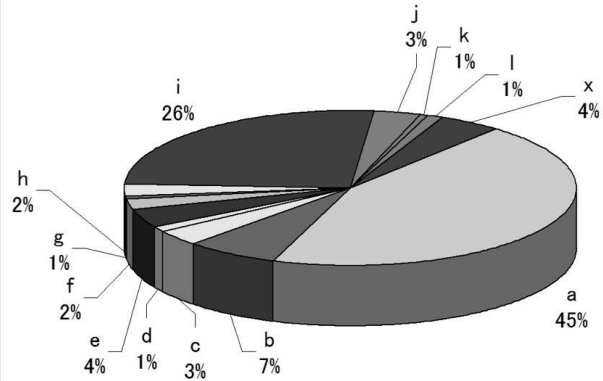Figure 4: Type of layout (upstairs)   Figure 5: Percentage for each type (upstairs)

show a stairway, and a few other objects in a large studio. They are, however, in different styles: No. 3 is traditional, whereas No. 17 is modern.

3.3. House shape

Sketches of the overall shape of the house shape were divided into 17 types by roof style and proportion of depth to width (Fig. 8). Figure 9 shows the percentage for each type of house shape. Type F obtained the highest percentage (34%). In addition, 67% of the chosen

Figure 6: Photographs No. 3 and No. 17   Figure 7: Photograph chosen (percentage)
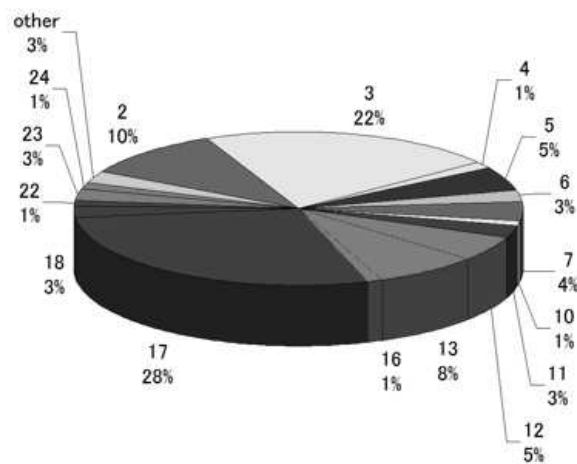
Figure 8: House shape types
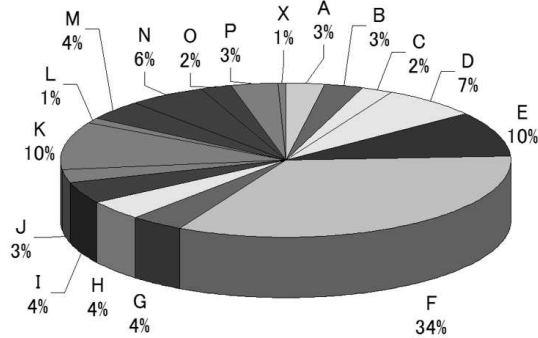
Figure 9: House shape percentages

sketches were the well-known gable-roof types (Type A – Type H). This indicates that it was imagined from the words, *'More than half of it consisted of a steep roof covered with red slate.'*

3.4. Inclusion of rooms not described

Some drawings contained rooms that were not described in the paragraph. We consider their presence in the four subtests.

3.4.1. Test A

Figure 10 shows the percentage of each room in the drawings. The dashed line separates the rooms described in the paragraph from those that were not. Undescribed rooms were
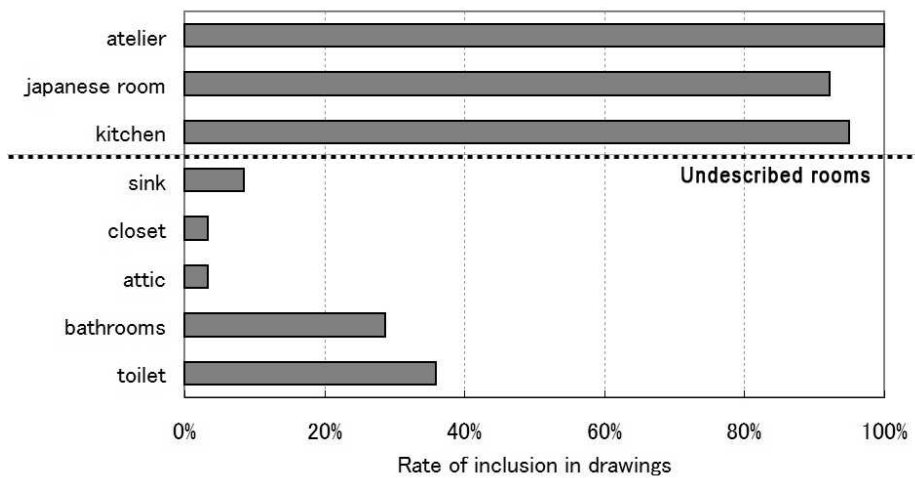
Figure 10: Percentage of drawings including various rooms (Test A)
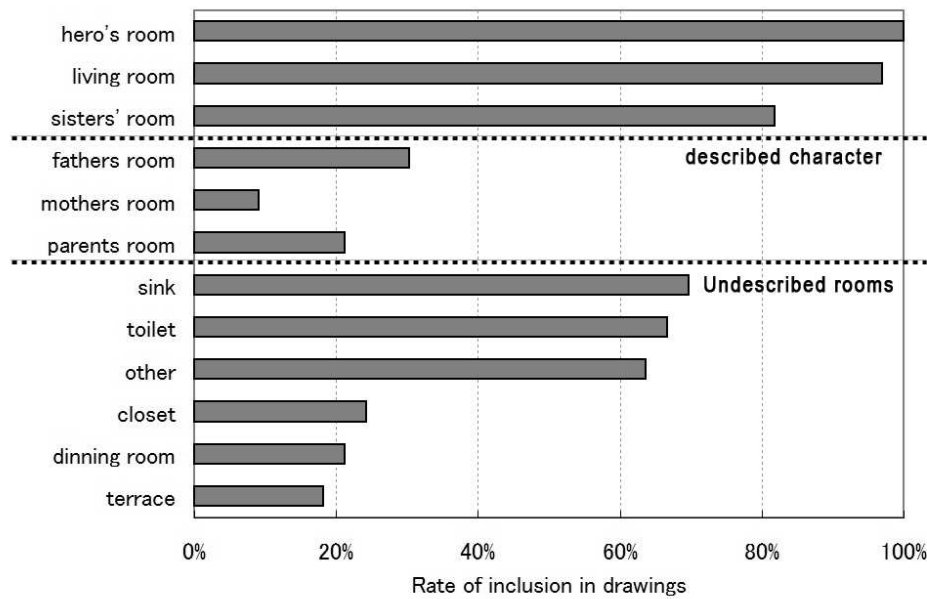
Figure 11: Percentage of drawings including various rooms (Test B)

included in the drawings; 37% of the drawings contained undescribed rooms that were toilets and 29% contained bathrooms.

3.4.2. Test B

Figure 11 shows the percentage of each room in the drawings for Test B. The two dashed lines divide the described rooms from the rooms of described characters, and then from the undescribed rooms. The only rooms clearly described in the paragraph were the hero's room and a living room. However, 70% of students drew nine kinds of rooms not described in the paragraph. 15–30% of the students included a room for one or more of three other characters who appear in the paragraph. Additionally, about 60% of the students drew various rooms for necessities, such as the sinks, bathrooms, and toilets.

3.4.3. Test C

The percentages of the inclusion of various rooms in the drawings for Test C are shown in Fig. 12. A dashed line divides the described rooms from the undescribed ones. The only rooms clearly described in the paragraph were two rooms and a tea arbor. Of the four tests, Test C had the lowest percentage of drawings that included the described rooms. This may indicate that the descriptions in the reading selection were not sufficiently accurate, which may be in part because the reading selection for Test C was the shortest of the four tests. However, 43% of students drew ten kinds of rooms that were not described in the paragraph. Approximately 46% included various necessities, such as an entrance hall, bathroom, or toilet.

3.4.4. Test D

The percentages of the rooms included in drawings for Test D are shown in Fig. 13. A dashed line divides the rooms described in the paragraph from those that are not. The rooms clearly described in the paragraph were an entrance hall, kitchen, living room, bedrooms, cellar, and
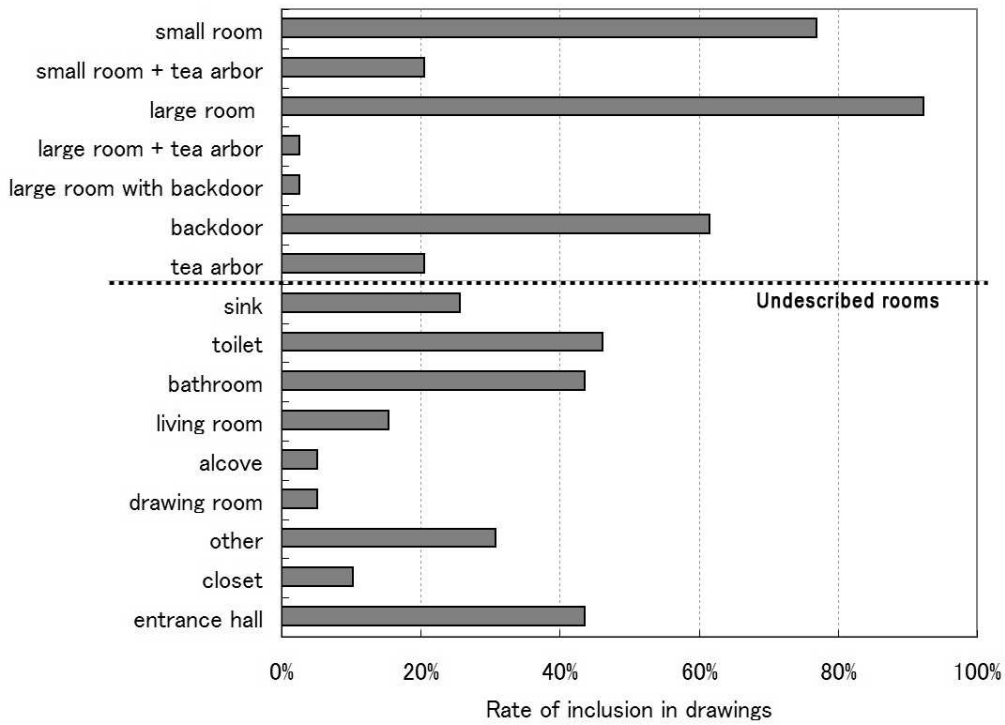
Figure 12: Percentage of drawings including various rooms (Test C)
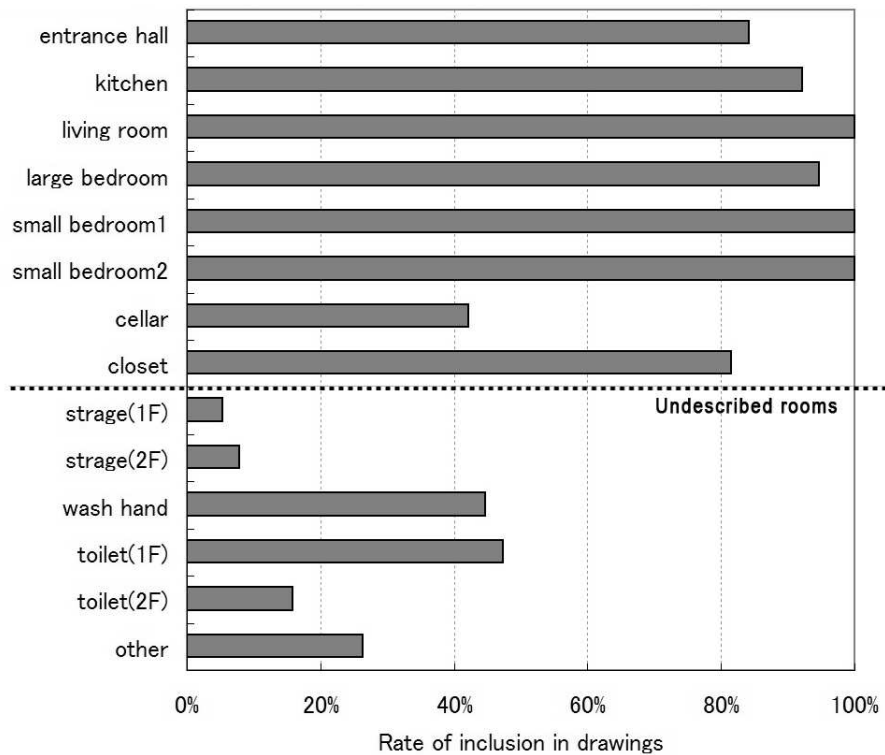

Figure 13: Percentage of drawings including various rooms (Test D)

closet. However, 47% of students drew four kinds rooms that were not described. Approximately 46% included various necessary rooms, such as a toilet and a sink. We conjecture that the students who drew the undescribed rooms imagined them more vividly than did the other students.

3.5. Corridor occupancy in the house

We focus on Tests B, C and D in the following analysis. The corridor occupancy is defined the percentage of corridor area to total floor area of the house. Figure 14 shows the relationship between the undescribed rooms and the corridor occupancy, for each subject. The number of undescribed rooms was calculated by subtracting the number of rooms described in the paragraph from the total number of rooms drawn. The correlations between the number of undescribed rooms and the corridor occupancy probability are shown in the table of Fig. 14. The corridor occupancy increases as the number of undescribed rooms increases in both Test B and Test D. Test B shows a significant correlation ($R = 0.398$, $P < 0.05$), while Test D does not. No other relationships were significant.

	Test B	Test C	Test D
average of corridor occupancy	21.3	24.1	16.3
average of number of undescribed rooms	4.1	1.2	1.7
correlation coefficient	0.398	−0.047	0.252
significant probability	0.024	0.800	0.128
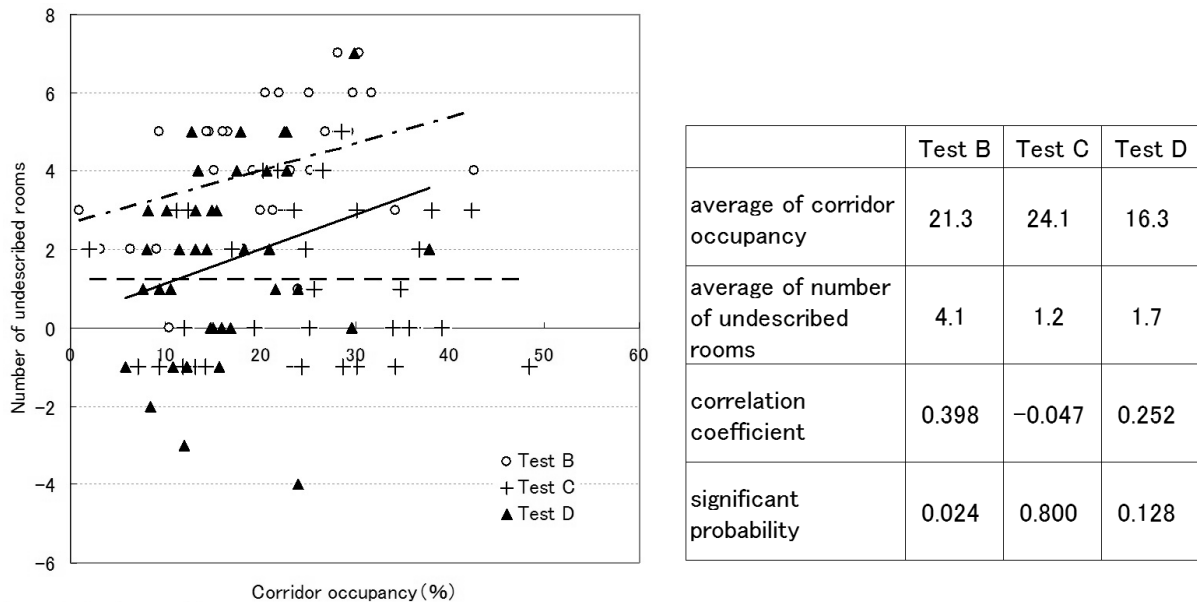
Figure 14: Corridor occupancy and undescribed rooms in each tests

3.6. Relationship between the MCT and the undescribed rooms

As shown in Table 2, the average scores of the MCT were higher for students who drew undescribed rooms than for those who did not. However, statistical analysis shows that there is no significant difference (5% level) between the groups. Therefore, this paper cannot demonstrate a relationship between spatial imagination ability (as measured by the SIT) and spatial ability (as measured by the MCT).

3.7. Relationship between the MCT and the number of vertices in the outer shape

Figure 15 shows the relationship between the number of vertices in the outer shape of the house and the MCT score for each subject. The number of vertices indicates the complexity

Table 2: Average score of MCT for students drawing undescribed rooms

undescribed room	none	one or more	significant difference
Test	Average score of MCT		
Test A	18.76	18.83	p>0.05
Test B	17.70	19.91	p>0.05
Test C	18.13	18.64	p>0.05
Test D	17.40	19.06	p>0.05

of the house plan. The right bottom table of Fig. 15 lists the means for each test and shows the relationship between the house plan vertices and MCT score. In Tests B and C, the number of vertices increased as the score of MCT decreased. The correlation coefficient is -0.35 ($P < 0.05$) in Test B and -0.42 ($P < 0.01$) in Test C. Test D did not show a significant relationship. These results suggest that the outer shape of the house tended to be simpler in students with higher MCT scores.

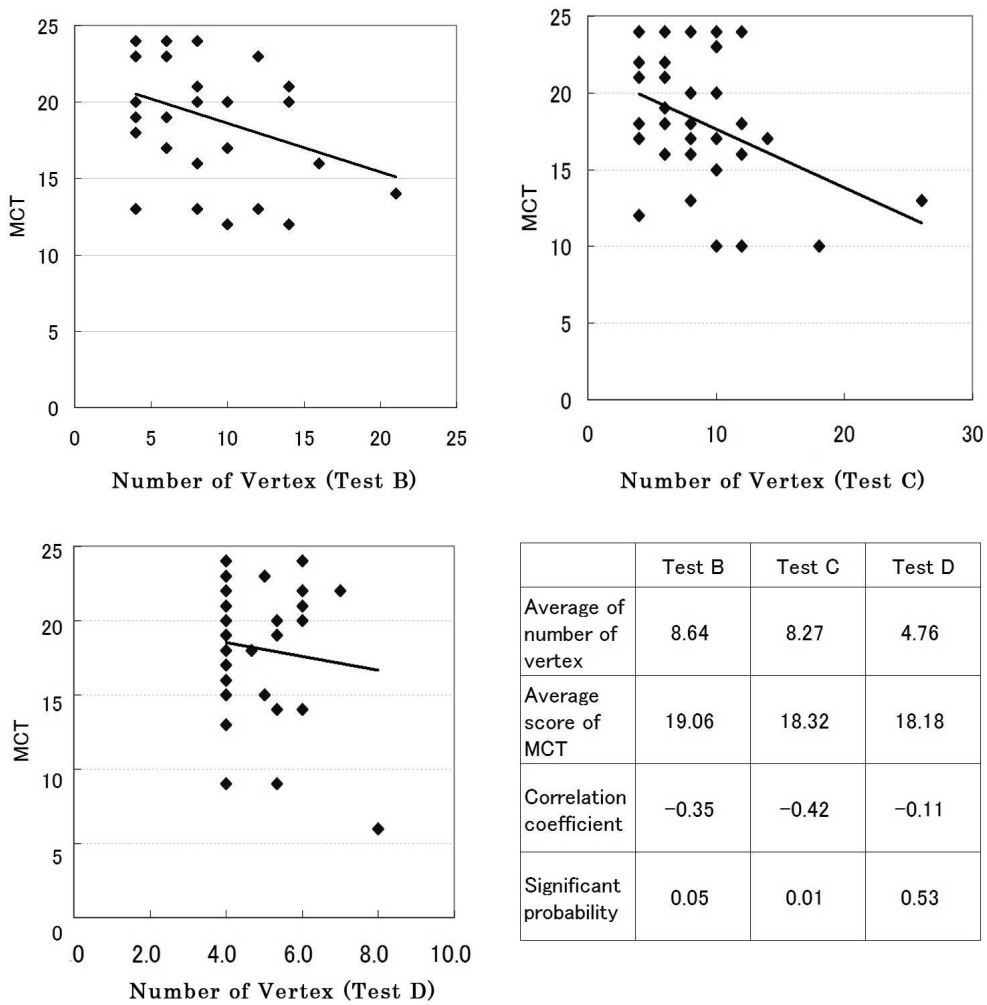|	Test B	Test C	Test D
Average of number of vertex	8.64	8.27	4.76
Average score of MCT	19.06	18.32	18.18
Correlation coefficient	−0.35	−0.42	−0.11
Significant probability	0.05	0.01	0.53

Figure 15: Number of vertices of the houses and Relationship between house vertices and the MCT scores

3.8. Architectural correspondence and the MCT

The architectural correspondence between the floor plan and the house sketch was investigated for 54 students who took Test B, C or D. The degree of the correspondence was classified into three levels: not adjusted, somewhat adjusted, and adjusted. The students who adjusted the architectural correspondence may have more clearly imagined the building described in the paragraph. The number of subjects with each degree of correspondence is presented in Table 3. On average, the MCT scores were higher for students who adjusted the architectural correspondence than for those who did not ($P < 0.05$).

Table 3: Architectural correspondence and average score of MCT

	Test B	Test C	Test D
Average of number of vertex	8.64	8.27	4.76
Average score of MCT	19.06	18.32	18.18
Correlation coefficient	−0.35	−0.42	−0.11
Significant probability	0.05	0.01	0.53

4. Conclusion

In this report, the Spatial Imagination Test (SIT) was developed and used to examine the ability of a person to imagine a scene that is described in a paragraph. The results are as follows.

1. Approximately half of the subjects who read the paragraph obtained a similar image for the spatial layout of the house. However, their designs had different styles.

2. Drawings of over 35% contained rooms that were not described in the paragraph. The majority of the undescribed rooms were sinks, bathrooms, and toilets; all of which are ordinary necessities.

3. The number of characters in the reading selection influenced the accuracy of the readers' imagination, as measured by the number of described rooms in the drawings.

4. Corridor occupancy increased as the number of undescribed rooms increased, in two tests out of three. Test B showed a significant correlation. No other relationships were significant.

5. The average scores of the MCT were higher for students who drew undescribed rooms than for those who did not. However, statistical analysis showed that there was no significant difference (5% level) between the groups.

6. An analysis of the number of vertices on the houses that were drawn suggests that the outer shape of the houses tended to be simpler for students with higher MCT scores.

7. On average, the MCT scores were higher for students who adjusted the architectural correspondence between the outer shape and the floor plan.

This paper identified some characteristics of the spatial imagination ability of readers. The influence of the author's descriptiveness and differences in the students' ability to visualize will be the subject of our further research.

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