

Mental Model Construction Process and the Time Variation

Toahiki Yamaoka

Faculty of Home Economics
 Kyoto Women's University
 Kyoto city, Japan
 Email: tyamaoka6@gmail.com

Abstract— The purpose of this study is to grasp temporal characteristics of the structural and functional models of a mental model. The temporal characteristics were examined from a viewpoint of thinking and memorizing. Tests were performed using wooden blocks. As a result, it was determined that the structural model is useful for constructing mental models; understanding only the functional models is not enough. For example, when the structural model is shown at first in an operational screen or user manual, users can understand the structure of the products or systems quickly and can operate them easily.

Keywords - mental model; construction process; time variation.

I. INTRODUCTION

Studies regarding temporal characteristics of mental models have not been addressed in previous studies [1][2]. As operational screens or user manuals of products become complicated and difficult to understand, a study of the temporal characteristics of mental models is very important. After users operate a product, such as a wi-fi router which is not familiar, they cannot usually memorize how to operate it because of temporal transition.

Mental models are important factors for users to successfully use products or systems. The mental model is defined as a system image in this paper. However, designers and engineers cannot understand how to design with mental models. The mental model consists of structural models and functional models. Structural models refer to how products or systems work and functional models refer to how to use the products and systems. The structural model shows the structure of products or systems, and the functional model shows the procedure of operation [3]-[8].

The provision of information in the structural models and functional models was examined in this study. The study details are described next. Participants were asked to construct blocks three times because of memorizing the final shape of the blocks.

- 1) Participants were showed information regarding the structural model (Section II).
- 2) Participants were showed information regarding the functional model first, followed by the structural model (Section III).
- 3) Participants were showed information regarding the functional model (Section IV).
- 4) Participants were showed the information regarding the structural model first, followed by the functional model (Section V).

The structural model, functional model and the combination of them can be evaluated by constructing the blocks without instructions.

The common information of the method is described as follows. 21 participants labelled from “A” to “U” participated in the studies. Only one participant answered only one task. The participants were students of Kyoto Women’s University in Kyoto and not trained for the test. The tests were performed to determine the role of structural models and functional models in the memorization of a mental model. As memorizing two times is insufficient to memorize complicated structures and the order of constructing wooden blocks, a task was done three times in order to fully memorize the structure and the order of building the structure [9]. The number of successfully completed shapes constructed from wooden blocks was evaluated.

II. STUDY 1

Participants were shown the information regarding the structural model of the object.

A. Method

Five participants were asked to construct wooden blocks such as cubes, rectangles, etc. The participants were students of Kyoto Women’s University and ranged in age from 21 to 24 years. The participants constructed a final shape according to the following instructions.

- 1) The first time, participants were shown the whole picture (the final shape) of the combination of cubes and rectangles (see Figure 1). They were then asked to construct the final shape showing the whole picture using wooden blocks.
- 2) The second time, the entire procedure in step 1) was repeated.
- 3) The third time, the entire procedure in step 1) was repeated once more.
- 4) The fourth time, participants were asked to construct the final shape without showing them the final shape first.

Five days later, they were asked to construct the final shape without any information.

B. Results and discussion

The five participants were able to construct the final shape (see Table I). Five days later, three participants could construct the final shape (see Table II). As the time to complete the final shape varied, Tables II, IV, VI, and VIII

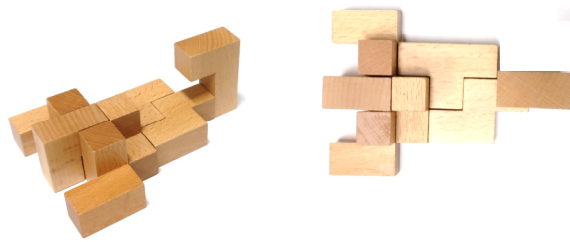


Figure 1. The whole picture of shape.

TABLE I. RESULTS ON THE FIRST DAY

First day				
Participant	First time	Second time	Third time	Fourth time
	Constructing the blocks according the whole picture each time			No instruction
A	S	S	S	S
B	S	S	S	S
C	S	S	S	S
D	S	S	S	S
E	S	S	S	S
Average time (sec)	144	28	29	23

S: Success, F: Failure

TABLE II. RESULTS FIVE DAYS LATER

Five days later					
Participant	A	B	C	D	E
No instructions	S	F	F	S	S

S: Success, F: Failure

do not show the average time. Showing the whole picture (final picture) means providing a structural model of the mental model.

The results show that the structural model seems to be useful for constructing a mental model. After the participants took time to construct the wooden shape at first, they could put together the blocks easily because they had constructed the mental model (see Table I). As the structural model can make participants think according to these results, they can memorize by cue of thinking.

III. STUDY 2

Participants were shown information regarding the functional model first, and then the structural model.

A. Method

Six participants were asked to construct wooden blocks such as cubes, rectangles, etc. The participants were students of Kyoto Women’s University and ranged in age from 21 to 22 years.

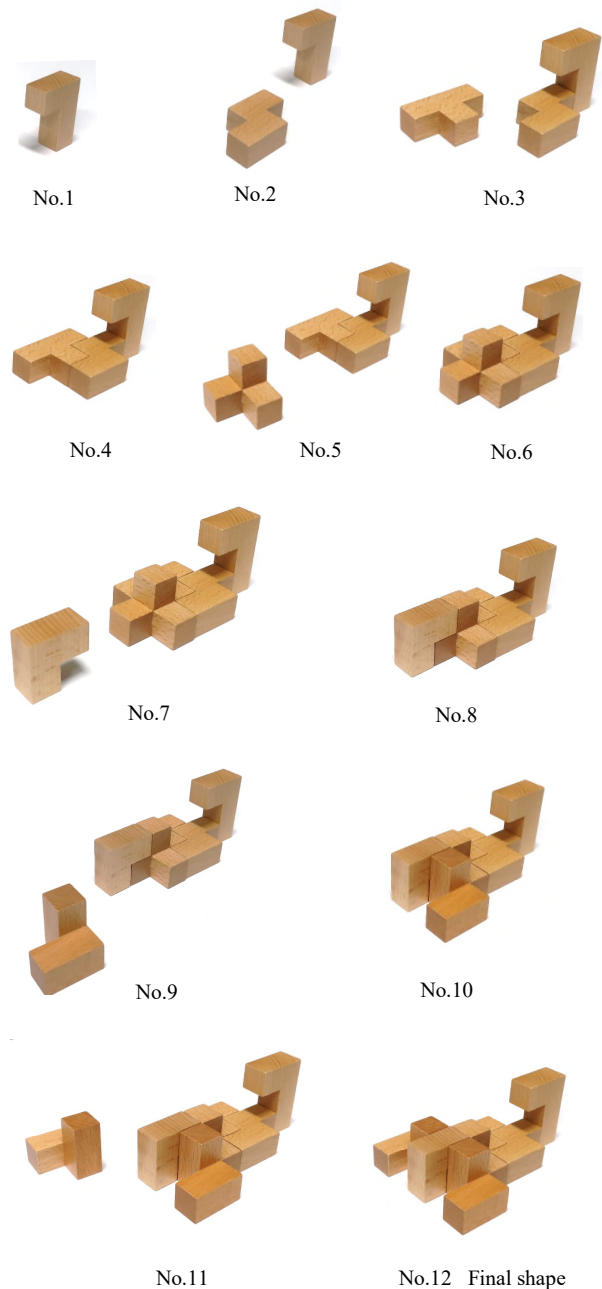


Figure 2. The shapes presented in order.

1) The first time, the participants were shown a part of the whole picture (final shape) combined of cubes and rectangles, in order. They constructed using the wooden blocks in order and completed the final shape (see Figure 2.)

2) The second time, the entire procedure in step 1) was repeated.

3) The third time, the participants were showed the whole picture of the combined cubes, rectangles etc. They

were asked to construct the final shape shown in the whole picture using wooden blocks.

4) The fourth time, they were asked to construct the final shape without showing the final shape first.

Five days later, they were asked to construct the final shape without any information.

B. Results and discussion

Three participants were able to construct the final shape. Five days later, two participants were able to construct the final shape.

TABLE III. RESULTS ON THE FIRST DAY

First day				
Participant	First time	Second time	Third time	Fourth time
	The parts of whole picture presented in order (Figure 2.)		The whole picture	No instruction
F	S	S	S	S
G	S	S	S	S
H	S	S	F	F
I	S	S	F	F
J	S	S	S	S
K	S	S	S	F
Average time (sec)	77	37	68	176

The whole picture: Constructing the blocks according to the whole picture. S: Success, F: Failure

TABLE IV. RESULTS FIVE DAYS LATER OF SIX PARTICIPANTS

Five days later						
Participant	F	G	H	I	J	K
No instructions	F	S	F	F	S	F

S: Success, F: Failure

Showing the parts of the whole picture presented in order means providing the functional model, while showing the whole picture (final shape) means the structural model (see Tables III and IV). The participants seem to be able to get the mental model by showing the whole picture which means the structural model compared with the results of study 2.

IV. STUDY 3

Participants were shown information regarding the functional model.

A. Method

Five participants were asked to construct the model using wooden blocks such as cubes, rectangles etc. The participants were students of Kyoto Women’s University and ranged in age from 21 to 24 years.

1) The first time, the participants were shown a part of the final picture in order to combine the cubes, rectangles and so on. They put together the wooden blocks in order and completed the final shape.

2) The second time, the entire procedure in step 1) was repeated.

3) The third time, the entire procedure in step 1) was repeated once more.

4) The fourth time, they constructed the final shape without being shown the final shape first.

Five days later, the participants were asked to construct the final shape without any information.

B. Results and discussion

Only one participant could construct the final shape (see Table V). Five days later, only the same participant could construct the final shape (see Table VI). The procedure to construct blocks according to the functional model is difficult and does not successfully allow the users to make a mental model.

The structural model seems to be useful for users to understand the structure or function of systems according to the results of studies 1 and 2.

TABLE V. RESULTS ON THE FIRST DAY

First day				
Participant	First time	Second time	Third time	Fourth time
	The parts of whole picture presented in order (figure 2.)			No instruction
L	S	S	S	F
M	S	S	S	F
N	S	S	S	F
O	S	S	S	S
P	S	S	S	F
Average time (sec)	64	37	32	22

S: Success, F: Failure

TABLE VI. RESULTS FIVE DAYS LATER OF FIVE PARTICIPANTS

Five days later					
Participant	L	M	N	O	P
No instructions	F	F	F	S	F

S: Success, F: Failure

V. STUDY 4

Participants were shown information regarding the structural model first, followed by the functional model.

A. Method

Five participants were asked to construct a shape using wooden blocks such as cubes, rectangles, and so on. The

participants were students of Kyoto Women’s University and ranged in age from 21 to 24 years.

1) The first time, participants were shown combined parts of the final picture, in order. They then constructed combined wooden blocks, in order, and completed the final shape.

2) The second time, the procedure in step 1) was repeated.

3) The third time, the participants were shown the final constructed object. They then constructed the final shape shown using the combined wooden blocks.

4) The fourth time, they constructed the final shape without being shown the final shape first.

Five days later, the participants were asked to construct the final shape without any information.

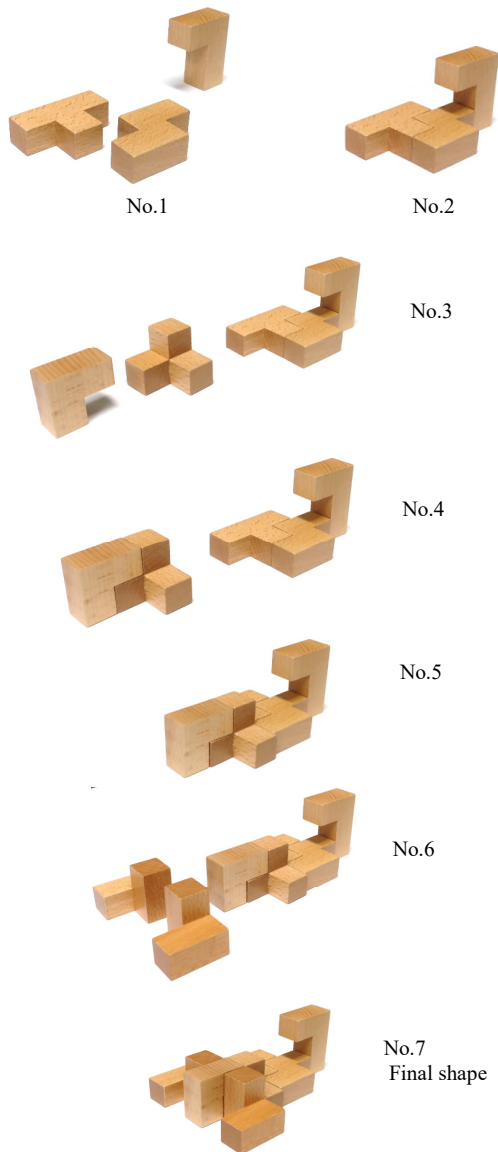


Figure 3. The grouped shapes presented in order.

B. Results and discussion

Four participants were able to construct the final shape (see Table VII). Five days later, only two participants were able to construct the final shape (see Table VIII).

The grouped parts of the whole picture presented in order represent both the functional model and the partial structural model. Since the procedure for users to read and understand each part and structure of the final shape was difficult, the idea to present one unit with some combined blocks seems to be useful. The structural model seems to be useful for users to understand the structure or function of systems according to the results of studies 1, 2 and 3.

TABLE VII. RESULTS ON THE FIRST DAY

First day				
Participant	First time	Second time	Third time	Fourth time
		The grouped parts of the whole picture presented in order (Figure 3.)		The whole picture
Q	S	S	S	S
R	S	S	S	S
S	S	S	S	S
T	S	S	S	F
U	S	S	S	S
Average time (sec)	51	27	61	40

The average time is calculated based on the data of participants Q,R,T and U.

TABLE VIII. RESULTS FIVE DAYS LATER

Five days later					
Participant	Q	R	S	T	U
No instruction	F	F	S	F	S

S: Success, F: Failure

VI. DISCUSSION

The tasks evaluated in each study are presented in Figure 4. Showing the grouped parts of the whole picture presented in order represents the functional model and structural model. Showing the parts of the whole picture presented in order represents the functional model. Constructing the blocks according to the whole picture each time represents the structural model.

For the no instructions cases, Table IX shows the relationship between the structural model and the functional model to verify the results of the cases with no instruction on the first day and five days later.

The structural model influenced the construction of the mental model according to Table IX. The structural model easily allows users to memorize the structure according to the results of the four studies. So, the structural model is an

important factor in constructing mental models. After we understand the structure or frame of systems, we can understand the substance of systems. Or, we can understand the substance of systems based on the context created by the functional model. The context can help users to convey the information of the system structure. Context helps users un-

TABLE IX. THE RELATIONSHIP BETWEEN STRUCTURAL MODEL AND FUNCTIONAL MODEL FOR VERIFICATION OF NO INSTRUCTIONS

	First day			Five days later
	Structural model	Functional model	Validity for no instruction	Validity for no instruction
Study 1	✓	---	100%	60%
Study 2	✓	✓	60%	33%
Study 3	---	✓	20%	20%
Study 4	✓	✓	80%	40%

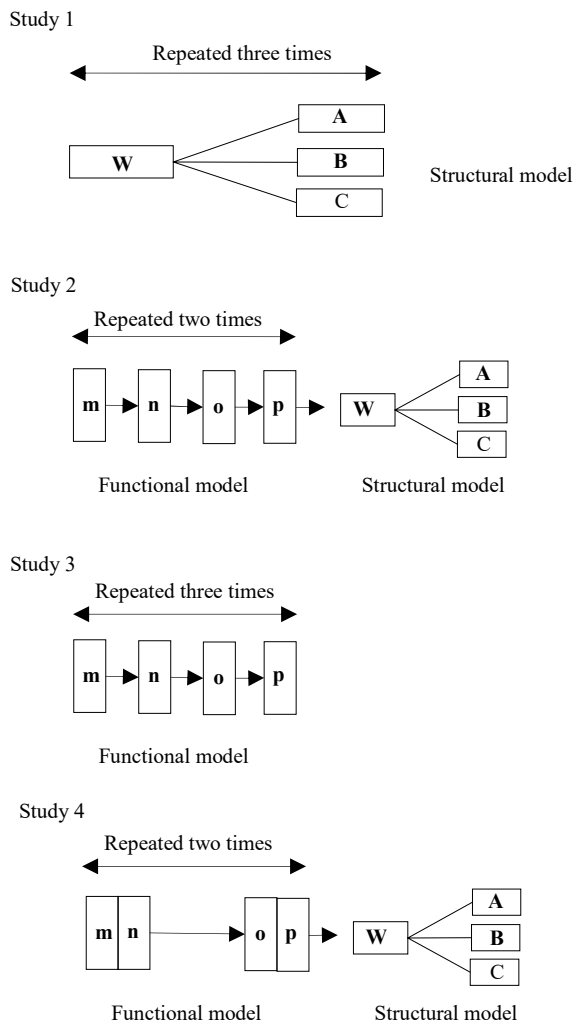


Figure 4. Study structure from study 1 to study 4.

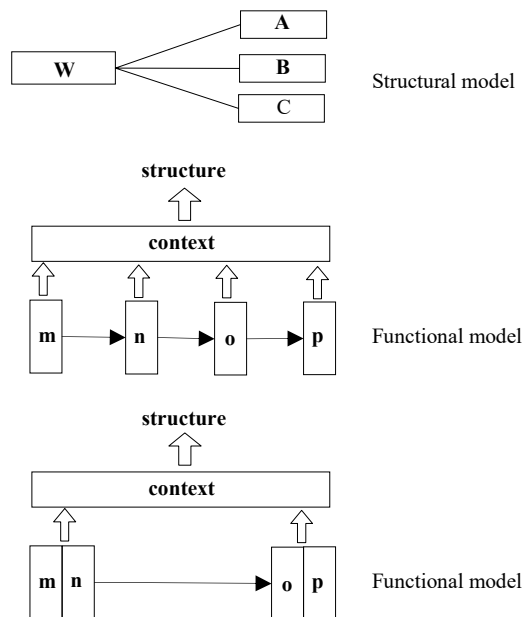


Figure 5. Relationship between structural model and functional model

derstand and memorize the structure of systems (see Figure 5.). Usually, the functional model causes trial and error to be used and creates the context as a result.

When we read sentences in operational manuals to understand the operating procedure, we normally cannot memorize the content. This shows why the three participants in study 3 could not memorize. The reason participants in study 3 were not able to memorize and construct the blocks is because there was no context with the story which showed that the final shape was a scorpion.

Providing opportunities to think about system structure is very important for users. When the participants tried to look at the final shape in study 1, they were able to understand the system structure. Understanding the system structure means grasping the relationship among the parts of the system. They thought about the structure and were then able to memorize it. If the final shape was announced as a scorpion, some participants seem to be able to construct it easier because of a general idea of name which contains the shape and the function.

VII. CONCLUSION

Thinking about the structure is very important to construct the mental model. Operating according to the procedure without thinking about the structure, such as the examples found in operational manuals, seems not to be sufficient.

The conclusions based on the four studies are as follows.

- (1) The structural model is useful for constructing a mental model.

(2) While functional models can create context using a story or other elements, they are also useful for constructing a mental model.

(3) Providing opportunities to think about the system structure is very important for users. Participants could not think or imagine the structure of the whole image (final shape) when they were using and understanding only the functional model.

(4) When the structural model was shown at first in the operational screen or user manual, users could easily understand the structure of products or systems and could easily operate them.

As user experience becomes an important factor to design products or systems, the mental model should be studied from the viewpoint of not only structural model and functional model, but also user experience.

ACKNOWLEDGMENTS

This work was supported by JSPS Kakenhi Grant number JP17K00739.

REFERENCES

[1] T. Yamaoka, "Examining the change of mental model from a viewpoint of time base and evaluation", The 4th International Conference on Ambient Intelligence and Ergonomics in Asia, October, 2019.

[2] L. Westbrook, "Mental models: A theoretical overview and preliminary study," *Journal of Information Science*, issue 6, vol. 32, pp. 563-579, 2006.

[3] J. Precece, Y. Rogers, H. Sharp, D. Benyon, S. Holland, and T. Carey, *Human-Computer Interaction*, Addison-Wesley, pp. 130-139, 1994.

[4] T. Yamaoka, "A basic consideration of evaluation method and construction model of mental model, " The 7th international conference on Kansei Engineering & Emotion Research (KEER2018), Kuching, Malaysia, 2018.

[5] T. Doi, "Mental model formation in user with high and low comprehension of a graphical user interface", *Journal of Human Ergology*, no.1, vol. 48, pp. 9-24, 2019.

[6] R. S. Bridger, *Introduction to Ergonomics*, third edition, pp. 554-557, CRC Press, 2009.

[7] J. P. Stephen, *The Human-Computer Interaction handbook*, pp. 63-75, CRC Press, 2008.

[8] C. D. Wickens, S. E. Gordon, Y. Liu, *An introduction of Human Factors Engineering*, Addison-Wesley Educational Publishers, p. 202, 1998.

[9] N. Katagiri, M. Hanatani, and T. Yamaoka, "Examining effective methods for constructing mental model," The 4th International Conference on Ambient Intelligence and Ergonomics in Asia, October, 2019.