

Article title:

Mental Model Construction Process and the Time Variation

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Education

*He received B.Eing degree in industrial design from National Chiba University in 1971 and Ph.D. degree in Ergonomics from National Chiba University in 1991.

Work experience

His speciality is Design and Ergonomics (CPEJ).

1971---1998

*Worked for Toshiba Corporation as Designer and Ergonomist.

*He was a member of ISO/TC159(Ergonomics).

1998---2014

He joined National Wakayama University as a professor of design and ergonomics.

*Emeritus professor of Wakayama University

2014---

Now he is working for Kyoto Women's University as a professor of design and ergonomics.

The topics of research

My interesting study is as follows.

1. **Cognitive Ergonomics**

a) Mental Model

The study has been supported economically by Japanese government.

b) Human Computer Interaction

c) Usability I've proposed usability methods.

d) UX (User experience)

e) System methodology

2. **Design**

a) Service design

b) User interface design

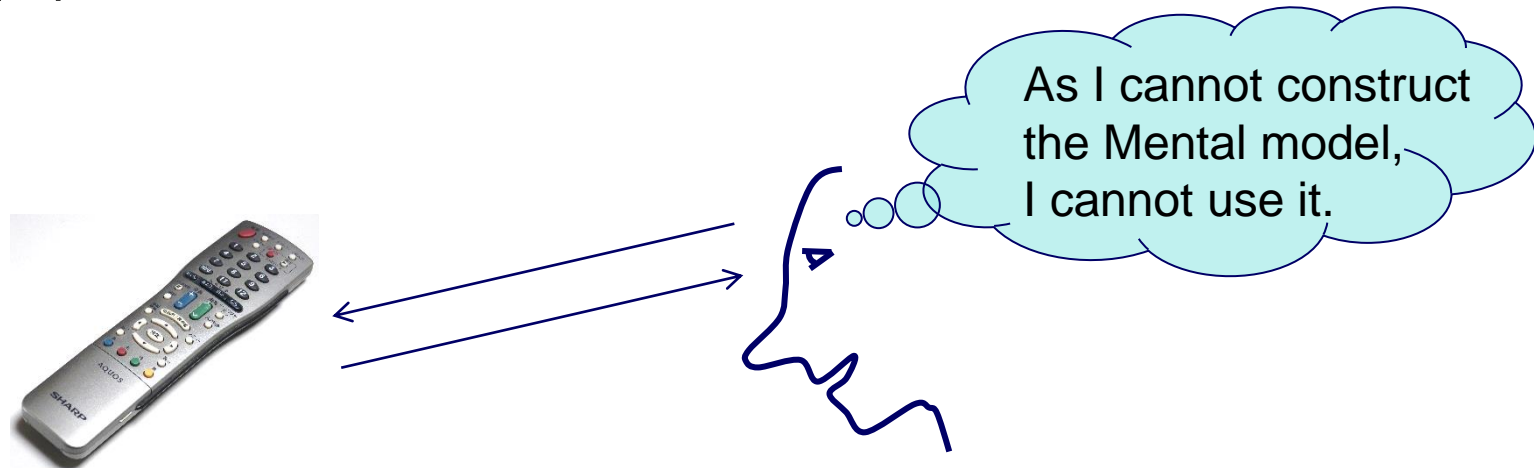
c) Universal design (Design for all, Inclusive design), Barrier free design

Introduction

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.

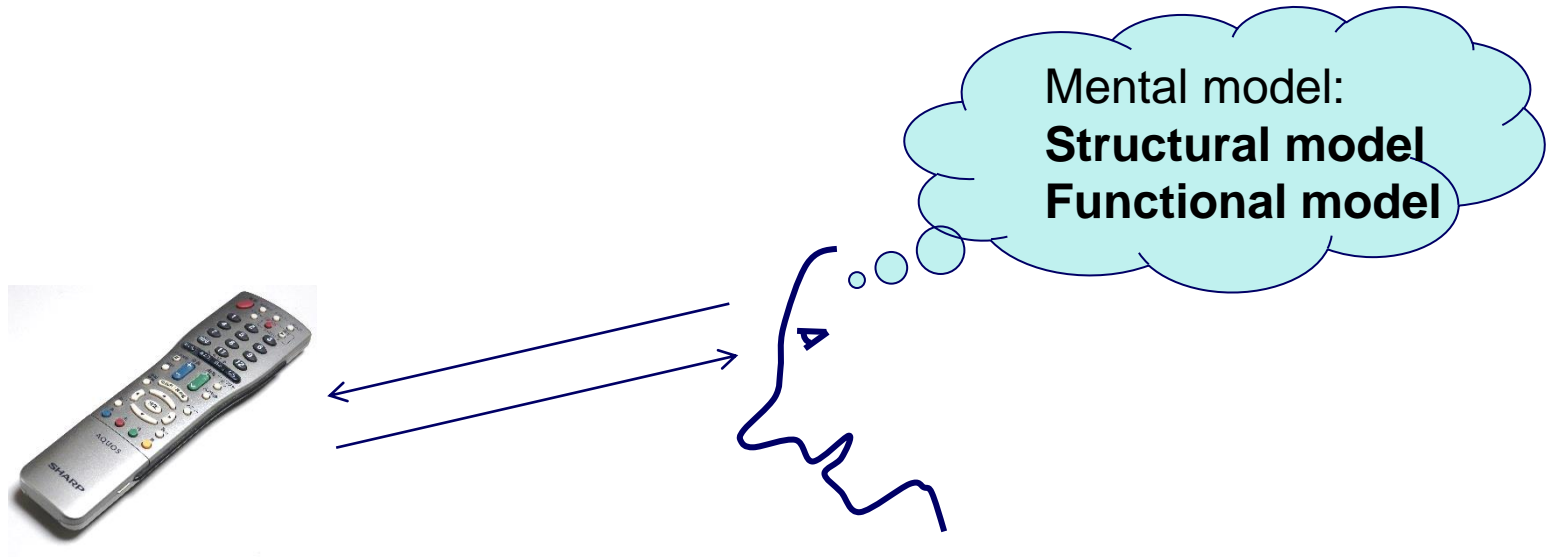


Introduction

The mental model consists of structural models and functional models.

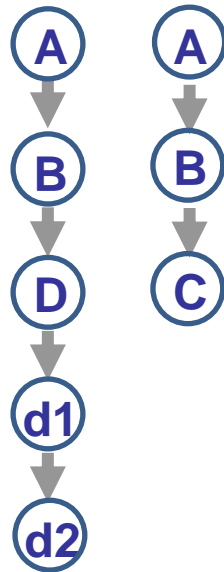
Structural models refer to how products or systems work and functional models refer to how to use the products and systems.

The **structural model** shows the structure of products or systems, and the **functional model** shows the procedure of operation.



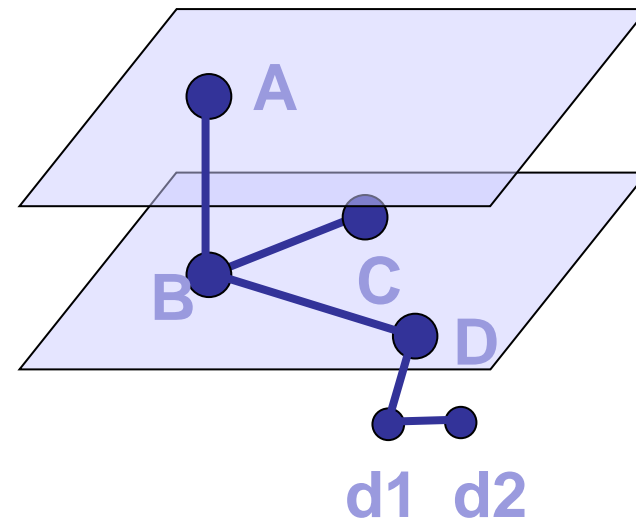
Introduction

Mental model



Functional model

Functional model:
the procedure of operation



Structural model

Structural model:
structure of products or systems

Introduction

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** (Study 1).
- 2) Participants were showed information regarding **the functional model** first, followed by **the structural model** (Study 2).
- 3) Participants were showed information regarding **the functional model** (Study 3).
- 4) Participants were showed the information regarding **the structural model** first, followed by **the functional model** (Study 4).

Study1

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

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.

Study1

- 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.

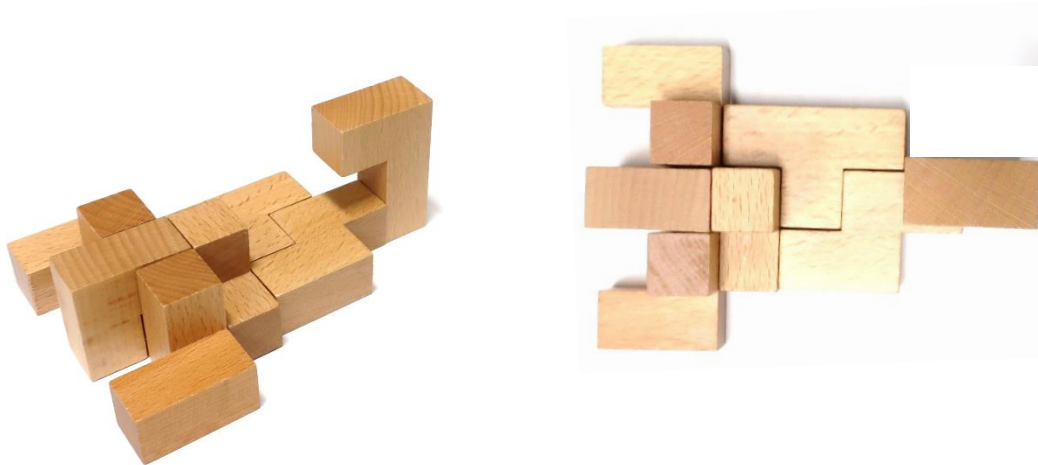


Figure 1. The whole picture of shape.

Study1

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 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.

Study1

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 (Structural model)			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

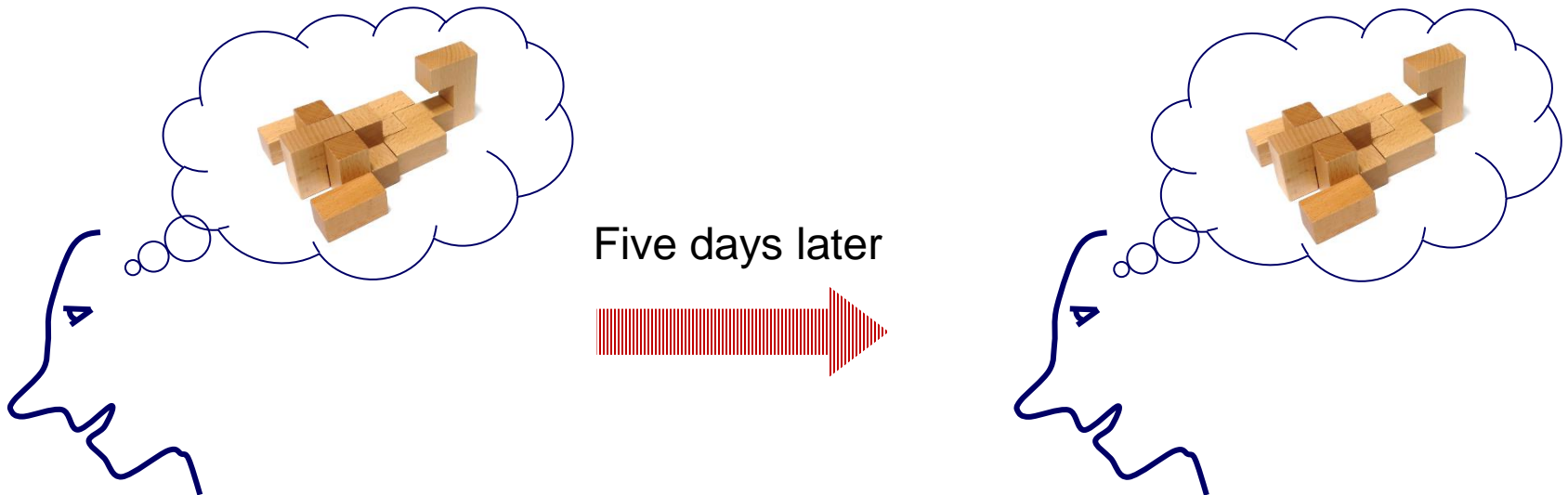
Study1

TABLE II. RESULTS FIVE DAYS LATER

Five days later					
<i>Participant</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
No instructions	S	F	F	S	S

S: Success, F: Failure

Success : three in five participants



Study2

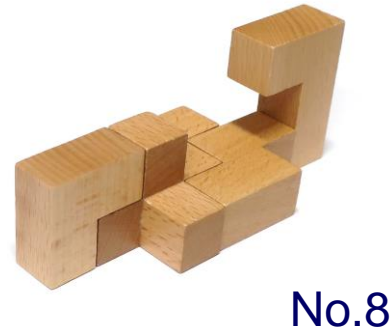
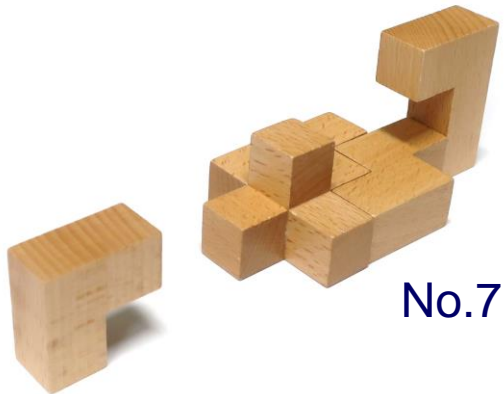
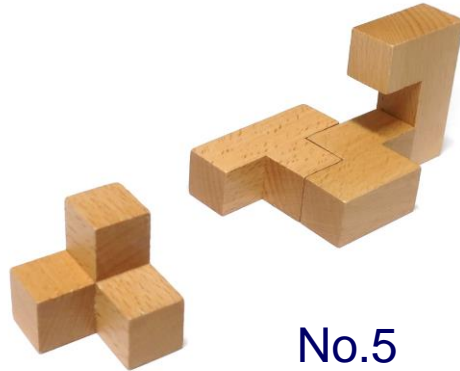
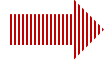
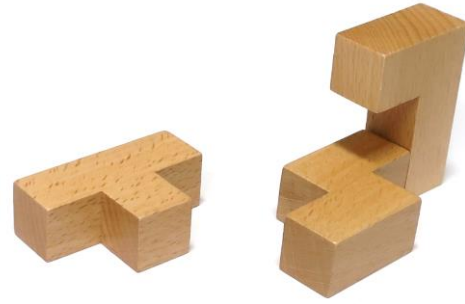
Participants were shown information regarding the functional model first, and then the structural model.

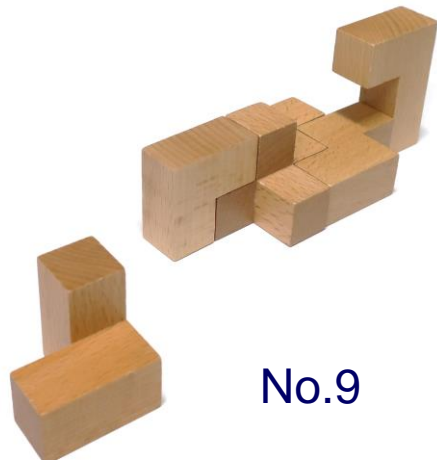
Method

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.

- 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.
- 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.

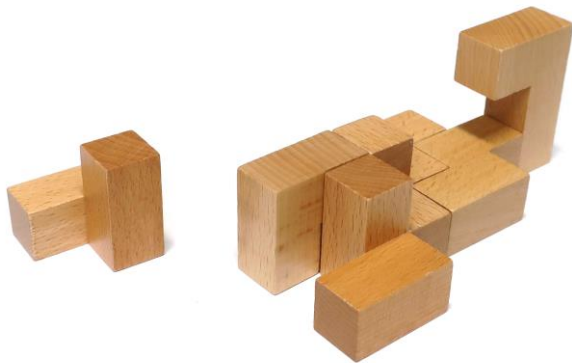




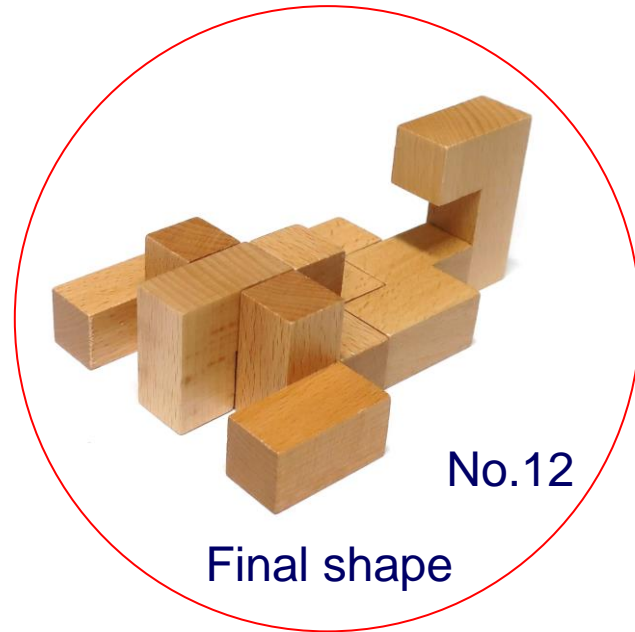
No.9



No.10



No.11



No.12

Final shape

Figure 2. The shapes presented in order

Study2

Results and discussion

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

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.

Study2

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.) (Functional model)		The whole picture (Structural model)	No instruction
<i>F</i>	S	S	S	S
<i>G</i>	S	S	S	S
<i>H</i>	S	S	F	F
<i>I</i>	S	S	F	F
<i>J</i>	S	S	S	S
<i>K</i>	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

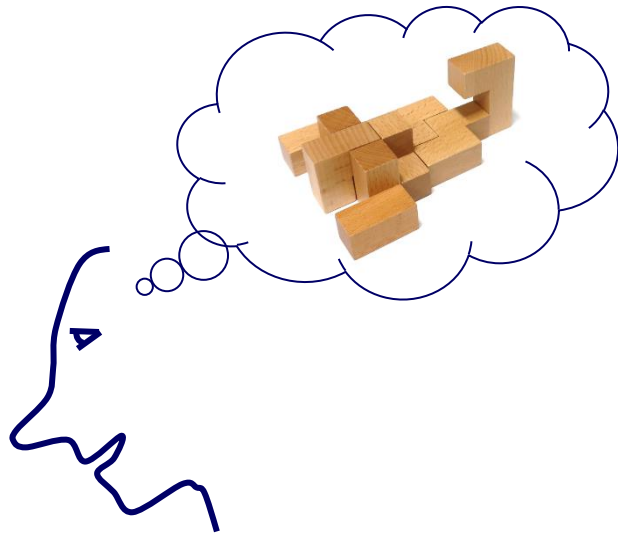
Study2

TABLE IV. RESULTS FIVE DAYS LATER OF SIX PARTICIPANTS

Five days later						
<i>Participant</i>	<i>F</i>	<i>G</i>	<i>H</i>	<i>I</i>	<i>J</i>	<i>K</i>
No instructions	F	S	F	F	S	F

S: Success, F: Failure

Failure : Four in six participants



Five days later



Study3

Participants were shown information regarding the functional model.

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.

Study3

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.

Study3

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.) (Functional model)		
<i>L</i>	S	S	S	F
<i>M</i>	S	S	S	F
<i>N</i>	S	S	S	F
<i>O</i>	S	S	S	S
<i>P</i>	S	S	S	F
Average time (sec)	64	37	32	22

S: Success, F: Failure

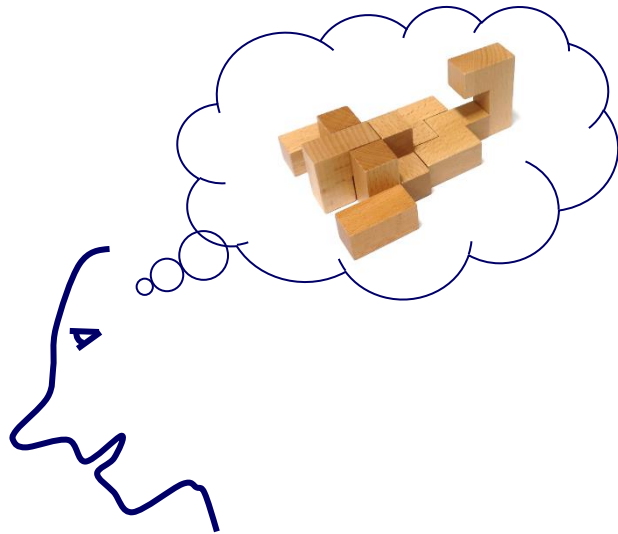
Study3

TABLE VI. RESULTS FIVE DAYS LATER OF FIVE PARTICIPANTS

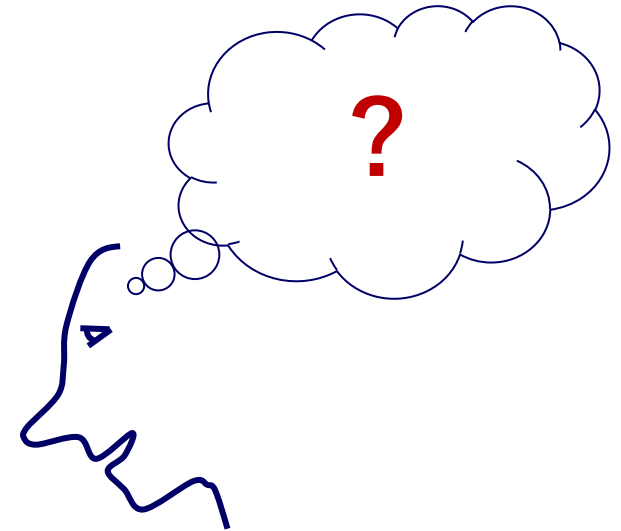
Five days later					
<i>Participant</i>	<i>L</i>	<i>M</i>	<i>N</i>	<i>O</i>	<i>P</i>
No instructions	F	F	F	S	F

S: Success, F: Failure

Failure : Four in five participants



Five days later



Study4

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

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.

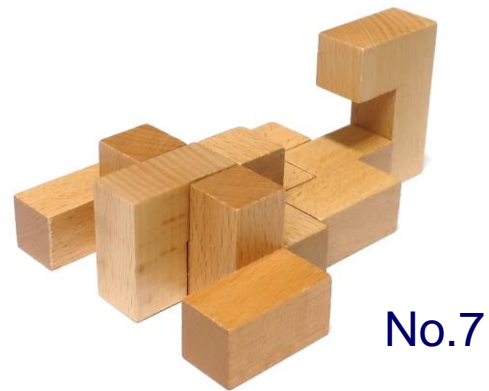
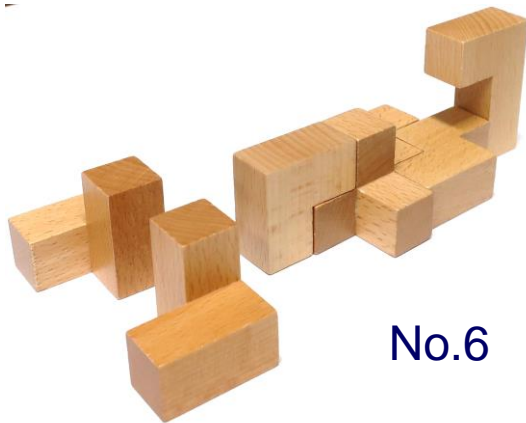
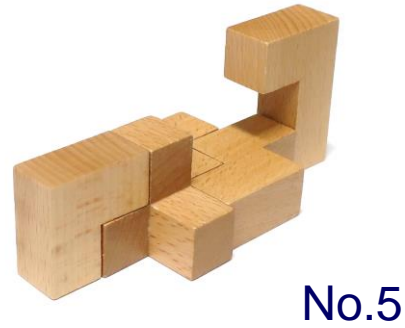
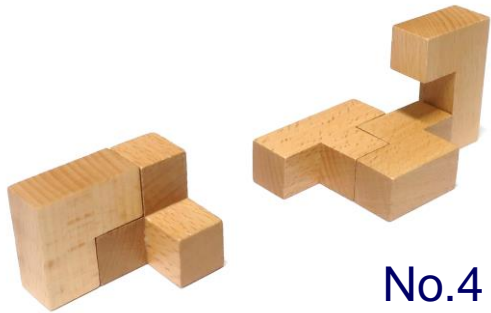
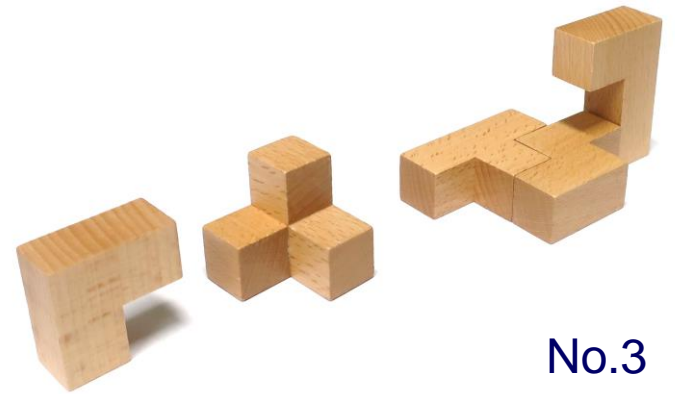
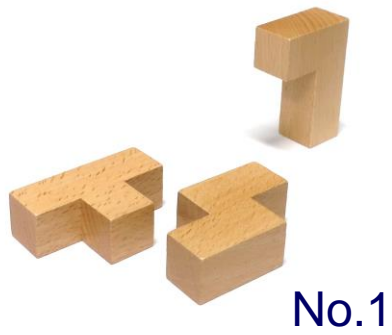
4) The fourth time, they constructed the final shape without being shown the final shape first.

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

Study4

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.



Study4

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.) (Functional model)		The whole picture (Structural model)	No instruction
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.

S: Success, F: Failure

Study4

TABLE VIII. RESULTS FIVE DAYS LATER

Five days later					
<i>Participant</i>	<i>Q</i>	<i>R</i>	<i>S</i>	<i>T</i>	<i>U</i>
No instruction	F	F	S	F	S

S: Success, F: Failure

Failure : three in five participants

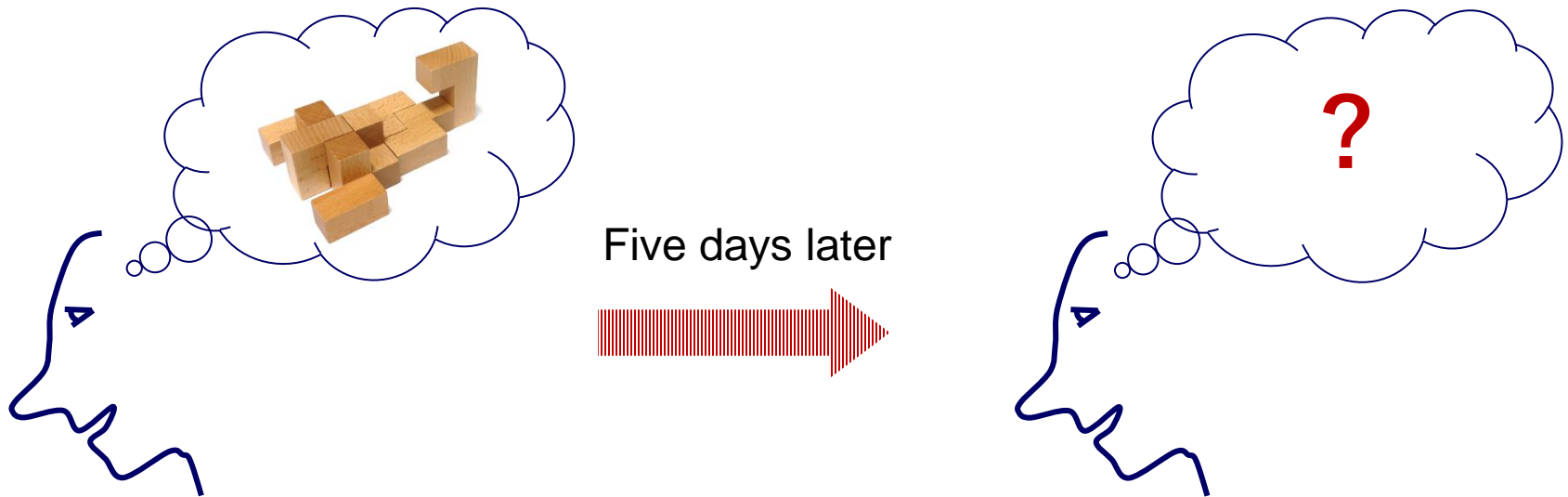


TABLE IX. THE RELATIONSHIP BETWEEN STRUCTURAL MODEL AND FUNCTIONAL MODEL FOR VERIFICATION OF NO INSTRUCTIONS

	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%

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.

TABLE X. Study structure from study 1 to study 4

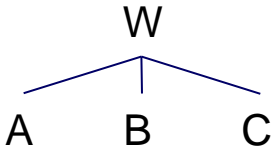
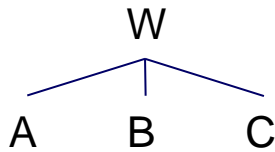
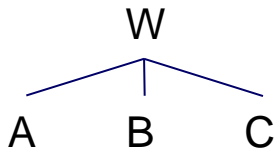
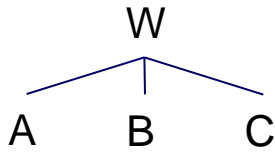
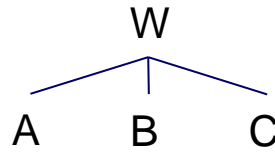
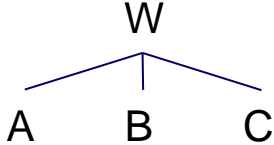
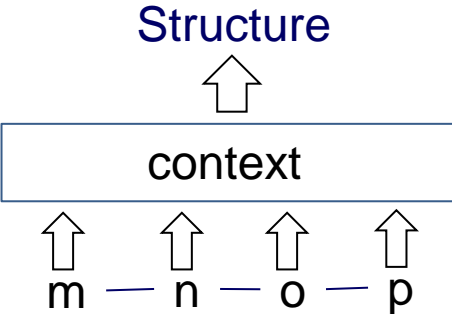
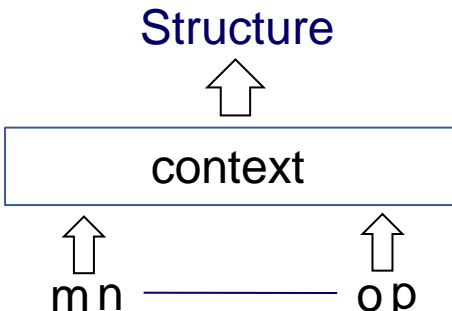
	First time	Second time	Third time
Study 1	Structural model 	Structural model 	Structural model 
Study 2	Functional model m — n — o — p	Functional model m — n — o — p	Structural model 
Study 3	Functional model m — n — o — p	Functional model m — n — o — p	Functional model m — n — o — p
Study 4	Functional model mn — op The grouped parts of the whole picture presented	Functional model mn — op The grouped parts of the whole picture presented	Structural model 

TABLE XI. Relationship between structural model and functional model

Model	Relationship between structural model and functional model
Structural model	 <pre> graph TD W --- A W --- B W --- C </pre>
Functional model (1)	 <pre> graph BT m --- n --- o --- p m --> context n --> context o --> context p --> context context --> Structure </pre>
Functional model (2)	 <pre> graph BT mn --- op mn --> context op --> context context --> Structure </pre>

Discussion-1

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

Discussion-2

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.

Conclusion

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.

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