On the Mesurement of Mental Models for Interface Design

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***Abstract*—The purpose of this paper is to provide a measurement of user's thought process after discussing the experiment with "degree of formed mental model", which involves a logical thinking. We studied 42 people based on questionnaire to measurement mental models. This method helped understanding the potential effectiveness of mental model measurement.**

Keywords-mental model; interface; cognition.

I. Introduction

We describe a method for measuring already formed mental models. The cognitive properties of people and interface designing for them are discussed in this paper.

An interesting approach is presented in this research. We would like you to pay attention to the operating side of the mental model system. This research is peculiar from the standpoint of supporting the operating side as a necessity in the constitution of a society [1].

It is necessary to apply the new method in the solution of usability problems. These problems in the system depend on mental model for 80 % [2]. Mental model is the dominant factor that determines the properties of usability. Mental model varies significantly according to cues on the interface. It is important for user that the amounts of information of user interface design on product is reduced.

It is assumed that mental model approach plays an important in an interaction between the users and the machines. When investigating accidents that happen in socio-technical systems, such as a lack of consideration of human factors generally occurs at the stage of designing the system and its operation. Mental model systems can cause accidents by two or more factors (the complexity and the unexpected error of the system) coming in succession. Therefore, micro-ergonomics [3] exist as a methodology to solve various problems concerning systems and the people who inhabit them.

The definition of mental model are described as follows. Mental model is an eagerness and willingness to do something or the reason why a people wants to do something. To determine motivation, the motivation and guarantee factors are needed. But, the guarantee factor is not referred to our research.

The mental model system refers to the set, the organization, the system, and the mechanism of elements for an organic relation of two or more elements affecting each other, and the settlement as a whole to function.

Many studies have been conducted on the correlation between mental model and cognition [4][5]. Many conventional studies have discussed the results of game or puzzle, used with logic [6][7].

One of the oldest subjects still discussed now is "what is the thinking process on products?" [5]. However, the past studies have not answered the question of their thought. A user interface evaluation has not been performed in detail with the proper amounts of cues for users. Few systematic studies have been reported on the user’s thinking.

In general, designing by the use of labeling as a cue on the products is a failure [7]. But, when operating a machine, we have used label by the buttons as an important cue. We could predict the action of machine by the use of labels on the interface.

Usability testing is the most effective evaluation through which one can know if the designer provided the right model to users [2]. But then, usability testing is costly, and the user’s stress and cognitive load increases with an increase in testing time. Usually, we do not know about users formed mental models and how user’s mental models matched designer’s models.

It is important that designer’s model is consistent with user’s model. A high degree of formed mental model means that user formed a correct model. We have to understand human as a component of the system; in a word, a participant. Therefore, it is necessary to measure the people's mental model to understand the internal structure of the system. How to help a user to form a correct model is provide cues such as affordability, mapping, and straight for the user.

Formed mental model is determined by 9 factors [4]. Questionnaires based on these factors have been designed; the degree of formed mental models is identified using these questionnaires [5].

However, this approach cannot explain how the users’ mental models were built, until a user interacts with a

 ISBN: 978-1-61208-325-4

product. Moreover, to clarify it, getting interaction interpretation takes some time. To avoid these problems, we have devised a new method by using a quantitative evaluation.

The purpose of this paper is to discuss an approach which quickly evaluates the degree of formed mental model and the interface design suitable for peoples' mental model, while considering the cognitive properties of a user when using an interface. Aside from helping the reader in the pencil - and - paper solution of problems, the analytical skill, which this paper aims at developing, may be useful in special situations. This paper will not go into detailed logic analysis, presuming the reader is familiar the reader will be familiar with the people's memory and thought perception. We discuss a situation which assumes the people are not very familiar with the control procedure of electrical appliances.

We have to comprehend the circulation of information. To do so, it is necessary to understand the relation of elements that prevent forming a mental model. Therefore, a survey was conducted at the interaction field. It is a possible approach that we can get a degree formed mental model. The measurements of mental model were performed according to the procedure described as follows.

II. METHOD

A mental model survey using a questionnaire and a structured interview were executed.

The questionnaire prepared by the measurement of mental model was conducted on the user in a lecture room at the college. This is an analysis system that measures the factors of Japanese mental models and converts them to an index as numerical values.

The following two points (Figure 1) are enumerated as the main points of the idea [8]. Functional model is a kind of a sequential plan in operating machines, such as, "do A, then B, then C", and so on. Structured model is a selective type of plan in doing machines, such as "if B is the D, do that".

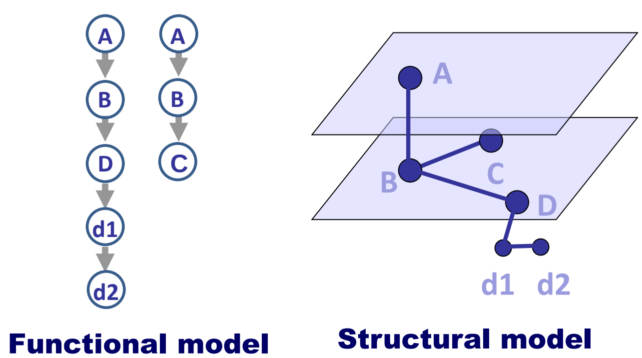

Figure 1. Mental model

C (components) level (Figure 2) is related to Structural model. "Choices" is key for good user interface (terms, visual cue are important).

P (process) level is related to Functional Model. Terms, visual cue are important (special operation such as long press, dual press) (Figure 2).

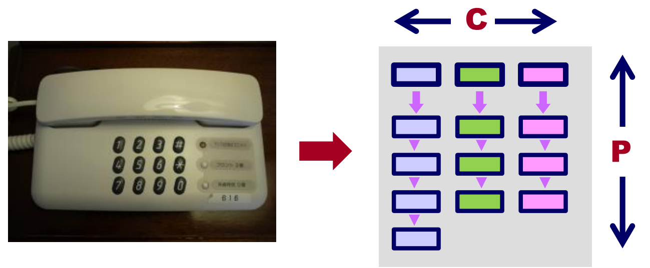

Figure 2. C level and P level

The mental model is operated based on the above-mentioned two points. It evaluates 13 question items in stages.

In order to understand the structure of the mental model, it is necessary to clarify contradictions between elements that prevent the effectiveness of the mental model.

We used the method based on memory of colors and auditory recollection in order to gather accurate information for our research,. The procedure is described as follows.

We performed interviews with 42 people (2 males, 40 females); the participants ranged in age from 20-22 in Japan. We only got to interview 42 people. We asked Nagano Prefectural College to find people for our survey. All participants are pursuing studies in life science as either a major or minor.

A structured interview was conducted with the participants. The questions consisted of product categories, such as faucet, calculator, alarm clock, kitchen timer, etc.

The questionnaire form, pens, and pencils were distributed. First, we chose the user or subject at random. We explained about objects and rules of the interface to each person, and then practiced once with them.

We demonstrated one example interface so as to familiarize the subject with the object and rules of interface sheet; the subjects operated by the themselves (Figures 3-15). After the questionnaire was completed, the forms were collected.

The measurement employed real interface picture. In Figures 9-11, the subject guesses the operation of their mock product. This is followed by a brief statement of the reason for their choices.

In Figures 13-15, the subject follows the same procedures as in Figures 10-12. The subject is asked why they guessed their particular buttons.

In Figures 4 and 5, the subject must guess one specific button from the complete deck. These functions are arranged in a designer's pattern. Figure 6 has only 6 labels facing up.

The procedure is described as follows.

We said, "Please write the procedure shown below

[A] →[+] →[B] →[---]".

Task 1:"Which direction to turn handles to get hot water?"

Task 2:"Show the procedure"

2-1: 2 + 3

2-2: 1000(yen) + tax

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2-3: $\sqrt{4} + 2$

Task 3: "Show the procedure"

3-1: 2 + 3

3-2: 2 × 3

Task 4: "How to set the time? Please change 2:17 to 11:45"

Task 5: "What is "reset"?"

Task 6: "How to set the time?"

Task 7: "How to set the time?"

After doing with each subject, we showed them three versions of a mock interface design that we created, which combines television, radio, and alarm clock. Our intention was to analyze the subject's various procedures when asked to perform any given task on our interface designs.

As in Figures 10, 11 and 12, the subject guesses one specific button from those facing down. We said, "Guess the numbers of the one or three mock buttons facing down and state the reason behind your choices. Besides, there are 12 buttons with labels facing down."

The interfaces are designated as task 8 or 11, 9 or 12, and 10 or 13. Subjects numbered the sheet to check starting from first and going to the end.

The experimenters randomly distributed one of two surveys to 42 members of an undergraduate class. 42 of the subjects completed a survey on the "functionality of control buttons on a product".

Designer's model on the interface was set to the procedure on the task 9 and 12; "power" button to "channel" button, "TV/radio" button to "channel" button.

Task 8 or 11; "Please image on the air. Listen to the news program by the use of the radio. How do you operate when listening or doing the radio?"

Task 9 or 12; "Please image on the air. Listen to the news program by the use of the TV. How do you operate when watching or doing the TV show?"

Task 10 or 13; "How do you operate when setting the alarm clock at am 6:30."

The surveys contained a series of graphics representing control buttons. The labeled product group was asked to complete the same survey to determine if product controls were uniformly understood, as well as to provide a comparison with the No-labeled group.

The participants were asked to write down the function of each button next to the graphic.

Figure 3. Faucet

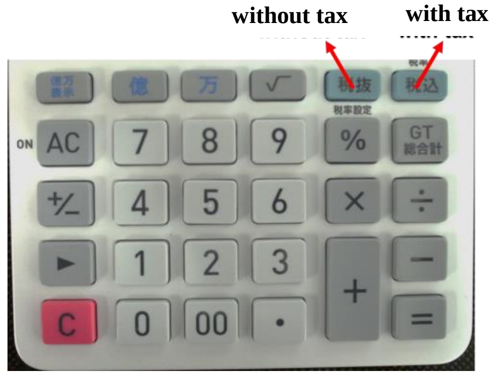

Figure 4. Calculator1

Figure 5. Calculator 2

Figure 6. Alarm clock

Figure 7. Kitchn timer

Figure 8. Alarm clock1 in the hotel (No label)

Figure 9. Alarm clock2 in the hote

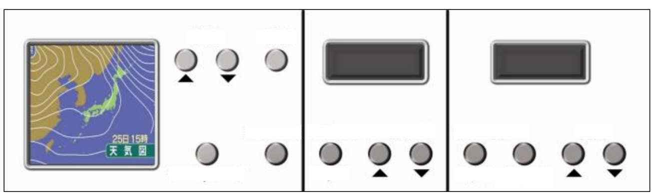

Figure 10. Setting the radio (No label)

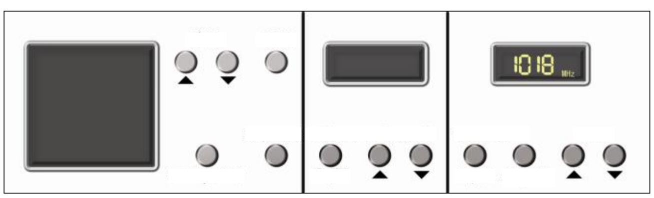

Figure 11. Setting the TV (No label)

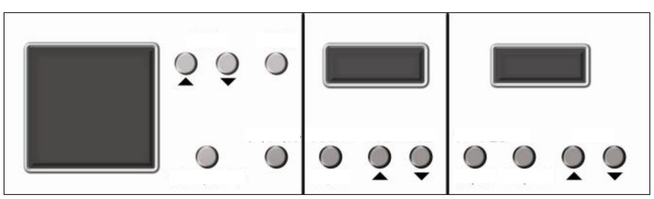

Figure 12. Setting the alarm clock (No label)

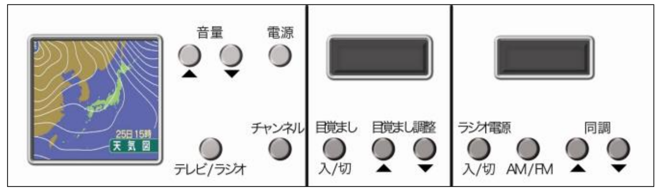

Figure 13. Setting on the radio

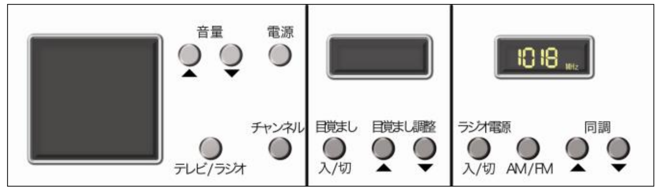

Figure 14. Setting on the TV

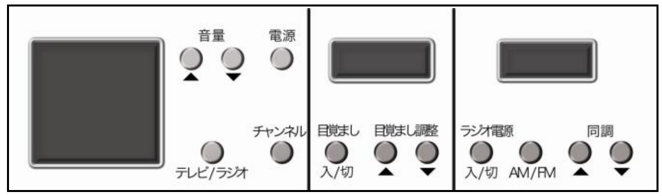

Figure 15. Setting on the alarm clock

III. RESULT

As a result, the formation of a mental model was observed for these interfaces at each task.

In task 1, 100% of the people guessed everything correctly. In task 2_1, 88% of the People guessed correctly. Cues were due to understand the direction to warm water. User's habit caused incorrect mental models to be formed.

In task 2_2, the mental model measures 90%. The other 58% use the correct pattern to guess the correct model in task 2_3. The other 42% did not use the correct pattern to guess the correct model. In task 2, this appears to use practice procedure; "√" button to "4" button.

In task 3, almost all the subjects answered inappropriately. The mental model measures 50%. Participants could not practice because of no knowledge about the device.

In task 4, 95% of the people guessed correctly at C level. The other 3% of the people guessed correctly at P level. The mental model measures 49%. 51% did not use the correct pattern to guess the correct model. Participants could not realize how many times they pushed the button; "mode / set" button.

In task 5, the mental model was determined to be 88%. The other 12% did not use the correct pattern to guess the correct model. We almost could found means on how to use it; "reset" button.

 ISBN: 978-1-61208-325-4

In tasks 6 and 7, the measures of No-label and label were determined to be 52% and 56%, respectively. It seems that this result did not depend on labeling for a mental model.

In tasks 8-13, the degree of formed mental model of labeling interface is larger than that of no label interface. It is probable that mental model was formed by the cues with labeling.

These results showed that when trying to guess the buttons rather than using their logic, they used their intuition, or they followed their instinct. Frequently, interface rules escaped their memory by themselves. The rate of correct answer is determined by these factors: the number of button and the alternatives.

Tasks 8-10 and tasks 11-13 show the rate of correct answer cue or alternative of each case in the mock interface, for example, the investigation revealed that 30 out of 42 subjects acted correctly. The rate of information was obtained by changing from the amount of cue. These results show that there is a marked increase in the rate of incorrect answers. The characteristics of such cues are assumed to be the origin of the increase of rate. Considering the previous results, this result was expected.

TABLE I. TASKS 1～7

	Task									
	1	2_1	2_2	2_3	3_1	3_2	4	5	6	7
C level	100	100	95	44	100	100	95	88	29	12
P level	100	76	85	72	0	0	3		75	100
	100	88	90	58	50	50	49	88	52	56

TABLE II. TASKS 8～10

	Task				
	8	9	10		
C level	48	40	0		
P level	90	88	–		
	69	64	0	44	Total

TABLE III. TASKS 11～13

	Task				
	11	12	13		
C level	71	60	31		
P level	77	100	15		
	74	80	23	59	Total

IV. DISCUSSION

This research aims to clarify an essential problem of the mental model, and to present a plan for its solution. The measurement approach to determine a solution based on this case was examined. User's mental model is reflected in that result. However, increasing the accuracy of method requires increasing many case studies.

Each of the 42 people selected played with ourselves and on their own. These results provided evidence that people have an illogical jump or mistakes. People might think that truth may exist, but they maintain that if it does, the mental model is incapable of attaining it. Humans may be narrow-minded and refuse to consider certain alternatives only because these alternatives do not meet their prejudgements assumptions about what is and what is not worth pursuing.

In our experiment, from the results in Figures 10-15, one can see that the people adjusted better to the pattern based on habit rather than their pattern. In other words, they did not adjust to a pattern. Moreover, the people save their cognitive resource, and have the characteristics called as "fixed action". When we changed from a pattern to another, with many buttons faced down, this caused a lot of stress for the subjects when having to guess the process in the pattern. The maximum amount of inappropriate cues indicates that the people's thought process is over the allowable maximum of cognition and they get an illogical jump. This should be the optimum amount cue.

This allowed us to further evaluate the functionality of our designs and understand how and why our subjects make certain decisions. By designing a product that is basic and easy to use based on our finding reduces the amount of stress on the mind, and makes it easy for the person to use.

We, however, have to think it over relate a trust, emotion, expectation, situation, human-relationship, etc. Human-computer interaction which should be accompanied by the appearance of mental model cannot be observed in the user's brain. In the future, this may provide a different result. Another case requires a more detailed discussion.

This measurement provided a reasonably good method for such assessments. The method offers many advantages over the conventional method. Applications include on-site testing of paper prototyping.

The mental model approach allowed us a glimpse into the mind of our subjects - that is, we were able to understand their mental model when faced with the decision making which is in fact one of the most important factors of universal design itself. Therefore, it was crucial that we guess the logic behind each person's thought process.

V. CONCLUSION

In conclusion to our research on decision making using the mental model check sheet, our results showed that people have illogical thinking when making a guess based on their mental model. It is likely that people would guess illogically, so in order to support their decision making we should design an interface that is suitable for this age group. In order to be successful with interface design, we must assess user's decision making. For the findings in our research, we proposed a method and gave an answer to this problem based on a concept "thinking or thought". This new proposal suggests "How to design for user" on the interface design of products.

We confirmed that our process had the effective to provide values. This method contribute to the improvement of the usability of interface.

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