JESK J Ergon Soc Korea 2016; 35(1): 53-65
http://dx.doi.org/10.5143/JESK.2016.35.1.53
http://jesk.or.kr eISSN:2093-8462

A Taxonomy of Uninterpretable Interactions from Interaction Design Perspective

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Received : September 16, 2015
Revised : October 08, 2015
Accepted : October 10, 2015

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Objective: The aim of this study is to configure a taxonomy of uninterpretable Interactions.

Background: Following the spread of the Internet, smart devices have increasingly covered our lives. Human beings are now living in an era of tremendous information explosion. We live with numerous interactive targets nowadays, and there are many ways to interact with these targets. Being an interaction designer in this era, we need to clearly understand the existing methods of the interaction. While Bill Moggridge posed interaction design as a new discipline in 1984 , it still has not formed a structured framework.

Method: This study categorizes uninterpretable interactions through case studies, and configures the taxonomy of uninterpretable interactions based on Object-Oriented View of interaction. To explore the use value and impact of the taxonomy of uninterpretable interactions, this study conducted an experiment and analyzed related results.

Results: The framework gives a positive impact on the design process, and interaction designers can clarify and broaden the scope of their ideas.

Conclusion: A study on the Taxonomy of Uninterpretable Interactions was the part that did not gain a lot of attention in the existing interaction process. The study made the part more clear. And the study also helps interaction designers expand their roles in the development process of products or services.

Application: The taxonomy framework of uninterpretable interactions might help interaction designers design uninterpretable interactions more clearly, and it can also be applied to design interpretable interactions.

Keywords: Interaction, Uninterpretable, Object-oriented view, State-state mapping, Taxonomy framework

1. Introduction

Human being's daily life is conducted through interactions with many objects and information. Before Bill (2006) used the term of interaction, people already interacted with so many objects. People actually used various types of expressions or terms on interaction. Due to the diffusion of smart devices, following the dissemination of computers and the Internet, information rapidly increases. The targets and modes of interaction in the contemporary era have been diversified much more than in the past. All interactions, however, are not always interpretable interactions in many

interaction processes. In reality, people are engaged in uninterpretable interactions in many cases. Due to tremendous information in everyday life, people need uninterpretable interactions, rather than interpretable interactions, according to situation. Such an uninterpretable interaction can be an essential type in some cases from the efficient, convenient or other aspect.

This study clearly defined the uninterpretable interaction. This study analyzed uninterpretable interactions through related cases, and configured a taxonomy. The configured taxonomy will become a taxonomy comprised of object-oriented view of interactions from the design aspect, based on sympathy between interaction designers and users. Such a taxonomy is forecast to help the interaction designer's role expanded in the development field of hardware or software. The role of interaction designers was hugely limited, while product development was carried out by existing development engineers. Through this study, more clear and systematized way of thinking can be offered in the actual interaction design process.

2. Definition of Uninterpretable Interaction

An uninterpretable interaction is an interaction literally. Namely, it should be discussed under the premise that an interaction is being made. If an uninterpretable factor is included in the interaction process, the interaction is defined as an uninterpretable interaction. To help understanding, this study investigated each definition of interaction using the theoretical concepts in the existing interaction design field, analyzed correlations between them, and clearly defined the concept of interaction.

2.1 Affordance and uninterpretable interaction

Since there is a premise that an interaction should be made, this study examined the concept of affordance, which is addressed the most in relation with the premise. Don Norman (2014) defined that affordance is a possible usage or method of an object decided by relationship between two interactive objects. This means making a person interpret which manipulation is possible. The fact that affordance exists means a precondition that an interaction can be made between two objects is equipped with. In summary, if affordance exists, an interaction is possible. When an interaction is possible, affordance exists. From this, it is understood that affordance exists in an uninterpretable interaction. There is one more thing to consider here, and it is the invisible affordance. Invisible affordance is the affordance that cannot be seen. For example, like a menu list is activated, when a person presses a button on the right side of the mouse, he/she can naturally manipulate in the situation that there is no signifier. Such a case can be regarded as invisible affordance. Is the interaction an uninterpretable interaction in the event that invisible affordance exists? The answer is not always. As defined above, an uninterpretable interaction is decided by uninterpretable factors existing in the interaction process. Because invisible affordance is the uninterpretable case appearing in the prior stage of interaction-progressing, the invisible affordance cannot be the basis to judge whether the following interaction is uninterpretable or not.

2.2 Unconscious and uninterpretable interaction

This study examined the relationship between an unconscious interaction and an uninterpretable interaction. An unconscious interaction is made in the unconscious state. Psychology defined unconsciousness as the mental state not consciously perceived. Such a definition is made from the mental aspect. Most human being's behaviors in everyday life are unconscious behaviors. Unconscious behaviors can be human's instinctive behaviors, and habits formed through repetitive behavior pattern and accidental behaviors made in an uninterpretable situation. The judgment on the status of unconsciousness is made by the cerebral activity of a human. An example can be like this: When a person performs a word document work or design work with a computer, the person often uses the function of "return". Namely, he/she returns to the previous screen using a combination of control+z (command+z) keys, when wrong input or wrong manipulation was made. If many steps are needed, human being does not make a conscious manipulation on how many steps need to undergo. A person repeatedly enters a key unconsciously, and a case exceeding originally expected value is caused in the course of doing it, which is generated frequently. On the other hand, a person

enters the exact number of combination keys consciously, when one or two steps need to go back. From this, it is known that an interaction can be made consciously or unconsciously according to the environment or situation with which a person faces, despite the same interaction. Looking at the factors of interaction, the combination keys of control+z (command+z) are interpretable factors. Therefore it is not right to see an unconscious interaction as equal as an uninterpretable interaction. The interaction factors can be interpretable or uninterpretable. Depending on situation, people unconsciously interact, irrelevant of the status of an interpretable or an uninterpretable factor. With all these, it is known that an absolute correlation does not exist between an unconscious interaction and an uninterpretable interaction.

2.3 Definition and scope of uninterpretable

Card, Stuart et al. (1983) said the interpretable process is made between the external world and human's cerebrum (Figure 1).

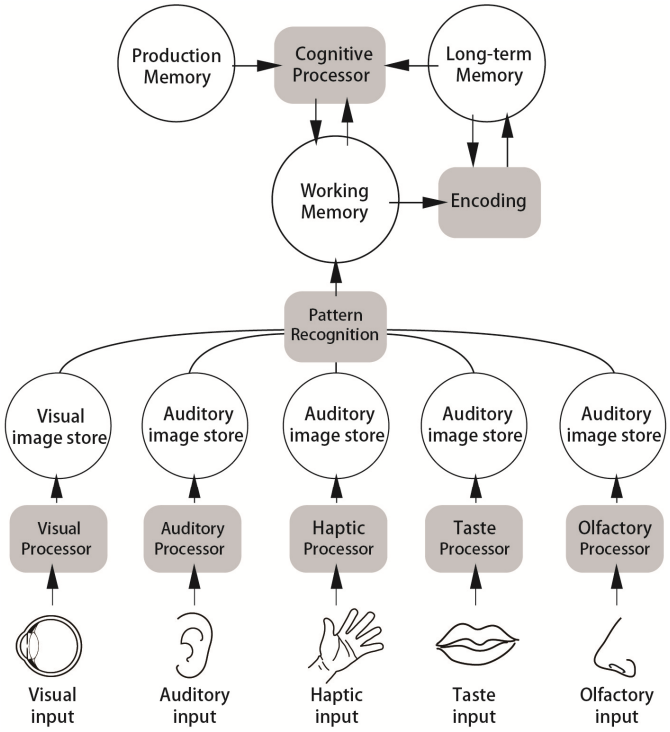


Figure 1. The model human processor - diagram

The interpretable process can be understood as a single direction process reaching from the external world to human's cerebrum. Existence in all cases existing in the external world is complex, and a complicated correlation is made. What a human senses is a certain state of the external world.

Humans sense many states of the external world through five senses. The sensed states undergo the interpretation state through human's cerebrum. The sensed state can be divided into an interpretable state and an uninterpretable state. If interpretation is possible, the state sensed through five senses is semantic existence. For instance, there are the cases of reading writings with eyes, listening to songs with ears, and smelling odors with nose. Here, writings, songs and odors are interpreted as semantic existence.

When a human sees letters, he/she interprets them as the meaning of a writing, and when a person hears sound, he/she interprets it as having the meaning of a song. On the contrary, an uninterpretable state means the sensed state through five senses is not a semantic existence. For example, when scribbles on a piece of paper by a child, before he/she learns how to write, can be meaningful as a drawing, but have no meaning as a letter, when it comes to a semantic interpretation. In this case, a child's scribbles can be seen as an uninterpretable state from the aspect of letter's semantic aspect. If a meaning does not exist in a state from the semantic aspect, this is an uninterpretable state from the semantic aspect. The state itself needs to be sensed in the semantic uninterpretable state. The status of an uninterpretable state should be judged from the status of meaning in the sensed state. If the state itself is not sensed, the judgment of the status of meaning cannot be made.

A human consists of biological structure, and human's cerebrum cannot make an absolute interpretation in the interpretation process of some states through five senses. As an example, let's assume that there is the length of an object, strength of pressure and the temperature. The state cannot be precisely interpreted without using a specific tool. The states of the external world have a standardized unit system generally. The states, for which precise interpretation is impossible, including kg, cm and pa can be defined as uninterpretable states. When such external world states are classified, there are the property degree demonstrating strength, pressure strength and temperature, and spatial degree indicating distance between objects, 2-dimensional area and 3-dimensional volume, and time degree showing the time degree of state. The property degree, spatial degree and time degree can be classified as the uninterpretable state of degree.

As state above, a human senses the state of the external world using five senses. Human's five senses, however, are not perfect, and his/her cerebrum cannot be seen as perfect either. Depending on situation, people cannot sometimes judge the existence of a state existing in the external world. For instance, let's assume that one writes something in the air with a finger. The track that the finger passes exits obviously, and it is clear that the track is a semantic existence like one sentence or one letter. The track, however, is invisible. In other words, the state can be sensed with human's five senses, but the trace of change of state is not left. Actually, one can interpret instantaneous change of state as an instantaneous state, and guess a word or a sentence that matches the track by making the track through a process combining each interpretable result in his/her cerebrum. What is discussed in this study is the trace of change of state itself. The writing written with a pencil and a writing written in the air with a finger are clearly different. In the former case, visible trace is left, and there was no difficulty in interpreting. However, in the latter case, the trace is invisible, and uninterpretable. The trace made by interpreting the instantaneous state in the cerebrum mentioned above is the trace made in the cerebrum literally, but is not the trace of change of state itself. The trace of state itself exists in the external world, and is invisible and uninterpretable. Such a case is classified as uninterpretable trace in the change of state.

3. A Taxonomy of Uninterpretable Interaction

3.1 Object-oriented thinking

The concept of object-oriented thinking was raised by a philosopher, Ludwig (1922). Ludwig Wittgenstein insisted that the world consists of simple basic objects. Such a concept just existed as a philosophical thought interpreting the world; however, it is widely used as one of the program design methods. The object-oriented approach in programming refers to starting from an objectively existing object in reality and building a software structure system. Software structure is interpreted with the vision looking at a problem, and the problem is converted into the corresponding programming code by mapping the problem to an analysis model. Humans should understand the real world as the true image of the world, and interpret the world as objects or correlations between the objects. The system made in this way can match the true image of the real world. This study applied the object-oriented thinking to the configuration of the uninterpretable interaction taxonomy.

3.2 State and state-mapping

A precondition is necessary to configure the uninterpretable interaction taxonomy with object-oriented thinking. Namely, there should be a method to interpret interaction itself. Luo (2014) defined the interaction process as state and state-mapping and change of state-mapping. This study classified uninterpretable interactions using the interpretation method stated above.

3.3 A taxonomy of uninterpretable interaction

3.3.1 Meaning-level of uninterpretable interaction

If there a semantic uninterpretable part exists among the factors of state in the state and state-mapping concerning a semantic uninterpretable interaction, the interaction is classified as a semantic uninterpretable interaction. One thing to be careful about is that the meaning here means the factor of state related with the interaction concerned. The sound upon tapping a telephone number cannot be judged as a semantic uninterpretable state, because the sound has no meaning from the aspect of a song. Since the meaning of a song in the interaction of tapping the telephone number is not related with the interaction concerned, the meaning does not have to be mentioned. Concerning a digital door lock, for example, an action to press the password number can be regarded as the change of state. First, tapping a number is indicated as a change of state, $\triangle S_{num}$ tap. The sound generated, when a number is tapped, is indicated as the change of state, $\triangle S_{sound}$. When the last number is entered in precise sequence, the door lock's locking system is released (Figure 2).

Figure 2. Door lock password number interaction

The change of state, $\triangle S_{num}$ tap, is the state consisting of interpretable factors. The mapped $\triangle S_{sound}$ has a meaning as the sound letting know about the tapped button's activation, but has no meaning as the tapped number or tapped sequence. Number or sequence is a semantic factor related with the interaction concerned. People cannot notice which number was tapped or what sequence of number was tapped with just hearing the sound. As another case, concerning the passcode input screen of iPhone, in the interaction that the empty circle at the top is filled, when the passcode is entered, has the meaning of sequence enabling to interpret the entered number sequence; however, it does not have a meaning of a number to perceive the entered number (Figure 3).

The factor of the state concerned is a semantic uninterpretable factor, and therefore the interaction can be classified as a semantic uninterpretable interaction.

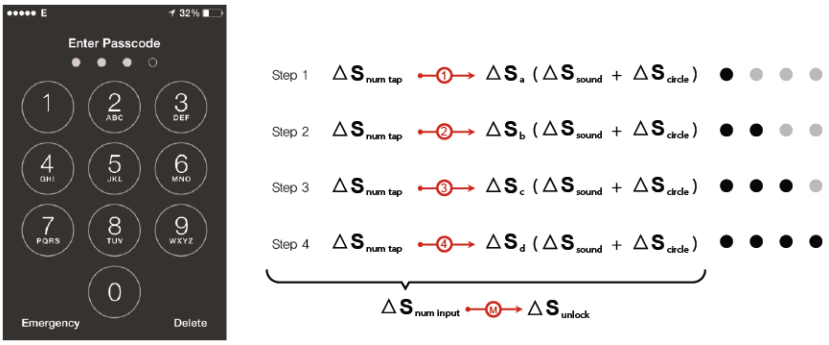


Figure 3. IPhone passcode interaction

3.3.2 Degree-level of uninterpretable interaction

The uninterpretable state of degree was defined and classified as the property degree, spatial degree and time degree above. Likewise, if there an uninterpretable factor of degree exists among the factors of state, the interaction concerned is classified as an uninterpretable interaction of degree.

(1) An uninterpretable interaction of property degree refers to an interaction of which factor property of a state is an uninterpretable interaction. The uninterpretable property means the property that the degree cannot be precisely interpreted including the strength of sound, the strength of pressure, temperature and brightness of light. Let's illustrate with the pressure sensing an interaction of the Apple watch. If the watch screen (watch mode) of Apple watch (I-watch) is pressed with a finger, the screen is down, and the watch screen selection mode is displayed (Figure 4).

Figure 4. I-watch force touch interaction

The strength of pressure in the interaction concerned is uninterpretable. As in the case, if the watch screen selection mode is assumed to be activated in the pressure strength change of 0~50Pa, humans cannot interpret 50Pa in terms of force. Such an interaction can be classified as an uninterpretable interaction of property degree.

(2) An uninterpretable interaction of spatial degree refers to an interaction having an uninterpretable spatial factor among the factors of state. Space, here, can be segmented into distance, area and volume.

The uninterpretable interaction of distance degree means an interaction containing an uninterpretable factor of distance in the interaction process. The paying interaction using NFC of a mobile device can be an example (Figure 5).

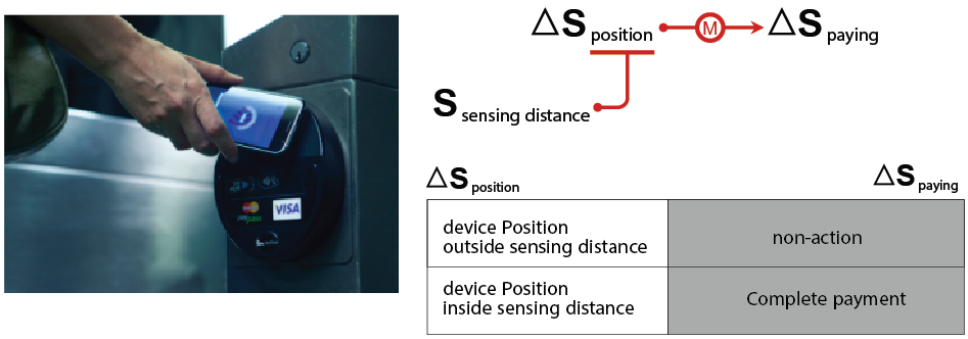


Figure 5. NFC paying interaction

Although the distance that can sense the interaction, people cannot interpret the degree of such a distance. If a mobile device is within the sensing distance, the sensing is carried out and payment is completed.

The uninterpretable interaction of area degree means the interaction containing an uninterpretable factor of area in the interaction process. Automatic video playback in News Feed of Facebook can be an example (Figure 6).

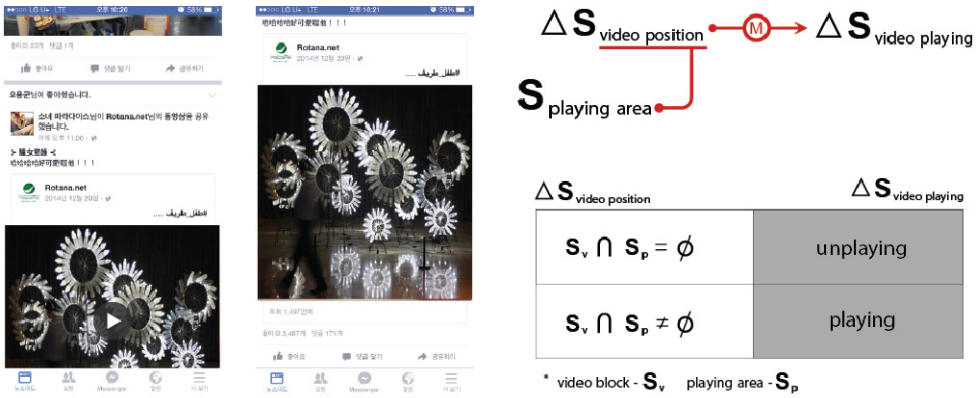


Figure 6. Facebook video auto playback interaction

As analyzed, the video starts to be played, if the intersection of the video block and playback area is not a null set. On the contrary, if the intersection of the video block and playback area is a null set, the playback stops or playback is not conducted. Although the video playback area exists, people cannot interpret the degree of the area.

The uninterpretable interaction of volume degree means an interaction having uninterpretable state of area factor in the interaction process. As an example, let's have a look at leap motion use process analysis (Figure 7).

$S_{hand} \xrightarrow{M} S_{virtual}$

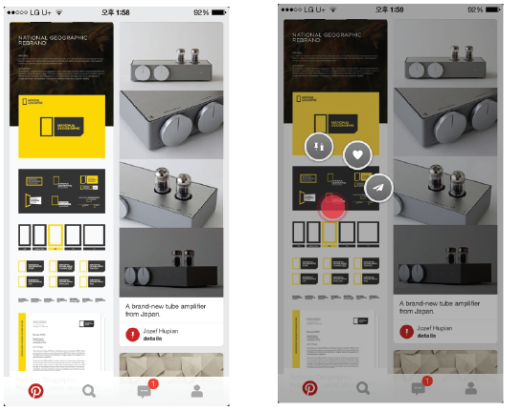
$S_{sensing\ area}$

S_{hand}	$S_{virtual}$
Position and gesture in sensing area	non-action
Position and gesture out sensing area	Corresponding position and gesture

Figure 7. Leap motion interaction

In the interaction, hands and the virtual hands in the monitor are the mapping relationship of state vs. state. However, there is a precondition that hands need to be within the leap motion sensing area. The leap motion sensing area is a 3-dimensional area. People cannot interpret the degree of the area.

(3) The uninterpretable interaction of time degree refers to an interaction having an uninterpretable time factor in the interaction factors. In the mobile and tablet version UI interaction of Pinterest, if a certain time is maintained in the state of a finger touching on the image, the navigation menu is activated. The action that a finger takes changes from non-touch state of the screen into touch state of the screen, and then a certain time is maintained, which is a change of state. What is mapping with it is the change of state, namely navigation menu's activation (Figure 8).



$\triangle S_{press} \xrightarrow{M} \triangle S_{menu}$

$\triangle t$

$\triangle S_{press}$	$\triangle S_{menu}$
press on the image & $\triangle t < 1S$	non-action
press on the image & $\triangle t > 1S$	vector-menu come out

Figure 8. Pinterest vector UI interaction

In this interaction, △t is an uninterpretable factor. People cannot know when the menu is activated after how much time should pass, without visible information. Likewise, the fingerprint recognition of iPhone or the explanatory information's activation of the menu icon in the MS Office are the same uninterpretable interactions of time degree.

3.3.3 Trace-level of uninterpretable interaction

The trace appears due to the change of state as defined above. The trace is actually the trace of change of state. If the uninterpretable trace exists in the change of state and the mapping of the change of state, the interaction is classified as an uninterpretable interaction. Figure 9 shows a knock code lock releasing interaction case (Figure 9).

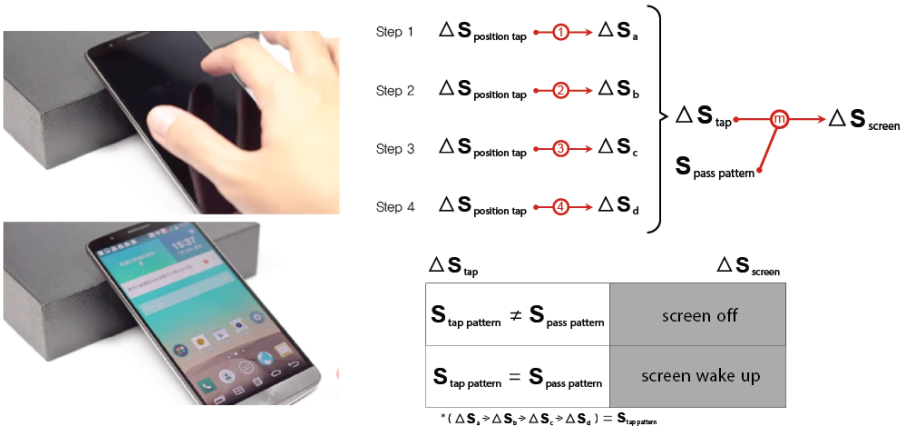


Figure 9. LG knock code interaction

The change of state, namely tapping the screen with a finger is repeated. The change of state that the screen is on upon the last tapping is generated. Here, a precondition that the pattern formed through finger tapping should match the existing set pattern exists. The change of state of finger tapping can be regarded as the process of forming code pattern, but the trace that the change of state left, namely the code pattern type, cannot be found by humans. The trace of change of state, $\triangle S_{tap}$, is an uninterpretable factor. The interaction containing the uninterpretable factor of the trace of change of state is classified as the uninterpretable interaction from the trace aspect.

3.4 Framework of uninterpretable interaction

The taxonomy framework of uninterpretable interactions can be configured as shown in Figure 10, based on the characteristics concerned (Figure 10).

Human's interpretation process is a single direction process reaching from the external world to human's cerebrum as mentioned above. Therefore, the part where uninterpretable state is generated exists within such a scope. Namely, the uninterpretable factors in an uninterpretable interaction can be judged to exist in the same scope.

Humans sense and interpret the state of the external world. In physics, the real world, that is, the world of materials is formed with material measure, space measure and time measure. Under the same logic, the state of the external world is said to consist of materials, spaces and time. The uninterpretable taxonomy level of degree in the taxonomy framework configured in this study consists of property degree, space degree and time degree. Therefore it contains the uninterpretable factors of the state of the external world. The uninterpretable taxonomy level of degree is the taxonomy level corresponding to the uninterpretable state.

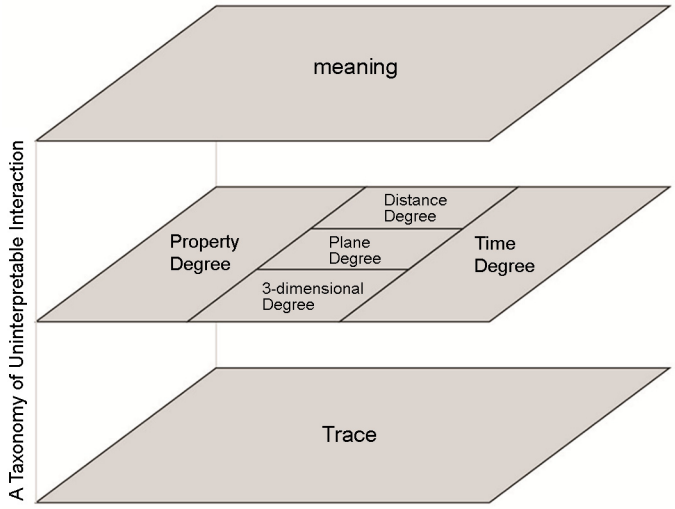


Figure 10. A taxonomy of uninterpretable interaction

Because the trace in the uninterpretable taxonomy level from the trace aspect is the trace of change of state, this taxonomy level is the one corresponding to the uninterpretable change of state. What needs to be made clear is that the state itself is interpreted in this taxonomy level, and only the change of state is uninterpretable. It is understood that the uninterpretable taxonomy level in the trace aspect is the uninterpretable taxonomy level of degree and antinomic taxonomy level.

The degree of state or the trace of change of state is interpretable in the semantic taxonomy level. The degree of state or the trace of change of state in this taxonomy level should be discussed under the premise that it is interpretable. In the semantic uninterpretable taxonomy level, state or the change of state is not viewed from the degree or trace aspect, but viewed from the semantic aspect. Although the degree of state or the trace of change of state are interpretable, if it does not have a meaning in the interaction configuration factor, the factor becomes a semantic uninterpretable interaction factor. From this, it is understood that the semantic uninterpretable taxonomy level is antinomic with the uninterpretable taxonomy level from the uninterpretable taxonomy level of degree aspect and the uninterpretable taxonomy level from the trace aspect.

Each taxonomy level in the taxonomy in this study can be interpreted that they are antinomic, and they are not included in each taxonomy. Looking at the interaction configuration scope, the taxonomy framework configured in this study is viewed as containing all uninterpretable interactions.

4. Experiment

This study conducted an experiment to find out the effects of the uninterpretable interaction taxonomy framework on real interaction design process. In the experiment, the effects of uninterpretable taxonomy framework on the design process were observed and analyzed.

4.1 Experiment design

The experiment target is set as two design groups consisting of interaction design majors. The two groups are named Group A and Group B, respectively. The same design improvement mission is given to the two groups, and they fulfill the mission in

different space, respectively. The number of participants is five for Group A and five for Group B, namely ten interaction design majors in total are selected.

Before they start design work in full swing, an explanation on the uninterpretable interaction framework is explained to the Group B, so that they can be fully aware of the details. The Group A performs the task in the state that they do not know the details of uninterpretable interaction framework, while the Group B performs the task in the state of fully aware of the framework details. While the progress is observed, the characteristics in the two groups' task performing process are analyzed, and the uninterpretable interaction framework is analyzed on what effects exist in the design process (Table 1).

Table 1. Experiment design

	Group A	Group B
Member	5	5
Use frame	No	Yes
Design task	Redesign door lock interaction	Redesign door lock interaction
Time	2 hours	2 hours
Recording	Stuff A	Stuff B

4.2 Experiment process

The experiment process on the design task performance is as follows (Table 2) (Table 3).

Table 2. Experiment time

	Group A	Group B
Use time (full)	2 hours	1 hour and 45min
Brain storming	50min	60min
Idea organize	30min	15min
Design explanation organize	40min	30min

Group A used two hours in total, and the time to be used for team member's brainstorming was 50min in the ideation process, and it took 30 min to select ideas and materialize them. It took 40min to perform design and wrap up. Group B used 1 hour and 45min in total, and the time to be used for team member's brainstorming was 60min in the ideation process, and it took 15min to select ideas and materialize them. It took 30min to perform design and wrap up. In terms of time, Group A used up all two hours, and Group B completed the task within the limited time.

Group A researched similar products in the brainstorming process, and drew ideas on new interactions of a door lock through mainly benchmarking. In the idea selection and materialization process, the process was carried out in a combining mode of the benchmarking samples drawn in the brainstorming process. Concerning the ultimate outcome, a new design was explained

Table 3. Experiment process

	Group A	Group B
Brain storming process	Benchmarking - similar products	Design target review & Benchmarking
Idea organize process	Modify benchmarking sample	Using framework - define ideas
Design output	Benchmarking images & sketches	Sketches & texts

with benchmarking images and sketches to help understanding. Group B started brainstorming, and analyzed existing products using the framework. They identified the current status, and started to offer ideas. They found ideas from other services, as well as from similar products. In the design wrapping process, design was wrapped using the uninterpretable taxonomy framework, and the ultimate outcome was produced by sketches and texts, rather than a benchmarking case.

4.3 Experiment result

In the brainstorming process, Group B's benchmarking and idea breadth were broader than those of Group A. In the idea arrangement process, Group B's was carried out more quickly than Group A, and the reason was that the communication process of Group B's team members was more systematic and quicker than Group A. In the ultimate outcome process, Group A explained new interactions with case images and sketches, but the conveying power of the case images was slightly low, and the explicitly of the explanation on the sketches was more insufficient, compared to Group B. Group B's explanation on sketches and texts was more explicit in terms of design intention and conveyance of improved part. From all these, this study found that using the framework can help clear and systematic thinking of designers in the design process.

5. Conclusion

The study on the uninterpretable interaction taxonomy was performed to make the part that people did not pay attention much in the existing interaction process clearer. The taxonomy is a taxonomy configured with the object-oriented view, based on sympathy between designers and users, not based on the development aspect. The taxonomy in this study is to help designer's role expansion in the product or service development process of a designer. The uninterpretable interaction framework has an active influence on making designer's thinking clear and expanding idea breadth in the design process. The framework does not just help uninterpretable interaction design. On the contrary, when the uninterpretable interactions are converted into interpretable interactions, the use of the uninterpretable interaction framework is possible. However, it is difficult to expect a lot with just one framework. The taxonomy framework in more cases needs to be built in the future. Although one framework's help is limited, the study on such a framework is judged to be required. Actually, a study on various types of interactions, which can be also just one piece in the study on interaction framework, should be conducted continually for the completion of a huge system.

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