製品意味論に基づきユーザの家電製品理解を理解する：事例報告
Understanding Users' Understanding of Electronic Products Based on Product Semantics — A Case Study

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Abstract
For now, more electronic products are introduced with multiple and high functionality to daily life, which are generally accompanied by complex operations, often causing unpleasant experiences and mental frustrations, especially for elderly users. To know how well older adults can use the electronic product and what kinds of processes they are taking as their problem-solving, a usability testing has been conducted in previous research. Krippendorff and Butter argued that users create meanings during interaction with the product. However, how can designers understand how users understand the meaning and promote a desired interpretation? The answer can be found in *product semantics*. Therefore, this study aims to give an overview of the theory of *product semantics* and try to propose a new perspective to clarify how users understand the meaning of electronic products in their own way.

Keywords — Product Semantics, Usability Testing, Elderly Uses, Electronic Products

1. Introduction

With the coming of the information age, more and more electronic products are introduced to people's daily life with multiple and high functionality. Those products are generally accompanied by complex operations which often cause unpleasant experiences and mental frustrations, especially for elderly users. Although the problems which older adults would face have been attributed to physical or cognitive aging, many of these issues arise from the fact that the designers tend to rely on their own intuition towards their designs, since not all of their decisions have a same impact on the users, especially with older adults as highly sensitive users (Harada, 2009). Krippendorff and Butter (1984) argued that users create meanings during interaction with the product. But how can designers understand how users understand the meaning and promote a desired interpretation? The answer can be found in product semantics (Parmentier et al., 2020) when applying into the real human-artifacts interactions. Therefore, this study aims to: (1) give an overview of the theory of product semantics and its relevant researches; (2) propose a new perspective to clarify how users understand the meaning of the electronic product in their way, with a case study of usability testing.

2. Product Semantics in Design

The term product semantics as applied to product design has its roots in cognitive psychology and was first presented with definition as "study of the symbolic qualities of human-made forms in the context of their use, and application of this knowledge to industrial design (Krippendorff & Butter, 1984)." Since product semantics was introduced to design in the 1980s, many researchers have already discussed this theory mainly in the meaning of functionality and emotionality. Compared to the discussions in the meaning of emotionality (Hsu et al., 2000, Petiot & Yannou, 2004, Mondragon et al., 2005, Lanutti et al., 2015, Kapkin & Joines, 2018, Khalaj, 2019) by various ways such as Semantic Differential Method, Kansei Engineering, the meaning of functionality has been less discussed. Here, the meaning of functionality can be regarded as a theory of meaning for artifacts in use mentioned by Krippendorff (2006), which explains how individuals understand their artifacts and interact with them for their own terms and reasons. The applications of the meaning of functionality in different products have been researched: You and Chen (2007) elucidated the role of affordances and product semantics in the interaction design for a stereo cassette recorder, Hsiao et al. (2012) established an online affordance evaluation model for measuring affordance degree to evaluate the usability of a steam iron, and Gabelloni et al. (2014) investigated the design phenomenon of altering the mapping between product (abdominal equipment) structure and functions and above all how it modifies the users' perspective. However, a few kinds of research considered the actual and dynamic usage by real users. Therefore, this study tried to reevaluate the product in the context of usability testing in the meaning of functionality in *product semantics*.

Krippendorff (2006) suggested that artifacts should be designed to supply three qualities of experiences to achieve meaningful interfaces: *Recognition*, *Exploration*, and *Reliance*, which can also be described as stages since they are experienced sequentially (Krippendorff & Butter, 2008). Fig.1 shows the relationships between these three types of experiences. *Recognition* includes correctly identifying what something is and what it can be used for; *Exploration* includes how it works and what to do to achieve particular aims; And, *Reliance* is operating something so seamlessly that attention can be on the sensed consequences of its use (Krippendorff, 2006).

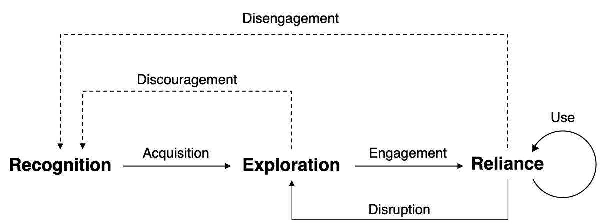

Figure 1. Transitions between three qualities of experiences (Krippendorff, 2006)

Considering that the purpose of usability testing is to determine how well people can use the product, in which that it is quite ubiquitous that the target artifact is generally introduced that "this is a thing for doing ……" , the stage of *recognition* is usually skipped or distorted by the experimenter. In other words, we monitor the stage of *exploration* until quitting for the reliance stage, during the usability testing. That is, we presuppose that a design, which provides good usability, could make a transition from *exploration* to *reliance* smoothly in this study.

In addition, the theory of meaning for artifacts in use provides numerous concepts for *exploration*: user conceptual models, constraints, affordances, metonyms, informatives, and semantic layers (Krippendorff, 2006). Those concepts can compose a checklist, shown in Table 1, which can be used to concretely elucidate whether the designs provide enough meaning of functions to users, or where users have troubles for understanding the products.

The term *Affordance* was first presented by Gibson with the description that "the affordances of the environment are what it offers the animal, what it provides or furnishes (Gibson, 1979)." In product semantics, it is said that affordance means the ability of perceiving usage directly, effortlessly, and without thinking (Krippendorff, 2006). It was described in *direct perception of usability*, *enacted affordances*, and *constructed affordances*.

Metonyms are parts taken to represent the whole to which they belong (Krippendorff, 2006). For example, the sign of a couple highly means the washrooms, or the image of a garbage can in the computer indicates the place users could delete their unwanted files.

Constraints are considered to limit the dangerous usage of the product. For example, the load-bearing capacity of bridges (*natural laws*), the shutdown system of microwave (*physical constraints*), a childproof design of medicine packages (*constraints that discriminate among users*), or double-check of deletion in the computer (*overridable constraints*). However, immoderate constraints or unthought constraints may make the products difficult to use — for example, the usage of a credit card (*unnecessary constraints*).

Informatives are a series of clues which are means to indicate how to proceed (Krippendorff & Butter, 2008), and primarily provide the functions of calling attention (*signals*), concerning current stage (*state indicators*, *progress reports*, and *confirmings*), and offering guidance and consequences (*affordings*, *discontinuities*, *correlates*, *maps of possibility*, *error messages*, and *instructions*).

Table 1. The Checklist for concretely elucidating whether the designs provide enough meaning of function to users (from Krippendorff, 2006)

Affordance	Direct perception of usability, Enacted affordances, Constructed affordances
Metonyms	
Constraints	Natural laws, Physical constraints, Constraints that discriminate among users, Overridable constraints, Unnecessary constraints
Informatives	Signals, State indicators, Progress reports, Confirmings, Affordings, Discontinuities, Correlates, Maps of possibility, Error messages, Instructions

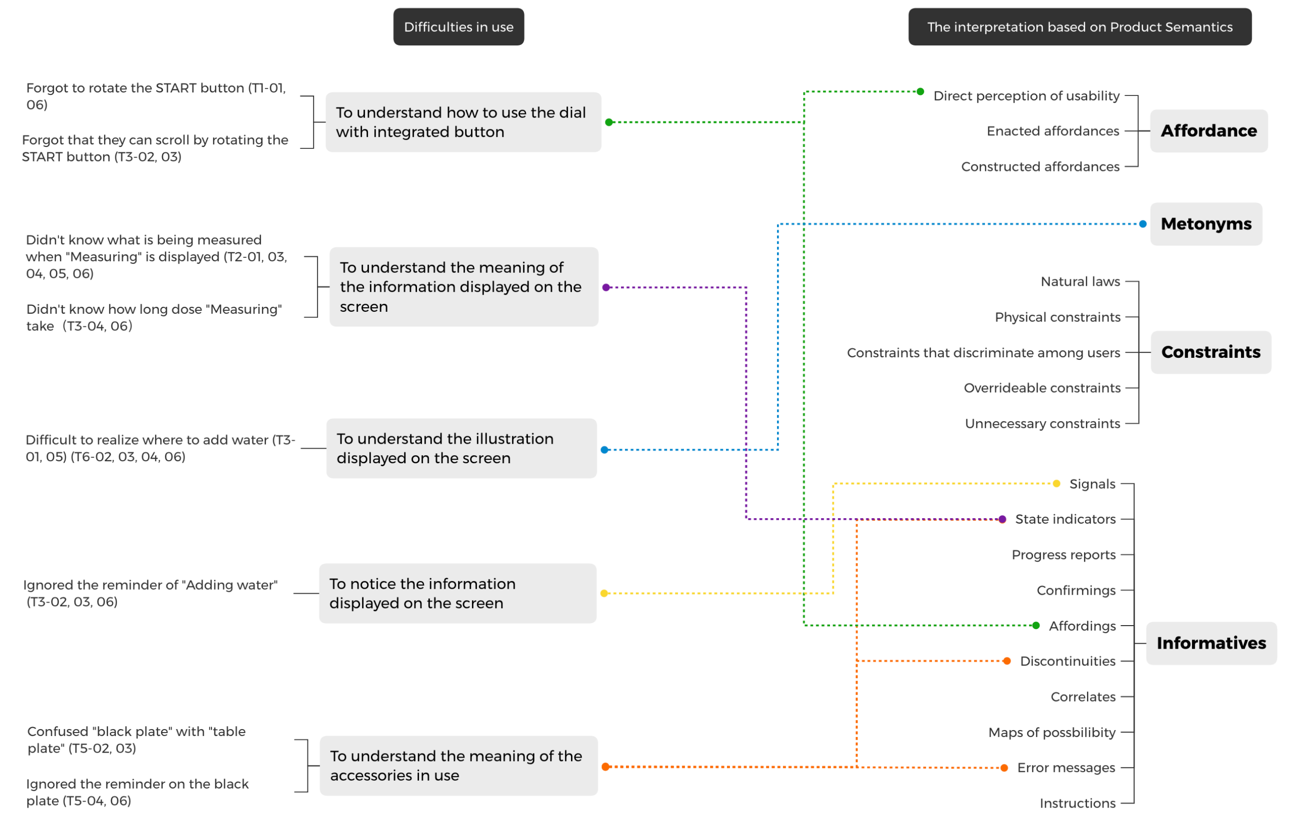

Figure 2. the Interpretation of Difficult-to-use Based on *Product Semantics* Theory

3. Usability Testing: A Case Study

A usability testing for a microwave was conducted with six older adults and a younger adult (3 males, mean age 74.33 yrs., SD 6.31) (Zhong et al., 2020). This microwave carried manual mode, which can be totally set up by the users according to their needs, and also auto menu mode, which provides a lot of recipes to help users cook easily. The participants were asked to perform six tasks using the microwave oven while executing thinking aloud. Since it may be hard to think aloud for some participants, and, at the same time, since we wanted more natural utterances, we gave them enough explanations, showed some demonstrations, and asked them to practice in advance. The interaction between participants and the microwave oven was recorded by three video cameras, including a wearable one, during the tasks. Tasks were: 1. Heat up a stew in a retort pouch (manual mode); 2. Warm up a cup of milk (automatic mode); 3. Defreeze the frozen chicken (automatic mode / Usage of Accessories); 4. Warm up the frozen rice (automatic mode); 5. Cook an herb chicken (automatic mode / Usage of Accessories); 6. Add water into water tank (for whom missed the operation which should be done in task 3: preparations). After tasks, an interview was conducted for further information or clarify the meaning of utterances by the participants in the usability testing.

Generally, the purpose of usability testing is to determine how well people can use the product and what kinds of processes people take as problem-solving. Even though how to execute the testing is rather strictly determined, analytic methods are almost free-format, frequently saying that it depends on contents and contexts of target artifacts. Thus, we think it may be valuable to have a frame of analysis with *product semantics*.

4. The Analysis of Usability Testing Based on Product Semantics

With the frame of *product semantics*, difficulties in use may be clarified easier. After the analysis of protocols and behaviors, we have briefly summarized the results as disruptions with START Button, LED Display, and Accessories in our previous research (Zhong et al., 2020), and specific problems showed up in the usability testing have been picked up, as shown in Fig.2, which also mentioned the information that the microwave oven tried to convey but failed.

Example 1 − Difficult to understand how to use the dial with an integrated button: Product should be expressive about their function and purpose through shape and texture (Boess & Kanis, 2008). However, over half of participants showed their confusion on the START button, including press and rotation two operations, which might provide an incomplete *direct perception of usability*. And even more, some of them tried to turn the page by pressing the upper-half or bottom-half of the button, which indicates that redundant meanings may be caused by the dotted line in the middle could not be understood by the users (see Fig.3 above). So, what if we change its appearances, such as its shape (e.g., arc) or height (see Fig.3 below)? A little change may bring a totally different perception.

Figure 3. START Button - Examples with different arcs.

Example 2 − Difficult to understand the meaning of the information (“Measuring”) on the screen: Almost every participant uttered their queries about the meaning of “Measuring”, which was displayed at some duration just after the START button was pushed. It is a procedure for estimating heating time by detecting the weight and the temperature of the food, meanwhile starting to warm the food in parallel. However, detecting time was usually longer than the users’ expectations, and some participants even canceled within this period. Maybe based on their understanding, the measuring stage was executed BEFORE the heating. In fact, the designers used a status indicator to tell the user the current status (see Fig.4 left). A *state indicator* shows the user what the artifact is presently doing and what mode of operation it is in (Krippendorff, 2006). Still, it confused the users because there is no indication of how long to wait and what the artifact is actually doing. In such cases, the use of *progress report*, which could tell the user how much has been achieved so far, maybe clearer (see Fig.4 right), in addition to the indication that the warming and measuring are occurring simultaneously.

Figure 4. Before and After of “Measuring”

Example 3 − Difficult to understand the meaning of the illustration and information ("Add water") on the screen: The participants might be unfamiliar with the meaning of "add water" itself because it is a quite new function in steam mode, which is uncommon in a usual microwave oven. The indication "Add water" appeared in the task of thawing the chicken (see Fig.5 left). The designers attempted to use the icon of drip for expressing the demand of action "to add water into the water tank." Obviously, it did not work well. Three participants, including the younger adult, ignored this information. This problem can be interpreted as two different situations: (1) users did miss the message on display, or (2) they noticed but intentionally ignored or misunderstood the meaning because they did not know what the sign "add water" exactly means, including that they had no idea where they should add water. The former can be handled with flickering signs (a kind of *signals* which can call attention) or changing positions if needed. As for the latter, tactfully using *correlates*, which bear physical or conceptual correlations between the location of the water tank and the location showed in the display, can help users learn better and faster (see Fig.5 right).

Figure 5. Before and After of "Add water"

Example 4 − Difficult to understand the meaning of accessories in use: The second last task was to cook a dish named "Herb Chicken", which need the usage of black plate for using the grill mode function. As shown in Fig.6, this microwave has many accessories for different modes, in which table plate (default one, mainly for microwave heating mode) and black plate (for grill or oven mode, cannot be used in microwave oven mode) are easily confusing. Although designers used the icons in white and black (*state indicators*) on the screen to match two plates respectively, and even it is carved that it cannot be used in microwave mode on the surface of the black plate (*discontinuities* in features suggest different meanings), when users did not know the differences between heating modes, they may get more confused. In fact, only one participant completed the task smoothly without any intervention. It means that those clues are not conspicuous enough. For this kind of operation with potential dangers, *error messages*, which explain what can be done when an action does not accomplish what the user had intended (Krippendorff, 2006), here the prohibition of the black plate, should be informed in the display if possible, and the design for constraints should be included.

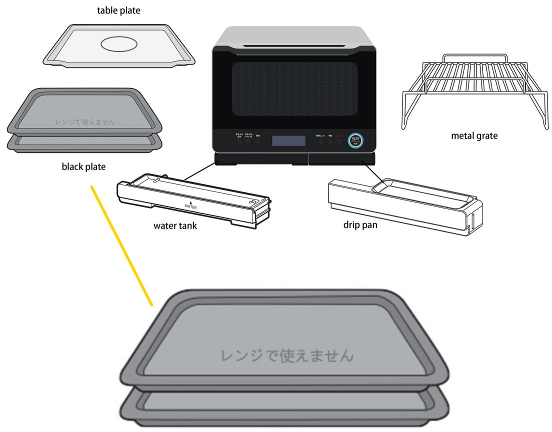

Figure 6. The Accessories

Discussions — Three Problems to apply product semantics to electronic products: Through this research, we also realized that there are some limitations on using the frame of product semantics to understand problems in designs of electronic products.

Firstly, the meanings of today's products, especially electronic products, are no longer as obvious as the simple objects did. They are always accompanied by complicated sequential operations, that is, the feedback of a product is no longer a reaction for one simple operation like press a button, but for a series of actions. Therefore, a new interpretation for the increasingly complex products is needed in product semantics.

Secondly, design characteristics (shapes, materials, colors, etc.) in product semantics can deal with something but not everything, especially for the problems which mainly embody in uses of language. Again, Japanese "add water" in Example 3, which can mean the situation of the water tank but the action of adding water into the water tank.

Last but not least, the hierarchy of context in use also needs to be considered. Nowadays, the improvement of information technology brings the products with different scale, just like the microwave oven in this research. For instance, Example 4 showed users' confusions with the scopes they should take: When should I interact with the microwave itself? When should I use the accessories outside the microwave? Those questions also need to be answered.

5. Conclusion

In this paper, an analytic method of usability testing on electronic products with the frame of *product semantics* is proposed. This method enables rapidly understand where the design should be improved. Since this study only found out "seems like" reasons for difficult-to-use, the validity of the design proposals mentioned above should be verified in future research. Some limitations are also pointed out to develop the theory of *product semantics*, which can explain the usages of electronic products, or information technology-based products. It might be necessary to improve the product semantic theory, or to find out a better interpretation in other design theory, or even other disciplines.

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