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KANSEI MODELING METHODOLOGY FOR MULTISENSORY UX DESIGN

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Abstract

Through a time-series of user experience(UX), multiple senses, such as vision, hearing, and touch, interact with a product. Cross-modal studies have shown that multiple senses interact each other and change their perceptions. In this paper, we propose a Kansei modeling methodology by considering multisensory interactions of UX. In this methodology, we structure the user's Kansei as a cognitive process involving four layers: physical quantity, perceived features, delight factor, and delightful experience. We extract the layered structure for each scene of the user experience. Each scene consists of the user's senses and action. With our modeling methodology, we extract cognitive components involving multimodal integration from comprehensive cognitive structures of the UX. Based on expectation theory as a principle of contextual cross-modal interactions, we identify the tolerance of a perceived feature that satisfies multiple delight factors, involving attractive and must-be qualities in the Kano model. We demonstrate the validity of the methodology with an experiment using of a hair dryer multisensory design.

Keywords: Design methodology, Early design phases, Multisensory product experience, Kansei, Human behaviour in design

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1 INTRODUCTION

In a user's interaction with a product, the user perceives product qualities through his or her multiple senses such as vision, hearing, and touch. Such a quality, the so-called Kansei quality, evokes customer's specific impressions, feelings, or emotions toward a product (e.g., comfort, luxury, or delight) (Yanagisawa 2011). Kano-defined nonlinear quality types are must-be and attractive qualities (Kano et al. 1984). A must-be quality is a quality that the product must have; this includes safety and basic functionality. The attractive quality provides satisfaction when fully achieved, but does not cause dissatisfaction when it is not achieved. Examples are aesthetics and perceived quality. A Kansei quality involves both must-be and attractive features. For example, a product sound must not be too loud or noisy (must-be). On the other hand, a cosy sound makes people feel good (attractive). Effective design with Kansei qualities needs to balance must-be and attractive qualities.

To design using Kansei qualities, engineering designers need to translate them into engineering properties. In a product development context, the word Kansei is often interpreted as a mapping function from sensory stimuli to psychological phenomena. Researchers and practitioners have developed several methodologies and tools to link product attributes and psychological phenomena with industrial applications [e.g., (Nagamachi 2002, Schütte et al. 2004, Yanagisawa 2011)]. Most of the studies model the customer/user Kansei under certain sensory modality conditions.

On the other hand, in the time sequence of user experience (UX) of a product, users switch their sensory modality from one state to another in cyclic interactions involving action, sensation, and meaning, as shown in Figure 1 (Krippendorff 2005). We expect that users will predict subsequent states between such transitions of state. For example, we expect a meal to taste a certain way based on how it looks, the weight of a product before lifting it, or the usability of a mouse by looking at it.

Prior expectation does not always correspond to posterior experience. Such disconfirmation between the expectation and the actual experience induces attention and evokes certain emotions such as surprise (Ludden et al. 2012), satisfaction, or disappointment (Oliver 1977, Oliver 1980, Spreng et al. 1996, Demir et al. 2009, Murakami et al. 2011). Furthermore, prior expectation may affect (i.e., change) the posterior experience. Research studies in many areas have observed such an effect, the so-called expectation effect, under different cognitive processes such as a desire for rewards (Schultz et al. 1997), emotions (Wilson et al. 1989, Geers and Lassiter 1999), and sensory perceptions (Deliza and MacFie 1996, Buckingham *et al.* 2011, Yanagisawa and Takatsuji 2015a). The expectation effect changes the disconfirmation between expectation and experience. Thus, the effect is not only a bias of experience but also a key factor that affects the emotional experiences of a product.

In this paper, we propose a novel Kansei modeling methodology for a time-series multimodal UX. In the methodology, we extract a comprehensive cognitive structure of user Kansei in multisensory interactions between a user and a product. From the cognitive structure, we extract design elements and their perceived features that affect both the must-be and attractive qualities of a product. We formulated functions with respect to the influence of the perceived features on both qualities considering the expectation effect of a prior state in sensory transitions. By applying the functions, we identified the tolerance of perceived features that satisfies both the attractive and must-be qualities. We demonstrate the methodology with a hair dryer as a case product for further discussion because it produces a variety of sensory stimuli sensed in different modalities such as vision, hearing, and touch.

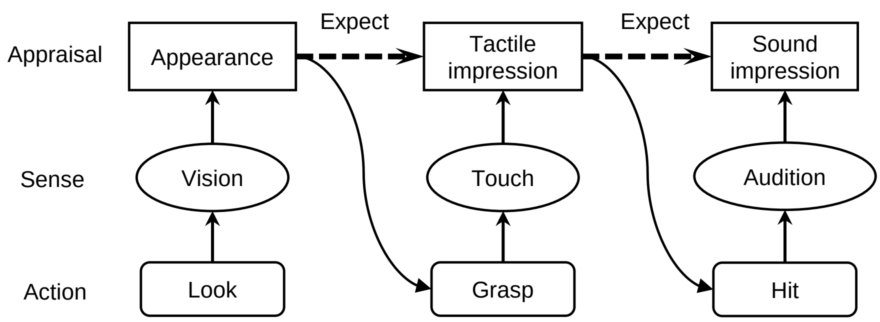

Figure 1 Sensory transitions and expectations in UX

2 A PROCESS MODEL OF USER KANSEI THROUGH INTERACTIONS BETWEEN USER AND PRODUCT

We assume the process model of user Kansei shown in Figure 2 as the basis of our methodology. The upper part represents the physical world involving a product, the user, and an environment. The lower part is the user's mental world, which involves a series of cognitive processes. The cyclic interactions of the user's actions and sensations work as an interface between the physical world and the mental world. The user acts toward the physical world and senses a stimulus from the physical world as a result of that action. For example, the user looks at and touches a product, and obtains visual and tactile sensation as feedback stimuli. Thus, action and sense are complementary.

The user perceives features from the interaction of action and sense. By combining these features, he/she finds certain meanings (Krippendorff 2005). The user evaluates the meaning in a situation [appraisals or estimates (Scherer et al. 2001)] and feels certain emotions. Emotions derive motivations to act toward the physical world (Fukuda 2010) such as approach or avoid (Crilly et al. 2004). This cyclic process continues during the interaction between the user and the product.

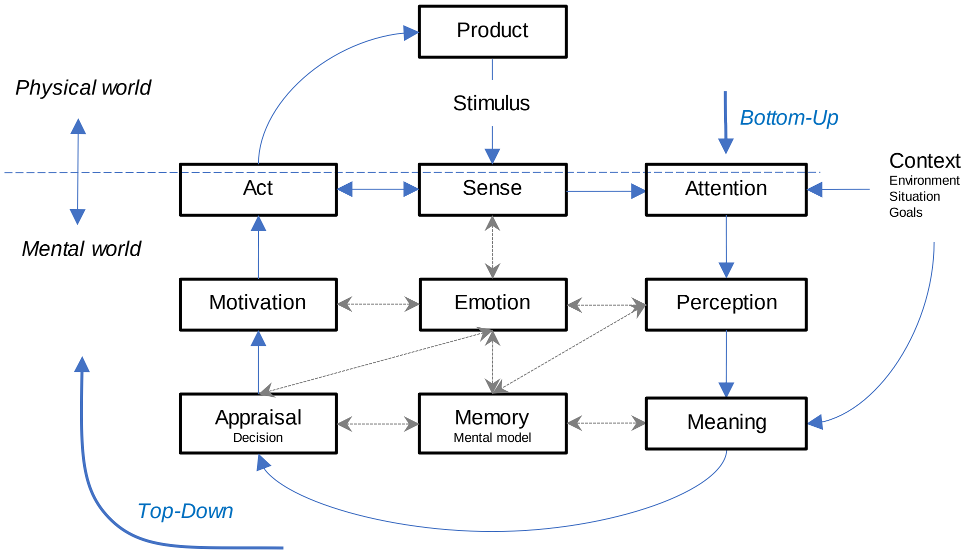

Figure 2 Cyclic process model of user Kansei in user-product interactions

It is mainly led in a bottom-up process in which the perception is driven by the products stimuli, involving so first the senses, then matching the information with the memory for its interpretation, and further achieving some actions(Baddeley 2009). This process can be seen in opposition to a top-down process in which user's behaviour is more influenced by conceptual data. In the bottom-up process, cognition is directed by the perceptual stimuli. This phenomenon is enabling the affordance (Gibson 1966) when our environment can sufficiently supply details related to the stimulus. Some product properties such as the size, shape, weight, colour, or sound, and related perceived quality, functionality, etc., provide some information to the user which does not depend on prior knowledge or past experience. In the top-down process, the user's mental model is built based from memory on past experiences, and the knowledge affects and changes each mental process (Kim *et al.* 2010).

For modelling the top-down process in the specific domain of product experience, a pioneering study was led in the field of packaging design (Smets and Overbeeke 1995). In this study the authors established formal relations between visual shape, colour and taste. The results showed that the users are able to match the taste of desserts and packaging. This means that designers can transpose one sensory modality into another. Results also emphasized a higher impact of colour features on taste perception in this particular context, in comparison to the shape impact (more abstract and learned). Finally, this study proved that designers and users judge design along similar dimensions, but designers are able to make more refined or subtle judgements. Indeed, perceptual training enables to differentiate sensory information more accurately.

There may be a contradiction between both bottom-up and top-down processes when the mental model bias a perceived feature as an expectation effect (Yanagisawa and Takatsuji 2015a, Yanagisawa and Takatsuji 2015b, Yanagisawa 2016). Yanagisawa formalized a computational model of expectation effect (Yanagisawa 2016). In the expectation effect model, perception was formalized as a Bayesian integration of prior distributions (or a mental model in memory) and sensory stimulus based likelihood function. Prior based estimates correspond to top-down process. Sense based estimates correspond to bottom-up. Thus, perception is a result of synthesis of top-down and bottom-up process. Expectation effect is the influence of prior (or mental model) on perception. A mental model interacts with cognitive components such as meanings, appraisals, emotion, and motivation, as well as perception.We assumed that the model can be applied not only to perception but also another cognitive component such as meanings (or semantics).

3 MODELING USER KANSEI STRUCTURE IN MULTISENSORY UX

Based on the process model of user Kansei shown in Figure 2, we model a user's cognitive structure and activities while interacting with a product. Figure 3 shows an example of a structural model that we extracted from the context of using a hair dryer. In Figure 3, the vertical axis represents the user's Kansei structure, whereas the horizontal axis represents the time series. On the bottom part, we placed a series of scenes. Each scene consists of an action-sense pair. For this example, we assumed a series of scene transitions where a user looks at his/her appearance, holds a hair dryer in his/her hand, turns on the switch, uses it to dry his/her hair, and hears the sound of it. For each scene, the user senses different sensory stimuli from the product. Based on the sensory stimuli, the user recognizes design elements such as product attributes and physical phenomena that occur in a scene. For example, a user recognizes the shape and colour by looking, the torque and texture by touching, the machine sound by turning on the switch and listening, and the inertia and hot air by using the product. These design elements are the targets of different expert designers/engineers and include styling, colour, ergonomics, and sound design. At the same time, a user perceives the features of each design element.
Based on a set of perceived features for each scene, the user expects and/or evaluates delight factors. In the example in Figure 4, we extracted four categories of delight factors: functionality, usability, reliability, and perceived quality. For example, the machine sound provides a perceived quality, such as comfort, as well as expectations of functionality such as product performance and reliability.

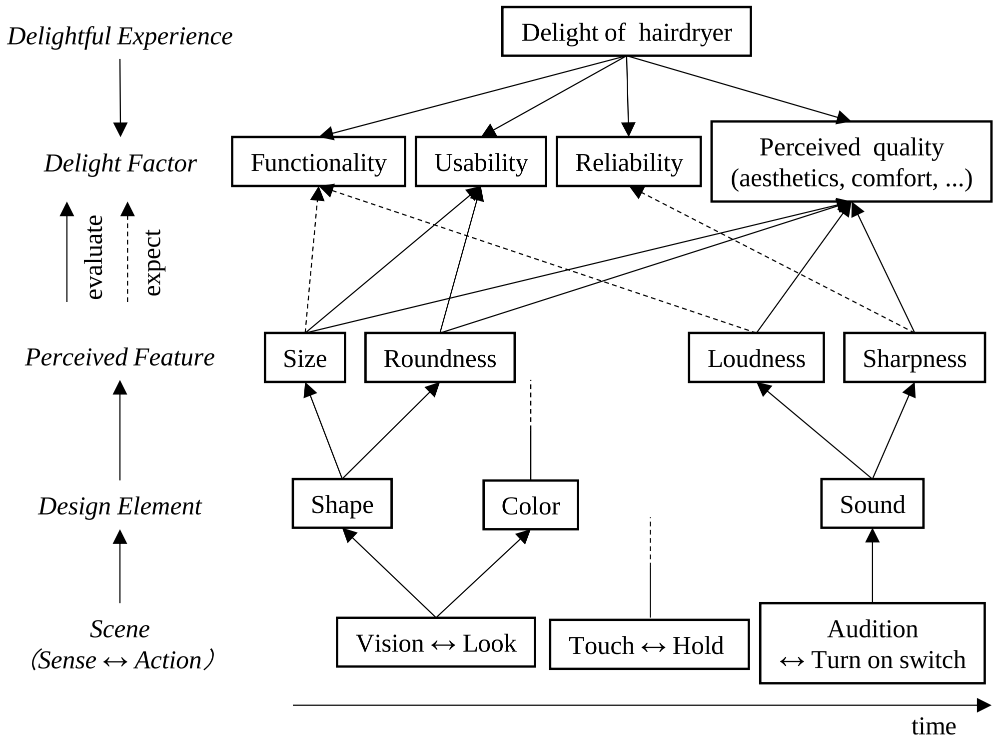

Figure 3 Modeling cognitive structure of user Kansei in UX

To extract the detailed cognitive structure between perceived features and delight factors, we applied a laddering technique based on the personal-construct theory (Sanui and Maruyama 1997). Figure 4 shows an example of an extracted causal structure for two scenes, including a pair with modality and action:

“vision-look” and “audition-turn on switch.” We can categorize the delight factors into must-be and attractive qualities. For example, the annoyance of a noisy sound must be avoided (must-be factor). A powerful impression may attract users because it provides an association with high functionality (attractive factor). Loudness is a perceived quality of a design element (sound) that affects both the attractive and must-be factors. Loud sound gives impressions of being both noisy and powerful.

The size in appearance affects powerful impressions. A large body is associated with a large motor and fan that provide powerful wind. This visual expectation may affect posterior auditory evaluation as an expectation effect.

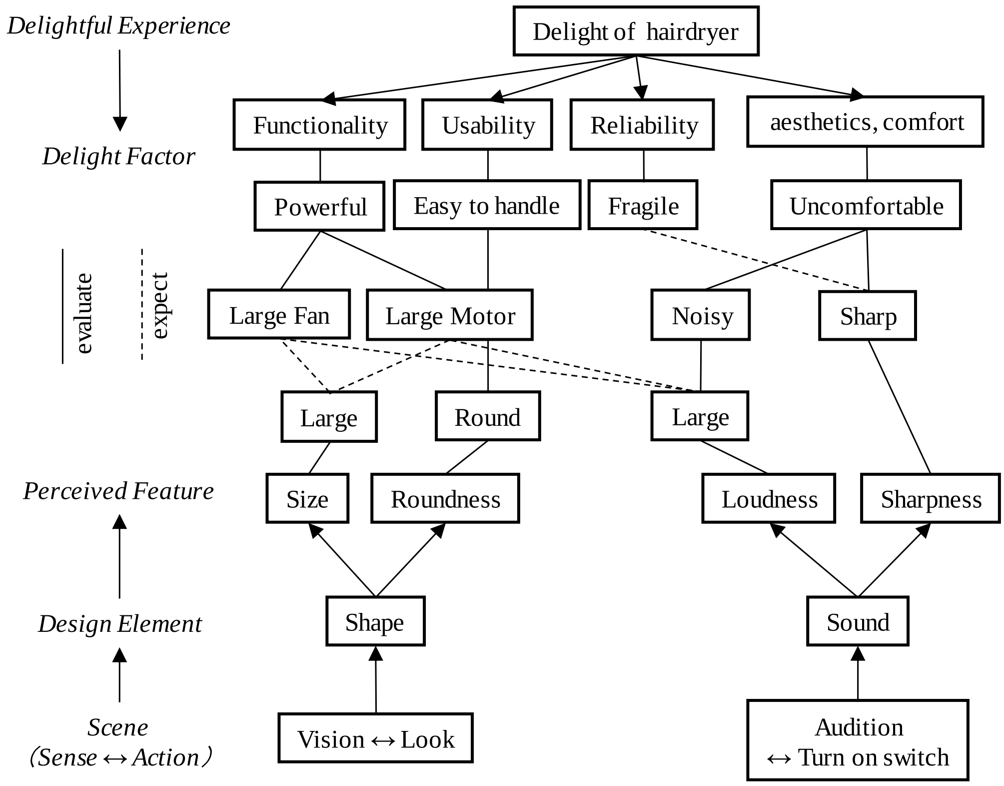

Figure 4 Example of extracted structure between perceived features and delight factors

4 FUNCTION MODEL OF KANSEI EVALUATION WITH EXPECTATION EFFECT

From the cognitive structure model shown in Figure 4, we found that the loudness of sound is a perceived quality that affects both the must-be quality (annoyance) and attractive factors (powerful). In this chapter, we discuss how to identify the tolerance of a perceived quality that satisfies both attractive and must-be factors. In the hair dryer example, we identify the tolerance of loudness that satisfies both avoiding annoyance and providing powerful feelings.

To identify the tolerance, we propose a function model with respect to the effect of a perceived quality on a delight factor. We consider the expectation effect (Yanagisawa and Takatsuji 2015a) in the function model. In case of Figure 6, the body size in appearance provides a visual expectation of “powerful.” This visual expectation affects the posterior auditory evaluation regarding a “powerful” feeling. In conventional studies, two different patterns of expectation effect, contrast and assimilation, were observed (Deliza and MacFie 1996). Contrast is a bias that magnifies the difference between prior expectation and posterior experience. Assimilation is a bias that diminishes expectation incongruence. Yanagisawa formalized a computational model of expectation effect using neural coding principles such as efficient coding and Bayesian decoding. From a computer simulations and experiments based on expectation effect model, he found that the pattern of expectation effect shifted from assimilation to contrast as the prediction error (the difference between predicted and actual value) increased (Yanagisawa 2016).

Based on the model, we hypothesized that the effect of perceived quality on the delight factor shapes the S-curve shown in Figure 5. In Figure 5, the vertical axis denotes the evaluation of the delight factor, whereas the horizontal axis denotes a perceived feature. We hypothesized that the origin of the S-curve corresponds to a level of expectation. In this case, the value of the horizontal axis represents the distance from the expectation level (i.e., prediction error). Based on the characteristic of the expectation effect found in (Ushakov *et al.* 2010, Yanagisawa 2016), we hypothesize that assimilation occurs around the expectation level, shown as greyed box in the figure, and contrast gradually occurs with increasing distance from the origin. Assimilation is a bias where the expectation pull perception in, so that the solid line should be closer to expectation level (the horizontal axis) than the liner dot line. In contrast, contrast is a bias where expectation push perception away, so that the solid curve should be father away from the horizontal axis than the liner line. Therefore, the function should be S-shaped. The slope of the curve comes close to a liner function as the expectation effect decreases.

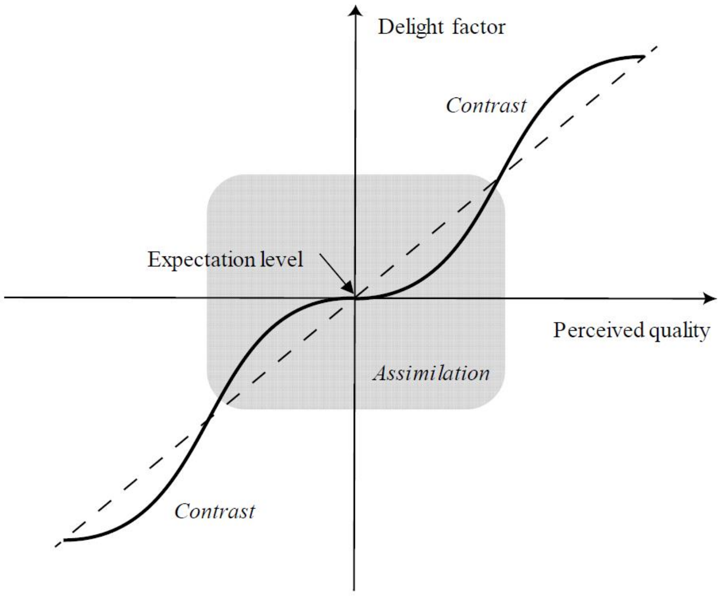

Figure 5 Function model of Kansei evaluation with expectation effect

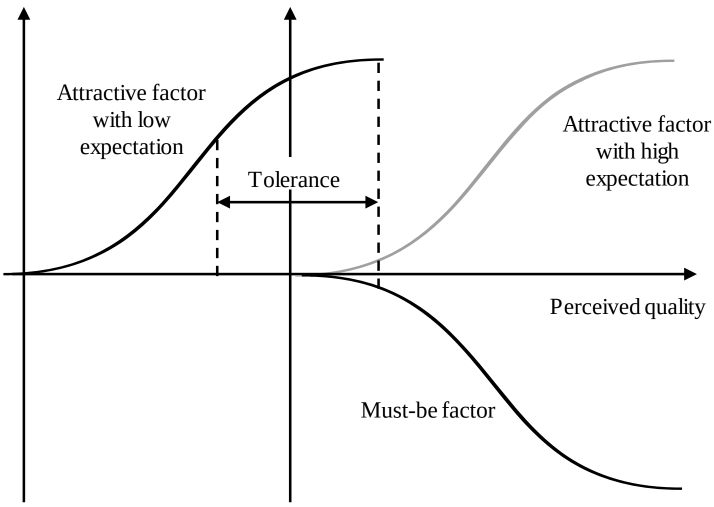

Figure 6 Tolerance of perceived quality that satisfies both attractive and must-be factors

We use the positive part of the S-curve as a function of the attractive factor and the negative part as a function of the must-be quality. If a perceived quality affects both an increasing attractive factor and a decreasing must-be factor, we need to balance the two factors. One idea to break through the trade-off issue is to shift the S-curve toward the horizontal axis by manipulating the prior expectation. For the hair dryer example, the loudness increases both the annoyance and powerful feeling. The body size in appearance increases the expectation of powerfulness. Thus, a decreasing body size in appearance decreases the expectation level of powerfulness and shifts the S-curve of the powerful feeling toward the left, as shown in Figure 6. As a result, the tolerance of loudness that satisfies both the attractive and must-be factors increases.

5 EXPERIMENT: EXPECTATION EFFECT ON DELIGHT FACTORS AND TOLERANCE IDENTIFICATION

5.1 Method

We conducted an experiment with participants by using hair dryers to validate the function model of the delight factor involving the expectation effect hypothesized in the previous chapter. As we discussed in previous chapters, we assumed that the loudness affected both annoyance and the powerful impression, and the body size in appearance provided a prior expectation regarding a powerful feeling. We asked participants to provide responses with regard to annoyance and the powerfulness of the hair dryer sound after showing its appearance. We prepared a typical hair dryer sound with different loudness levels as stimuli. We manipulated the expectation level by adjusting the body size of the hair dryer in appearance. Participants responded for all combinations of loudness and body size so that we could investigate the influence of the visual expectation effect on the delight factors as functions of loudness.

5.2 Materials

Figure 7 shows photographs of hair dryers that we used as visual priors. We used a typical hair dryer (Panasonic, EH-NA96) and modified the body size by using image processing. A sample with a big body is approximately two times as large as the original. The small sample is approximately half the size of the original. We presented each photo on a monitor (EIZO, CG222W). For sound stimuli, we used a stationary sound recorded using a microphone near a typical hair dryer (TESCOM, TID2000). We prepared 10 levels of loudness ranging from 8 to 22 sone. We presented each sound by using a stereophonic sound environment (Xite-3D Pro) so that the position of the sound source was assigned to the visual prior.

Small size *Original* *Big size*

Figure 7 Visual priors of a hair dryer

5.3 Participants

Eight male volunteers aged 21 to 24 years served as experiment evaluators. They were undergraduate or graduate students studying mechanical engineering at the University of Tokyo. All participants were physically healthy.

5.4 Procedure

The participants were invited individually into the isolated test room. Each participant was seated on a chair in front of the monitor, which was set on a table. After agreeing to informed consent, the participants received written instructions for the procedure. We conducted the following two sessions:
First session: We presented each hair dryer photo to the participants and asked them to predict how big the sound was for each. We played the hair dryer sound and gradually decreased the volume so that the loudness ranged from 22 to 8 sone. Each sound was played for 2 s. After the participants responded, we played the hair dryer sound again and gradually increased the volume so that the loudness ranged from 8 to 22 sone. We asked the participants to respond when the sound matched their prediction during the

increasing and decreasing sessions. We used an average score of the two responses to loudness as predicted by looking at the appearance.

Second session: We presented a photo of a hair dryer with the predicted sound for 2 s as a prior. After presenting the prior, we played a sound stimulus involving a loudness randomly selected from the 10 levels between 8 and 22 sone. We asked the participants to respond their feeling with respect to words “powerful” and “noisy” for each stimulus sound. For each word, the participants responded whether they felt or not. The duration of the sound stimulus was 2 s. We repeated the abovementioned trial for all combinations of three priors (photo and predicted sound) and the 10-s stimulus. Thus, the total was 30 trials.

5.5 Results and discussion

Figure 8 shows the average scores of loudness that participants predicted for each hair dryer photo. The predicted loudness tends to increase as the body size in appearance increases. We found that the body size had a significant effect on the loudness predictions [$p < 0.001$, $F = 3.47$]. We conducted a pairwise comparison between each body size and found significant differences between the small size and the original [$p = 0.001$], the small size and big size [$p < 0.001$], and the original and big size [$p = 0.005$].

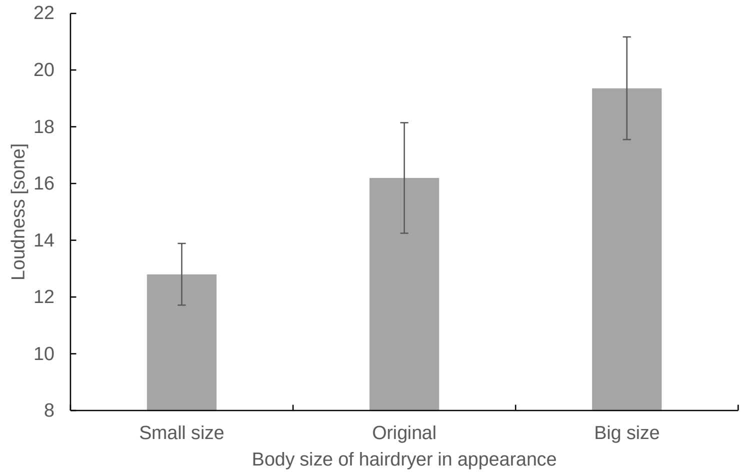

Figure 8 Average loudness predicted by body size in appearance

Figure 9 shows the frequency rates of participants who responded “powerful” or “noisy” for each sound stimulus as a function of loudness. Different plots denote different body sizes in appearance. The red plot denotes a response of “noisy,” and the blue plot denotes a response of “powerful.” We applied the following logistic function in Equation (1) to fit these plots for each condition:

$$p = \frac{1}{1 + \exp(-\alpha - \beta \cdot loudness)} \quad (1)$$

where p is the frequency rate of the responses, and α, β are coefficients. The logistic functions shape the S-curve. We assumed that the logistic function fits to the function model as discussed in the previous chapter. The logit of p forms a linear function as shown in Equation (2):

$$\mathrm{logit}(p) = \ln\left(\frac{p}{1-p}\right) = \alpha + \beta \cdot loudness \quad (2)$$

We can apply the least square method to estimate the coefficients.

For “powerful” responses, the slope of the curves decreases as the body size increases. The loudness level at which the response rate rises increases as the body size increases. Participants expected a more powerful sound for a bigger body than a smaller one. As we hypothesized, the visual expectation affected the loudness level at which participants evaluated the loudness as “powerful.” A higher expectation of “powerful” for a big body in appearance increased the loudness level. In particular, the small-sized body provided a powerful impression for a sound of lower loudness. For example, at 16 sone, half of the

participants responded that the sound was powerful for a small size body, but no one responded the same for a big-sized body.
Although the slope of the "noisy" curve tends to decrease as the body size increases, the difference is smaller than in the "powerful" case. We hypothesized that the level of "noisy" cannot be accurately predicted with body size (Figure 6). An uncertain expectation does not provide a prominent bias of the expectation effect(Yanagisawa 2016). Such an asymmetric nature regarding the extent of the expectation effect provides a tolerance of perceived quality that satisfies both the attractive and must-be factors. In the case of Figure 9, we can say that the range from 14 and 18 sone is a tolerance of loudness that provides a powerful feeling and avoids annoyance with a small-sized body in appearance.
Results of both "powerful" and "noisy" demonstrated that the function model based on the expectation effect can be applied not only to perception but to higher cognitive components such as meaning (or semantics).

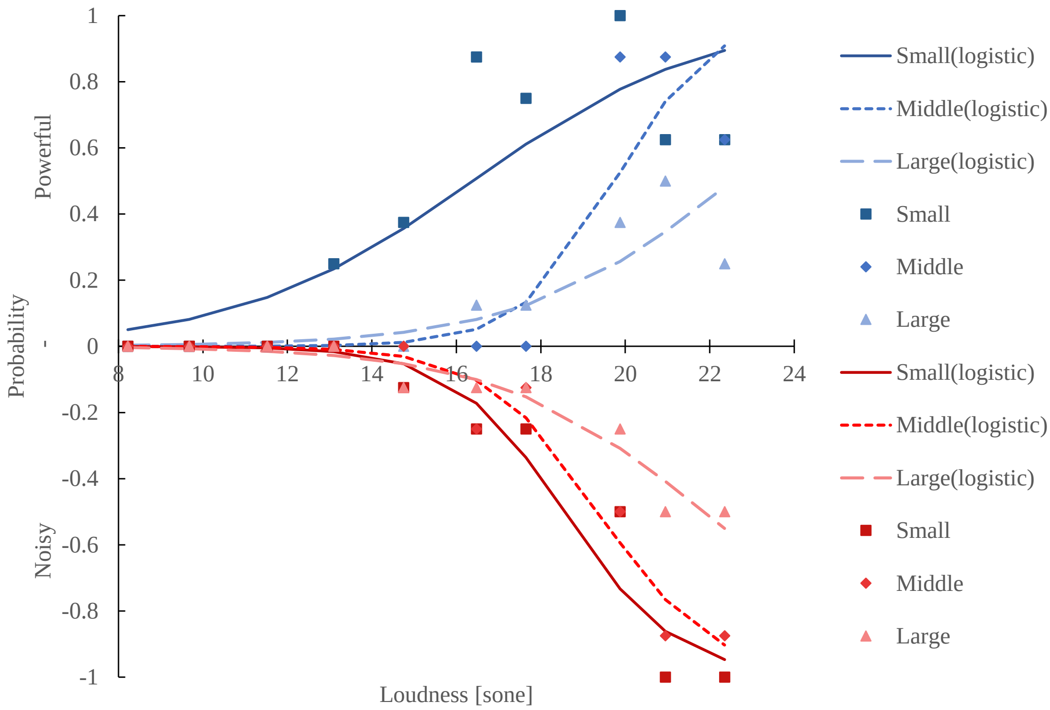

Figure 9 Frequency rate of "powerful" and "noisy" responses as a function of loudness for body size in appearance

6 CONCLUSIONS

We proposed a Kansei modeling methodology for multisensory UX. With the methodology, we modeled a comprehensive cognitive structure of a user's Kansei in a time series of user-product interactions. We demonstrated that the model helps designer to extract 1) design elements and perceived features that affect both the attractive and must-be qualities, and 2) a set of scenes that affect the common delight factor. To identify a tolerance for perceived features, we proposed a function model of a delight factor based on an expectation effect model validated at perception level in our previous studies (Yanagisawa 2016). From an experiment using a hair dryer in this study, we demonstrated that the model can be applied to semantic level (or meaning in Figure 2) such as "powerful". With the model. we identified the tolerance of loudness that satisfied both the powerful feeling and annoyance avoidance. We found that the tolerance differed depending on the body size in appearance as a visual prior. Therefore, we can apply the expectation effect to increase the tolerance.

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