A methodology for extracting expectation effect in user-product interactions for multisensory experience design

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Received: 1 August 2018; Revised: 3 January 2019; Accepted: 7 February 2019

Abstract
The study proposes a methodology for extracting and applying expectation effect in multisensory user–product interaction to balance the design attributes that satisfy must-be and attractive qualities in the Kano model. Satisfying both qualities is assumed to be an objective of product design. This study modeled users’ cognitive process of cyclic user–product interactions. Using the model, the proposed method extracts users’ cognitive structure and state transitions while interacting with a product. The cognitive structure reveals the design attributes affecting must-be and attractive qualities as well as prior cue of the expectations of these qualities. Tolerance for design attributes to satisfy both qualities and the expectation effect of prior factors are discussed. The methodology is validated using a hair dryer as a case product. Another case product (camera) demonstrates how cognitive cues work as well as sensory cues as expectation effect. The proposed methodology supports designers and researchers in structuring multisensory user–product interactions as a series of state transitions of users’ cognitive model. The structure helps to extract product attributes that affect both attractive and must-be perceived qualities and attributes involving expectation effect on product qualities. The method of experiment 1 can be applied to assess tolerance for product attributes to satisfy perceived qualities. The method of experiment 2 can be applied to assess the effect of prior expectation induced by both sensory and cognitive attributes, such as a product class, on perceived quality.

Keywords: Design, Product, Kansei, Emotion, Experience, Expectation, Multisensory, Cross-modal, Sound

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 qualities, the so-called perceived qualities, evoke consumers’ 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, Seraku, Takahashi and Tsuji, 1984). As Figure 1 shows, a must-be quality is a quality that a product must have, including safety and basic functionality, whereas an attractive quality provides satisfaction when fully achieved but does not cause dissatisfaction otherwise. Examples of an attractive quality are aesthetic pleasure and comfort. A perceived quality involves both must-be and attractive features. For example, a product’s sound must not be too loud or noisy (must-be), but may or may not have a cozy sound, which makes people feel good (attractive). Effective design thus needs to balance must-be and attractive qualities.
To design with perceived qualities, engineering designers, for example, need to translate them into engineering properties. In a product development context, the Japanese term *kansei* is often used to mean mapping functions from sensory stimuli to psychological phenomena, such as perception and emotions. Researchers and practitioners in *kansei* engineering have developed several methodologies and tools to link product attributes and psychological phenomena with industrial applications (Nagamachi, 2002; Schütte, Eklund, Axelsson and Nagamachi, 2004; Yanagisawa, 2011). Most of the existing studies model customer/user *kansei* under certain sensory modality conditions.

In the time sequence of user–product interaction, users switch their sensory modality from one state to another in cyclic interactions involving action, sensation and meaning (Krippendorff, 2005). Users are expected to predict subsequent states between such transitions of state. For example, consumers 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.

However, prior expectation does not always correspond to posterior experience. Such disconfirmation between expectation and actual experience induces attention and evokes certain emotions, such as surprise (Ludden, Schifferstein and Hekkert, 2012; Yanagisawa et al., 2019), satisfaction, or disappointment (Demir, Desmet and Hekkert, 2009; Murakami, Nakagawa and Yanagisawa, 2011; R.L. Oliver, 1977; Richard L. Oliver, 1980; Spreng, MacKenzie and Olshavsky, 1996). Prior expectation may also affect (i.e., change) the posterior experience. Researchers in many areas have observed such an effect, the so-called expectation effect, under different cognitive processes, such as a desire for rewards (Schultz, Dayan and Montague, 1997), emotions (Geers and Lassiter, 1999; Wilson, Lisle, Kraft and Wetzel, 1989) and sensory perceptions (Buckingham, Ranger and Goodale, 2011; Deliza and MacFie, 1996; Yanagisawa and Takatsuji, 2015). Figure 2 shows the relation of expectation disconfirmation and expectation effect. 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. However, methodologies to apply the expectation effect to a product experience design have not been developed.
In this paper, we propose a methodology to extract expectation effect in time-series multisensory user–product interactions and then apply the effect to improve perceived qualities. 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. By applying the notion of expectation effect, we identify the tolerance for perceived features that satisfy both attractive and must-be qualities. We demonstrate the methodology with a hair dryer as a case product for further discussion because a hair dryer produces a variety of sensory stimuli sensed in different modalities, such as vision, hearing and touch. We show that cognitive cues, such as product category, work as expectation effect on the evaluation of perceived qualities, using a camera shutter sound as a case study.

2. Process model of user Kansei through user–product interactions

We assume the process model of user kansei (Yanagisawa et al., 2016b) shown in Figure 3 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 serve as an interface between the physical and mental worlds. The user acts toward the physical world and senses a stimulus from the physical world as a result of such action. For example, the user looks at and touches a product, and obtains visual and tactile sensation as feedback stimuli. Thus, action and sensation are complementary.

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

The user’s mental model is built based on past experiences, whereby knowledge affects and changes each mental process. A mental model can bias a perceived feature as an expectation effect (Yanagisawa, 2016a; Yanagisawa and Takatsuji, 2015a, 2015b). Yanagisawa (2016a) formalized a computational model for expectation effect shown in Figure 4. In the expectation effect model, perception is 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 a top-down process, whereas sense-based estimates correspond to a bottom-up one. Thus, perception is a result of the synthesis of top-down and bottom-up processes. Expectation effect is the influence of prior estimates (or mental model) on perception. A mental model interacts with cognitive components, such as meanings, appraisals, emotion and motivation, as well as perception. Although the expectation effect model has been validated only in perception, the model can be applied to other cognitive components, such as meanings (or semantics).

![Fig. 3 Process model of user Kansei](image-url)
3. **Modeling user cognitive structure in multisensory user–product interaction**

Based on the process model of user *kansei* shown in Figure 3, we model a user’s cognitive structure and activities while interacting with a product. Figure 5 shows an example of a structural model extracted from the context of using a hair dryer: the vertical axis represents the user’s hierarchical cognitive structure, whereas the horizontal axis represents the time series. The bottom part of Figure 5 lists a series of scenes composed of action–sense pairs. 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 the machine. 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 color of the hair dryer 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 operating the product. These design elements are the targets of different expert designers/engineers and include styling, color, ergonomics and sound design. 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 perceived qualities that affect total perceived experience. In the example in Figure 5, we assumed four categories of perceived qualities: usability, functionality, comfort and reliability. For example, the machine sound may affect comfort, as well as expectations of functionality, such as product performance and reliability.
To extract the detailed cognitive structure between perceived features and perceived qualities, we applied a laddering technique based on personal-construct theory (Sanui and Maruyama, 1997). Figure 6 shows an example of an extracted cognitive structure between the perceived qualities and the perceived features for two scenes, including a pair with modality and action: “vision–look” and “audition–turn on switch.” We can categorize the perceived qualities into must-be and attractive qualities of the Kano model. In figure 6, the boxes with bold lines represent attractive qualities, and the boxes of dashed lines represents must-be qualities. For example, the annoyance of a noisy sound must be avoided (must-be quality). A powerful impression may attract users because it provides an association with high functionality (attractive quality). Loudness is a perceived feature of a design element (sound) that affects both attractive and must-be qualities. A loud sound gives the impression of being both noisy and powerful. The size in appearance likewise affects powerful impressions. A large body is associated with a large motor and fan that can provide powerful wind. This visual expectation may affect posterior auditory evaluation as an expectation effect.

Fig. 5 User's cognitive structure and activities in user–product interactions
4. Expectation effect and tolerance identification

Prior expectation affects posterior perceived experience due to the expectation effect. In a sensory transition in a product experience, such as from vision to hearing, users expect and evaluate perceived qualities based on perceived features in each sensory scene. For example, section 3, we extracted a cognitive structure where both body size as visual cue and sound loudness are associated with powerful feeling. With the notion of expectation effect, we hypothesize that the prior expectation of powerful feeling associated with visual body size affects posterior powerful feeling evaluation as a function of sound loudness.

In previous studies, two different patterns of expectation effect, namely, contrast and assimilation, were observed (Deliza and MacFie, 1996). Contrast is a bias that magnifies the difference between prior expectation and posterior perception. Assimilation is the other way around: a bias that diminishes the difference. If expectation effect is contrasting, then a low expectation leads to a high perception. For example, the less powerful feeling a user expects from a small body size, the more powerful feeling s/he perceives with respect to the same loudness. If expectation effect is assimilating, then opposite case occurs: the less powerful feeling s/he expects with a smaller size, the less powerful feeling s/he evaluates with respect to the same loudness sound.

If a perceived feature both increases attractive quality and decreases must-be quality, then a way to balance the two qualities is needed. Expectation effect can be applied to break through the trade-off issue. For the hair dryer example, loudness increases both annoyance and powerful feeling. The body size increases the expectation of powerful feeling. If contrast occurs, a smaller body size provides lower expectation of powerful feeling and shifts the function of loudness, thereby increasing positive evaluation, as shown in Figure 7. As such, the tolerance for loudness that satisfies both powerful feeling and not being noisy increases. In contrast, if assimilation occurs, a bigger body size increases the evaluation of powerful feeling. Consequently, tolerance decreases.

(Yanagisawa, 2016a) found that the pattern of expectation effect shifted from assimilation to contrast as the prediction error (the difference between expected and actual value) by using a computational model of expectation effect. More than certain prediction error causes contrast, whereas small prediction error causes assimilation. This trend corresponds to an experimental model (Ushakov, Dubkov and Spagnolo, 2010).

Therefore, prediction error between prior expectation and posterior experience is an important factor to ensure the tolerance level with expectation effect. The experiments in this study show how prior expectation alters posterior
evaluation to ensure tolerance.

![Expectation effect on perceived quality evaluation and tolerance for perceived feature that satisfies both attractive and must-be qualities](image)

5. **Experiment 1: expectation effect of perceived feature on perceived quality and tolerance assurance**

5.1 **Method**

From the user’s cognitive structure and activities in user–product interaction shown in Figure 6, we assumed that loudness as a perceived feature affected both annoyance (must-be quality) and powerful feeling (attractive quality), whereas body size as appearance provided a prior expectation regarding powerful feeling. In this experiment, we quantitatively assessed the visual expectation effect on both perceived qualities as a function of loudness and then determined the tolerance to satisfy both qualities. Participants were asked to provide responses with regard to annoyance and powerfulness of the hair dryer sound after being shown its appearance. We prepared a typical hair dryer sound with different loudness levels as auditory stimuli. We manipulated the expectation level by adjusting the body size of the hair dryer in appearance. The participants responded for all combinations of loudness and body size. The responses for the same loudness sound were compared between different expectations and different sizes in appearance.

5.2 **Materials**

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

5.4 Procedure

The participants were invited individually into an isolated test room. Each participant was seated on a chair in front of a monitor, which was set on a table. After providing informed consent, the participants received written instructions for the procedure.

The experiment involved the following two sessions. In the first session, we assessed loudness expected from different body sizes in appearance. We presented each hair dryer photo to the participants. The participants were asked to predict how big the sound was for each dryer. We played the hair dryer sound clip and gradually decreased the volume so that the loudness ranged from 22 to 8 sone. Each volume level 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. The participants were asked 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.

In the second session, we assessed the expectation effect of body size on the two perceived qualities. We presented a photo of a hair dryer on the screen 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. The participants were asked to respond whether they felt “powerful” or “noisy” for each stimulus. The duration of the sound stimulus was 2 s. The abovementioned trial was repeated for all combinations of three priors (photo and predicted sound) and the 10-second stimulus. Thus, the total was 30 trials.

5.5 Results

Figure 9 lists the average scores of loudness that the participants predicted for each hair dryer photo. The predicted loudness tended to increase as the body size appearance increased. Body size had a significant effect on the loudness predictions ($p < 0.001$, $F = 3.47$). A pairwise comparison between each body size revealed 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 10 gives the number of participants who responded “powerful” as a function of loudness for each size in appearance. The distributions for each body size appearance were different. For the small size, the number of responses started to rise from a loudness of 13.1 sone. More than half of the participants responded “powerful” with respect to sounds of loudness ranging from 16.475 to 22.35 sone. For the middle body size, the range of the responses shifted to the left where loudness is from 19.875 to 22.35 sone. For the big size in appearance, the range of responses was similar to the case of the middle size. The number of responses for the big body size was lower than that for the other sizes. For all loudness levels, except 20.95 sone, less than half of the participants did not respond “powerful.” On the whole, the small body size provided a powerful feeling from less loudness compared with the bigger body size.

Figure 11 shows the number of participants who responded “noisy” as a function of loudness level for each body size appearance. The distributions for each body size were similar among all body sizes. More than half of the participants responded “noisy” to both loudness levels of 20.95 and 22.35 sone with respect to all body sizes. Half of the participants responded “noisy” to a loudness of 19.875 sone in both small and middle sizes. The big size had fewer responses compared with the other size conditions.
5.6 Discussion

The experiment confirmed that body size appearance works as a cue for predicting sound loudness. The smaller body size the participants saw, the less loudness they predicted. For the responses of powerful feeling as a function of sound loudness, we observed that the smaller body size elicited “less loud” responses from the participants. This result suggests that visual expectation of the body size works as contrast effect, in which prediction error is amplified in participants’ perceptions. Meanwhile, for the responses on “noisy” feeling, expectation effect could not be determined. A previous study suggested that uncertain expectations provide only a small extent of expectation effect (Yanagisawa, 2016a). As assumed, the participants hardly predicted the “noisy” feeling of sound based only on body size. The participants expected powerful feeling with the appearance of body size, affirming the contrast effect.

As we discussed in the previous section, in contrast effect, a smaller expectation provides bigger tolerance for the perceived feature that satisfies attractive and must-be qualities. In the case of the hair dryer, the smaller body size provided more tolerance for loudness that satisfies both “powerful” feeling and “not being noisy.” Indeed, Figures 10 and 11 show that more than half of the participants were satisfied with both qualities in loudness ranging from 16.475 to 17.65 sone when the body size was small. Meanwhile, when the body size was either middle or big, loudness ranging from 19.875 to 22.35 sone provided a “powerful feeling” but was deemed “noisy” as well. Thus, the small body size involved more tolerance for loudness. This result supports our hypothesis.

These results suggest that the visual attribute, such as body size appearance, can be an important factor to guarantee the tolerance for auditory attributes, such as loudness, for the satisfaction of both attractive and must-be qualities.

6. Experiment 2: expectation effect of cognitive attribute

A product consists of cognitive attributes, such as product category and brand, as well as physical design parameters (e.g., size and loudness). Experiment 2 investigated the expectation effect of cognitive attributes on perceived feature evaluation.

We used a digital camera as a case product. We focused on releasing a shutter as a user’s action because the action triggers the main function of a digital camera: taking a photo. Before and after releasing the shutter were assumed as prior and posterior experiences. Before releasing the shutter, a user can recognize a product class, such as full-size SLR or compact camera, based on visual and tactile information. After releasing the shutter, the user hears a shutter sound as a sensory feedback. A product sound, such as a shutter sound, is regarded as an important factor that provides a sensory pleasure experience and image of the product. The gap between expected and actual shutter sound may affect a customer’s satisfaction. For example, high-class and full-size SLR cameras can be expected to give a low-pitch, massive sound. Customers may be disappointed if a full-size SLR camera gives a high-pitch, light sound. We hypothesize that a product class provides a cue of prior expectation, which affects posterior shutter sound impressions, such as massive feeling, as...
an expectation effect.

6.1 Method

We compared participants’ responses of “massive–light” feeling between all combinations of camera bodies from different product classes and different pitch shutter sounds. The participants evaluated each shutter sound sample using an even-levels Likert scale: “very massive,” “massive,” “kind of massive,” “neither massive nor light,” “kind of light,” “light,” and “very light.” As a control condition, participants evaluated each shutter sound sample only, without knowing the product class (blind evaluation). We evaluated expectation effect by comparing with responses of the blind condition.

6.2 Materials

To control for product class, we prepared three camera bodies: a full-size single-lens reflex (SLR) camera (Cannon EOS 5D Mark II), a compact SLR camera (Cannon EOSS KISS X3) and a smartphone (Sony Ericson Xperia S0-01C) as shown in Figure 12. Expectation of massive feeling of shutter sound was assumed to decrease in the order of the full-size SLR, compact SLR and smartphone. We embedded a pressure sensor to trigger the playing of given shutter sounds from a headphone. As for the shutter sound, we recorded a typical SLR shutter sound (Sony A7 Mk2) and manipulated the sound pressure level of the high and low frequency bands. We deemed the level of less than 100 Hz as the low-pitched band and that of more than 100 Hz as the high-pitched band. Five shutter sound samples were created for each band, as shown in Table 1, so that the massive–light feeling differs gradually from sample #1 to #7.

Table 1 Amplification degree of high- and low-pitched bands (dB)

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-pitched band</td>
<td>+5</td>
<td>+3</td>
<td>0</td>
<td>-3</td>
<td>-5</td>
</tr>
<tr>
<td>Low-pitched band</td>
<td>-5</td>
<td>-3</td>
<td>0</td>
<td>+3</td>
<td>+5</td>
</tr>
</tbody>
</table>

(a) full-size SLR camera (b) Compact SLR camera (c) Smartphone

Fig. 12 Three camera bodies used as priors

6.3 Participants

Ten male volunteers aged 22 to 25 years served as experiment evaluators. All participants are different from the experiment 1. They were undergraduate or graduate students studying mechanical engineering at the University of Tokyo. All participants were physically healthy. Regardless the participants’ prior experience of using camera, we assumed that the lower-pitched shutter sound generally makes more massive impression than the higher-pitched shutter sound.

6.4 Procedure

The participants were invited individually into an isolated test room. Each participant was seated on a chair in front of a table. After providing informed consent, the participants received written instructions for the procedure. In the blind session, the participants listened to the five shutter sound samples from a headphone. The participants were asked to indicate the extent of their “massive–light” feeling using the Likert scale for each sample. The participants evaluated the five shutter sound samples with different body types with five-minute break intervals. For each trial, the participants were asked to hold a camera body and then press the shutter button. Participants listened to a sound sample and indicated their feeling using the Likert scale. In both sessions, each shutter sound was presented three times. The order was randomized.
We inserted a white noise clip between trials to avoid ordering effect.

6.5 Results

Figure 13 shows the average responses of “massive–light” for each sample; different color bars represent different conditions of body type, including the blind condition. Participants evaluated the high-pitch sound sample (#1 and #2) as “light” and the low-pitch sound, “massive.”

We conducted two-way repeated measures ANOVA with sound sample and body type as independent variables, and “massive-light” scores as the dependent variable. Both sound sample \([F(4,1007.5) = 1284.1, \ p < .001]\) and body type \([F(3,39.2) = 49.9, \ p < .001]\) showed significant main effects on “massive-light” responses. The interaction between sound sample and body type was not significant \([F(16, 3.47) = 1.27, \ p = .23]\). Table 2 shows the results of Bonferroni-corrected paired comparisons of the average scores between body types. Significant differences were seen between all pairs, although the difference between the blind and compact SLR conditions was marginal.

![Fig. 13 “Massive–light” scores for each combination of different pitch shutter sounds and expectation cues (blind, different product class)](image)

**Table 2 Statistical differences between expectation cues (blind, different product class)**

<table>
<thead>
<tr>
<th>Paired body-types</th>
<th>Difference</th>
<th>F-value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blind Full-size SLR</td>
<td>0.3111</td>
<td>5.2684</td>
<td>0.0000</td>
</tr>
<tr>
<td>Blind Compact SLR</td>
<td>0.1356</td>
<td>2.2955</td>
<td>0.0994</td>
</tr>
<tr>
<td>Blind Smartphone</td>
<td>0.3978</td>
<td>6.7360</td>
<td>0.0000</td>
</tr>
<tr>
<td>Full-size SLR Compact SLR</td>
<td>0.4467</td>
<td>7.5639</td>
<td>0.0000</td>
</tr>
<tr>
<td>Full-size SLR Smartphone</td>
<td>0.7089</td>
<td>12.0044</td>
<td>0.0000</td>
</tr>
<tr>
<td>Compact SLR Smartphone</td>
<td>0.2622</td>
<td>4.4405</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Note: SLR=Single-lens reflex

The expectation effect is highlighted in Figure 14, which provides the difference in the scores between each body type condition and blind condition for each sound sample. In the figure, the positive values indicate that the participants reported “massive” more compared with the same sound sample in the blind condition. Meanwhile, the negative values represent the other way around: less massive than same sound sample in the blind condition. We used the score differences as the extent of the expectation effect. For all sound samples, the extent of expectation effect increased as body size decreased from full-size SLR to smartphone.
7. Discussion

The participants evaluated lower pitch shutter sound as more massive. Statistical differences were noted in the score between all conditions of expectation cues, with an exception for that between blind and compact SLR conditions (Table 2). These results supported our hypothesis that a product class recognized with body type affects massive–light evaluation of shutter sound as expectation effect.

The difference in the massive score from the blind condition increased as body size decreased (Fig. 14). The smartphone provided more massive impression to the same shutter sound samples compared with the blind condition. In contrast, the full-size SLR provided less massive impression to the same shutter sound samples compared with the blind condition. We could assume that the participants expected a smaller body size, such as a smartphone, to be less massive in shutter sound than they would a bigger body size, such as a full-size SLR. Thus, the differences between the expected and actual sounds were amplified. In other words, the contrast effect occurred as an expectation effect. As a result, the participants evaluated a massive feeling for the same shutter sound with a smaller body size (smartphone) than a bigger one (full-size SLR).

8. Conclusions

The proposed method for structuring user–product interaction revealed the user’s cognitive structure for each scene and transitions between scenes. We assumed two layers in the cognitive structure, that is, perceived features and perceived qualities. Perceived features are naturally derived from design elements recognized in each scene, which consists of a pair of sense and action. Perceived qualities are higher concepts that directly affect whole user experience, such as perceptions of comfort, usability, functionality and reliability. Kano model provides exhaustive classification for perceived qualities into three: must-be, performance and attractive qualities. This study attempted to link perceived features and perceived qualities using the laddering technique based on personal-construct theory. As demonstrated using the hair dryer example, the stepwise process based on a framework serves as systematic guide to model user–product interactions in exhaustive manner.

With the structured user’s cognitive model, we extracted perceived features that affect both must-be and attractive qualities. With respect to user experience, satisfying both must-be and attractive qualities is a condition of good design. Thus, the study revealed the tolerance for such perceived features where both qualities are satisfied. The expectation effect is a second factor of tolerance.

Experiment 1 demonstrated that body size appearance (prior expectation) alters the expectation effect of sound loudness on powerful feeling (attractive quality). The smaller body size provided less powerful feeling for the same
loudness sound. This expectation effect can be considered as contrast effect, in which the difference from prior expectation cued by visual information (body size) was amplified in perception. In the contrast effect, tolerance can be increased by decreasing prior expectation. This experimental finding suggests that a designer has to consider design attributes that can cue expectation effect, as well as a design attribute that directly affects target perceived quality. Tolerance influenced by expectation effect can be quantitatively derived by conducting sensory evaluation experiment following the method of experiment 1, in which possible expectation cues are manipulated as factors. Quantitatively derived tolerance can be used to design a combination of design attributes (i.e., body size and sound loudness) that satisfies both must-be and attractive qualities.

Experiment 2 showed that cognitive attributes, such as product category, work as a cue of prior expectation and cause expectation effect on perceived qualities, as well as physical design parameters, such as body size appearance. Participants’ evaluation of the shutter sound regarding “massive–light” feeling changed according to product category (smartphone, compact SLR and full-size SLR). The participants evaluated the same shutter sounds as more massive with the smartphone condition compared with the full-size SLR condition. People may expect a full-size SLR to have a more massive sound than a smartphone. The gap between the expected and actual shutter sound with respect to massive feeling was thus amplified. Therefore, product category worked as a contrast effect on massive feeling of the shutter sound. This result suggests that evaluation of perceived features is influenced by cognitive attributes, if the attributes work as cue of expectation. Product brand, class, and price could be candidate expectation cues and possibly cause expectation effect. Designers have to consider such bias from product cognitive attributes in designing perceived quality.

The validation of this study is limited to two products: hair-dryer and camera. More case studies are needed to generalize the effectiveness of proposed methodology and the impact of the expectation effect on user–product experience. Nevertheless, this study provides experimental evidence for the existence of the expectation effect caused by both physical and cognitive attributes, as well as the methodology to extract and assess their effect quantitatively.

Acknowledgments

This work was supported by KAKEN (No.15K05755 and No. 18H03318) and Sony Global Manufacturing & Operations Corporation (SGMO). We would like to thank to Professor Tamotsu Murakami at The University of Tokyo (UTokyo), members of the Design Engineering Lab. of UTokyo, Dr. Kazuko Yamagishi of SGMO and collaborators from Sony group for supporting this project.

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