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Design and value of product sound

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ABSTRACT

Sounds a product makes can affect that product's commercial value. It is important to understand what makes customers sense a product sound as connoting value, the amount of that value, and what acoustic features affect this evaluation. The present study conducted psychoacoustical experiments on such issues. An experiment investigating the structure of evaluation of vehicle door-closing sounds revealed hierarchical relationships between factors related to perceived emotional benefits (e.g., a feeling of security) and functional benefits (e.g., being solidly made) at higher levels, and factors related to acoustic features (e.g., abundant low-frequency components) at the lowest level. These benefits seem to affect consumers' purchasing behaviours. Major hierarchical structures related to these benefits appear capable of informing the design direction of door-closing sounds. Additionally, two experiments assuming customers' product selection were conducted regarding home appliances (vacuum cleaners and hairdryers). One experiment employed a contingent valuation method to estimate the value added to a product through sound quality improvement. The results suggest awareness of the considered price and the indication of sound output when purchasing, and previous experience of being distracted by product noise, affect whether participants accept a product with improved sound quality. The other experiment, adopting conjoint analysis, showed that improvement in sound quality and noise reduction increase the perceived utility of products, although the product price was regarded as the most important attribute. The results suggest sufficient design of product sound will affect customers' selection of a product. Non-acoustic factors such as indication of sound output also appear important in enhancing the value of a product's sound.

Keywords: Product sound, Value evaluation, Design
I-INCE Classification of Subject Numbers: 63, 67

1. INTRODUCTION

Sounds from products are known to affect those products' commercial value. Therefore, manufacturers' engineers have been striving to design and create product sounds that project quietness and/or good sound quality [1]. Such sounds evidently contribute in differentiating products. Product sounds are one possible aspect that helps articulate a product or manufacturer's branding.

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Product sounds that are well-designed and have good sound quality supposedly add value to the product, subsequently differentiating the product from others. This introduces questions as to what type of product sound adds such value, and how much value is added through the sound design. Such information may be useful when engineers develop products in consideration of how the sound will be designed.

To address the above questions, a previous study was conducted to grasp people's perceptual structure in value evaluation of door-closing sounds, and to comprehensively understand various factors affecting such evaluation [2]. Additionally, other studies have compared the value of various characteristics of home appliances such as hairdryers and vacuum cleaners, and have quantitatively evaluated value added by product sound quality, using a monetary unit [3, 4]. The present study reviews these previous studies concerning product sound quality, and discusses considerations and strategies regarding design of product sound.

2. Branding of products through sound design

Manufacturers adopt various branding strategies to differentiate their products that are in competition with similar products in the market. Several types of features characterise products, including sound. For instance, a motorcycle's engine sound has served to shape its branding [5]. This sound involving "the throaty pounding and off-cantered drumming beat" has established value in the market. People evidently might recognise the manufacturer's motorcycle through its engine sound.

Sounds of such products seem to possess certain value. So then, how much actual value does the product sound contribute? What type of sound features affect customers' value evaluation and purchasing behaviour? This evaluation may be affected by factors unrelated to sound itself; these include imagery associated with the product sound as well as acoustic features, such as the sound's energy and spectral characteristics. Importance should therefore be placed on proper understanding of factors related to this evaluation and purchasing behaviour. In such investigation, analysis of the product sound with regard to the generally recognised value may enhance knowledge about sound design methodology. The sound of the abovementioned motorcycle is a highly suitable target for such analysis.

3. Investigation of factors affecting the value evaluation of product sound

3.1 Experiment using evaluation grid method

Apart from motorcycle engine sounds, vehicle door-closing sounds affect perception of product quality. Such sounds should give customers the impression of luxury and safety. Hearing these sounds at automobile dealerships may affect purchasing behaviours. Factors affecting value evaluation of door-closing sounds have therefore been investigated [2].

The present analysis applied the evaluation grid method (EGM) to grasp the structure of value evaluation of a door-closing sound. EGM uses interviews to comprehend factors (or perspectives) and requirements in evaluation of an environment, and relationships among factors of individuals evaluating that environment [6, 7]. Although EGM was developed for that purpose, several studies have adopted it to explore the perceptual structure of value evaluation of products such as in vehicle door lock sounds and motorcycle styles [8, 9].

For understanding value evaluation of door-closing sounds, a psychoacoustical experiment using EGM was conducted. First door-closing sounds of six various types of vehicles, which were recorded in the open air using a head-and-torso simulator (Brüel &

Kjær type 4100), were used as stimuli (Table 1). In the actual experiment, 15 pairs of six types of door-closing sounds (i.e., [6×5]/2 pairs excluding presentations in the reverse order) were presented to participants via headphones (Sennheiser HD580). Participants first compared the stimuli in each pair (e.g., stimulus A and stimulus B), rating them on a seven-point scale ranging from “highly unattractive” to “highly attractive.” Regarding the more attractive (more satisfactory) stimulus of each pair (e.g., stimulus A), participants were asked the following.

To elicit perspectives in evaluation of stimuli, Question 1 was used to find why one stimulus was more attractive than the other. The given reasons (e.g., description Z in the answer “Because stimulus A is Z.”) were used as the original evaluation factors.

Question 1: Why do you think stimulus A is more attractive?

Then, to elicit factors at the higher levels of the hierarchical structure related to the obtained Z, Question 2 inquired about why the original evaluation factor was given (*ladder-up procedure*). Through this process, benefits yielded by that original factor were identified.

Question 2: Why is the state corresponding to Z of stimulus A more attractive for you? (when the participant answered “Because stimulus A is Z” for Question 1)

Finally, Question 3 was for identifying concrete requirements, such as the acoustic characteristics of stimuli related to the original evaluation factors (*ladder-down procedure*).

Question 3: What is necessary for a door-closing sound to have a state of Z?

Participants’ answers were recorded via interview regarding each pair of stimuli.

Twenty-five men and 15 women aged 19–25 years participated.

Table 1 Characteristics of vehicles whose door-closing sounds were recorded

ID	Country of manufacture	Vehicle classification	Engine displacement [cubic centimeters]	Price [million yen]
A	Japan	Light	660	1.2–1.6
B	Japan	Compact	1500	1.5–2.2
C	Japan	Minivan	2000	1.9–3.6
D	Japan	Minivan	2400	2.4–4.1
E	Germany	Convertible	3200	4.4–5.8
F	Germany	Full-size luxury	6000	32

3.2 Hierarchical structure of value evaluation for door-closing sounds

Participants’ answers for original evaluation factors and factors elicited by the laddering technique were schematised. Figure 1 is a diagram of the hierarchical structure obtained from all participants’ answers. Straight lines represent associations between original evaluation factors and factors at the higher/lower levels. The original evaluation factors were positioned at the middle level. At the higher level, factors elicited through the ladder-up procedure were separated into two levels based on degree of abstraction [10]. Factors concerning the emotional benefit given by the original evaluation factors were positioned at the highest level. However, factors concerning the functional benefit given by such factors were positioned between the highest and middle levels. The concrete factors elicited by the ladder-down procedure were positioned at the lowest level.

The obtained hierarchical structure shows several strong relationships among factors (Fig. 1). One is the relationship regarding the emotional benefit of a “feeling of security” at the highest level. This was linked with functional benefits such as “feeling of the door closing” and “solidly made” and the original evaluation factor “massive sound” at the middle level. The functional benefit of "feeling of the door closing" was related to acoustic characteristics at the lowest level, such as "high energy in the low-frequency range" and "rapidly damped." However, the acoustic characteristic of "containing high-frequency components" was also linked with the factor of "feeling of the door closing." The door-locking device (i.e., door latches) seemed to emit sounds with high-frequency components [11].

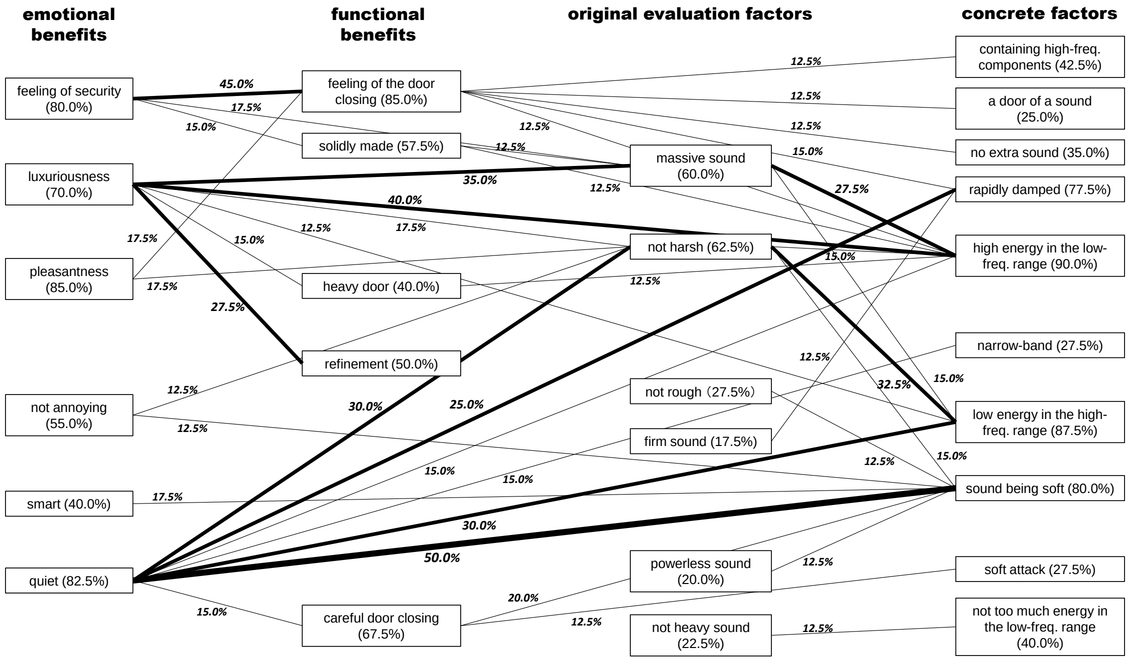

Figure 1 Hierarchical structure of value evaluation for door-closing sounds. Response rates of each factor are indicated in boxes. Straight lines represent associations between original evaluation factors and factors at the higher/lower levels. The strength of between-factor association is expressed by appearance rates and line thickness (thin lines: ≤20%, medium-thickness lines: 21% to 49%, thick lines: ≥50%).

Another strong relationship is that for the emotional benefit of "luxuriousness" at the highest level. This benefit was linked with functional benefits such as "heavy door" and "refinement" and the original evaluation factor of "not harsh" at the middle level. Additionally, "luxuriousness" was strongly linked with the original evaluation factor of "massive sound" at the middle level, and the acoustic characteristic of "high energy in the low-frequency range" at the lowest level.

The results indicate that abundant low-frequency components and a lower quantity of high-frequency components evidently are essential factors in creating "massive" and "not-harsh" door-closing sounds. Such sounds evoked a feeling of the door closing and the imagery of the vehicle door's strength as functional benefits, and were associated with various emotional benefits, such as feelings of security, luxuriousness, and pleasantness.

The emotional benefit of "quiet" at the highest level was directly associated with acoustic characteristics such as "low energy in the high-frequency range," "rapidly damped," and "sound being soft" at the lowest level. Moreover, indirect relationships were also found between these acoustic characteristics and "quiet" through the original evaluation factor of "not harsh." These relationships reveal that understated door-closing sounds and sounds with rapidly damped energy were associated with the impression of quietness. The results suggest a door-closing sound with lower overall energy would be found more satisfactory.

A previous study stated that the value of sound comprised functional value and aesthetic (sensual) value, and the latter was evidently more important toward product differentiation [12]. This aesthetic value is similar with the emotional benefit in the present study. Therefore, it should be emphasised when design seeks to improve product sounds. Factors obtained as the emotional and functional benefits at higher levels of the hierarchical structure might suggest design directions for door-closing sounds.

4. Factors affecting customers' purchasing behaviour

4.1 Experiment using contingent valuation method

Various factors affect customers' behaviour when purchasing a product. A psychoacoustical experiment was conducted using the contingent valuation method (CVM) [13] to address the questions of what type of factors affect purchasing behaviour, and whether product sound affects purchasing.

CVM has been employed to estimate the change of utility (i.e., degree of satisfaction [14]) brought by changes in the natural environment, using a monetary unit [13]. This involves questionnaires to which participants respond regarding their willingness to pay (WTP) or willingness to accept compensation (WTA) for protection or destruction of environmental resources. In the present study, to evaluate the change of utility that sound quality improvement provided, respondents expressed their WTP for such improvement [3].

A psychoacoustical experiment was conducted using CVM to estimate the value added to hairdryers via improved sound quality. Participants were first presented with paired stimuli based on the assumption that the former stimulus was noise from the original product and the latter from a product with improved sound quality. The paired stimuli were binaurally delivered via headphones (STAX Lambda Nova). Participants were then asked how much they would pay for the improved product extra to the original product price. Extra costs were presented to participants twice (i.e., repeated dichotomous choice contingent valuation [15]), and the participants were asked to respond "yes" or "no" to each amount. When a participant accepted an extra payment the first time (T1), a higher amount was then presented (T2H). When a participant rejected the extra payment the first time, a lower amount was then presented (T2L). Five patterns of extra cost were prepared (Table 2). One of these was randomly selected and presented to each of the 176 participants (114 men, 62 women). The original product price was 3,800 yen (~US$34, €31), the average market price for a hairdryer.

Table 2 Patterns of extra cost presented in addition to original price (in yen)

	Pattern				
	1	2	3	4	5
Extra cost for the first presentation (T1)	50	100	500	1000	2000
Higher amount for the second presentation (T2H)	100	500	1000	2000	5000
Lower amount for the second presentation (T2L)	10	50	200	500	1000

Participants were also asked to report the following personal attributes: sex, age, annual income, frequency of hairdryer use, points (such as performance, appearance, power consumption, indication of sound output and price) checked when purchasing products ("not checked" or "checked"), judgment of whether the improved product's sound quality was better than that of the original ("not improved" or "improved"), and personal experiences of being distracted by a hairdryer's noise ("no experience" or "experience").

4.2 Factors affecting customers' purchasing behaviour

Logistic regression analysis was performed on the questionnaire results. In this analysis, the dependent variable was the probability a participant would accept the improved product instead of the original (probability of acceptance, P_{yes}), and questionnaire results including personal attributes and amounts of extra costs agreed to or refused by participants were independent variables.

Table 3 shows statistically significant variables and their estimated coefficients in the obtained logit model for the hairdryer. Five variables were statistically significant, at $p<0.05$: "indication of sound output" and "price" in the points checked when purchasing products, "judgment of the sound quality between paired stimuli", "participant experiences of being distracted by noise from a hairdryer" and "extra amount that would be paid in addition to the original price."

*Table 3 Statistically significant variables and their estimated coefficients b in obtained logit model on the probability of acceptance (**p<0.01, *p<0.05)*

Variable (personal attribute)		*b*	*p*
Points checked when purchasing products	(indication of sound output)	0.755	*
〃	(price)	-2.002	*
Judgment of the sound quality between paired stimuli		3.136	**
Participant experiences of being distracted by noise from a hairdryer		0.810	*
Log (extra that would be paid in addition to the original price)		-1.694	**

Estimated coefficients of "price" in the points checked when purchasing products and "extra amount that would be paid in addition to the original price" were negative. The result for "extra amount" indicates that when the extra amount increases, the probability of acceptance (P_{yes}) decreases. Similarly, if price is regarded as important when purchasing a hairdryer, P_{yes} will decrease. These results appear reasonable because lower-priced products are generally preferred.

Conversely, estimated coefficients of the variables "indication of sound output" in the points checked when purchasing products and "judgment of the sound quality between paired stimuli" were positive. If indication of sound output is regarded as important, and if participants respond that stimulus with improved sound quality is preferable in comparing sound quality between paired stimuli, P_{yes} will increase. These results appear reasonable because products with good sound quality are generally preferred. The estimated coefficient of the variable "participant experiences of being distracted by noise from a hairdryer" was also positive. This indicates that such experience raises P_{yes}.

The results revealed that customers' experience of being distracted by product noise would affect their product selection. Many recent home appliances have their sound output (operating noise level) indicated in their performance labelling, and such indication evidently affects product selection. Customers' purchasing behaviour thus appears to be influenced by non-acoustic factors such as a personal experience, as well as their perceived quality of product sound.

5. Importance of attributes characterising products

5.1 Experiment using conjoint analysis

Customers typically make purchasing decisions with due regard to characteristics such as appearance, functionality, and price, as well as sound. To investigate the importance customers place on product sound, a psychoacoustical experiment was conducted using conjoint analysis [4]. This approach has been employed in marketing research for estimating the importance of such product characteristics.

Conjoint analysis hypothesises a model, in which overall judgment (i.e., willingness to purchase) of a product with various characteristics (i.e., attribute levels) is assumed equivalent to the linear combination of the partworth scale value of each attribute level. That value (or utility scale value) represents the desirability [16] or attractiveness [17] of each attribute level for respondents. Conjoint analysis decomposes a respondent's overall judgment of products into separate partworth scale values for each attribute level; the relative importance of a product's multidimensional attributes are also obtained from those values.

Rating experiments for various vacuum cleaners were conducted. Conjoint analysis was applied to rating results of participants' willingness to purchase products. To present a range of products in the experiment, participants were shown stimulus cards displaying various product characteristics expressed by an image and text. Product characteristics were represented by six attributes: manufacturer, style (upright or cylinder), vacuum system, additional functions (high-performance filter systems and functional inlet), noise (A-weighted sound pressure level [SPL] in dB or sharpness as calculated by Zwicker's model [18], in acum), and price. Two to five levels were established for each attribute (Table 4). Twenty-five stimulus cards (Fig. 2) were created through orthogonal design using combinations of these attribute levels.

The rating experiment adopting each attribute concerning noise (A-weighted SPL and sharpness) was conducted separately. Sound stimuli for each level of A-weighted SPL and sharpness were synthesised from the recorded noise of a vacuum cleaner. These were presented to participants via headphones (Sennheiser HD580) to identify the attribute levels.

Twenty-five men and 25 women aged 18–32 years participated.

Table 4 Vacuum cleaner attribute levels

Attributes		Levels
Manufacturer		A, B, C, D, E
Style		cylinder, upright
Vacuum system		with vacuum bags, with cyclone technology
Additional functions		a) and b), a) only, b) only, nothing
a) high-performance filter systems		
b) functional inlet		
Noise *	(A-weighted SPL / dB)	54 dB, 59 dB, 64 dB
	(sharpness / acum)	1.96 acum, 2.21 acum, 2.46 acum
Price (JP yen: ¥, US Dollar: $, Euro: €)		¥15000 ($135.8, € 120.5)
		¥25000 ($226.3, € 200.8)
		¥35000 ($316.9, € 281.1)
		¥45000 ($407.4, € 361.5)

*In one vacuum cleaner experiment, the noise attribute was A-weighted sound pressure level (SPL), while in the other it was sharpness.

No.1

Manufacturer	C	
Style	cylinder	
Vacuum system	cyclone technology	
Additional functions	a) high-performance filter systems	with
	b) functional inlet	without
Noise	64 dB	
Price	¥45000	

Figure 2 Example of a stimulus card for a vacuum cleaner.

5.2 Relative importance of vacuum cleaner attributes and partworth scale values of attribute levels

Conjoint analysis was applied to rating results to obtain the average relative importance values for vacuum cleaner attributes (Fig. 3) and partworth scale values for each level of the attributes of noise and price (Figs. 4 and 5).

As shown in Fig. 3, values of relative importance in each attribute were almost identical between the two experiments with different noise attributes. The relative importance of price was notably greater than that of other attributes. This shows that participants regarded the vacuum cleaner's price as the most important point when considering a purchase. The relative importance of noise was around 10% and similar to that of the functional attribute of the vacuum system, although it was seen as less important than the additional functions and manufacturer.

As shown in Figs. 4 and 5, partworth scale values increase as prices fall, and are highest at the lowest prices. For noise, the scale values increase as A-weighted SPL and sharpness values in acum decrease. This suggests products with lower noise emission and lower energy in the high-frequency region may make customers more satisfied.

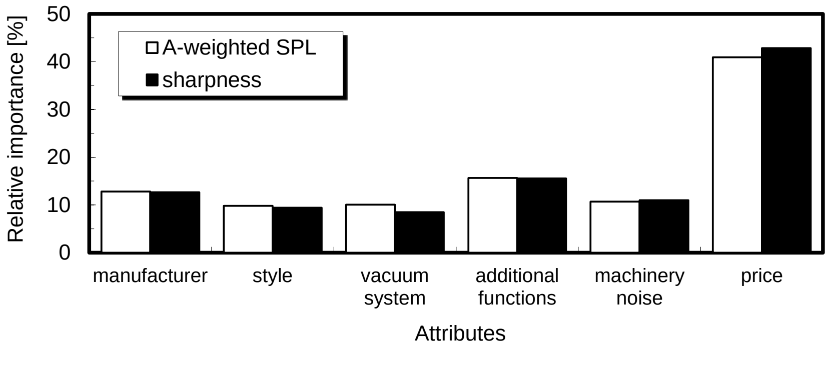

Figure 3 Results of relative importance for vacuum cleaner attributes in experiments adopting noise attributes of A-weighted sound pressure level (SPL) and sharpness.

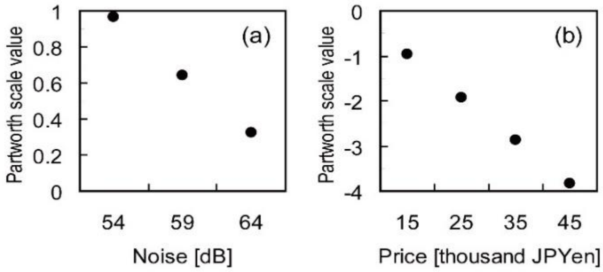

Figure 4 Partworth scale values of noise and price attribute levels (left: A-weighted sound pressure level, right: price).

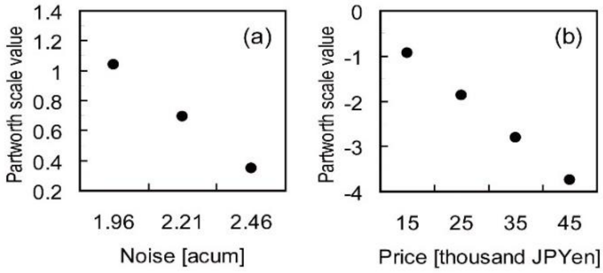

Figure 5 Partworth scale values of noise and price attribute levels (left: sharpness, right: price).

6. Economic valuation of product sound

There is a question of how much value the improvement of sound quality and design of product sound add to the product. Results from CVM experiments (section 4) and experiments adopting conjoint analysis (section 5) show that such added value could be evaluated in monetary units.

From the logit model obtained in the CVM experiment for hairdryers, the probability of acceptance P_{yes} could be represented as a function of the "extra amount that would be paid in addition to the original price T" (Fig. 6). WTP was evaluated using a monetary amount corresponding to the centroid (P_{yes}=0.5) of the curved line in Fig. 6. WTP for improved sound quality was found to be 469 yen (~US$4.3, €3.8), equivalent to approximately 12% of the original price (3,800 yen, or ~US$34.4, €30.5).

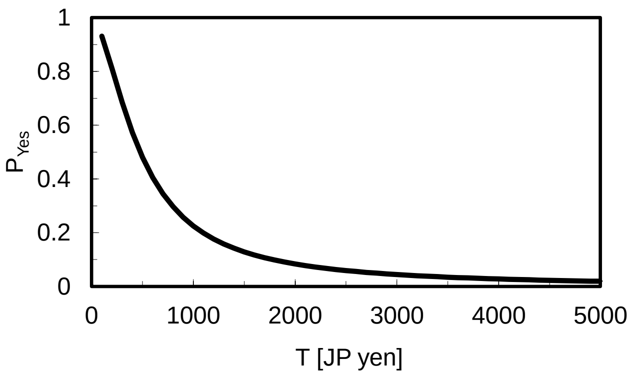

Figure 6 Probability of acceptance P_{yes} as a function of "extra amount that would be paid in addition to the original price T" in the experiment for hairdryers.

Similar evaluations were made in the vacuum cleaner experiments employing conjoint analysis. Economic valuation of the partworth difference between two adjacent levels in the noise attribute was conducted using a monetary unit. The estimated value of a 5-dB reduction was 3,347 yen (~US$30.3, €26.9), and 3,692 yen (~US$33.4, €29.7) for a 0.25-acum reduction in sharpness. These values represented 11.2% for the former and 12.3% for the latter, of 30,000 yen (~US$271.6, €241.0), which was the average of the four price levels (Table 4).

Another CVM experiment on vacuum cleaners and an experiment using conjoint analysis on hairdryers was also conducted. Throughout all experiments, results of economic valuation showed that improvement of sound quality or noise reduction equated to be 12% of the original prices of either appliance. These results suggest these enhancements raised the products' commercial value.

7. DISCUSSIONS AND CONCLUSIONS

A series of experiments were carried out to comprehend various factors affecting the value evaluation of door-closing sounds, and investigate the relative importance of noise among various attributes characterising hairdryers and vacuum cleaners [2-4]. Economic valuation for improvement of sound quality and noise reduction were also examined.

Several strong relationships between factors at the lower level and higher levels were found in the hierarchical structure obtained from experiments employing the EGM (Fig. 1). The structure suggests acoustic characteristics such as abundant low-frequency components and a smaller quantity of high-frequency components largely affected value evaluation of the door-closing sound. These spectral characteristics could help create door-closing sounds evoking impressions of massiveness and non-harshness. They were also associated with emotional benefits such as feelings of security, luxuriousness, and pleasantness, as well as functional benefits such as the feeling of the door closing and the imagery of the door's strength. These evidently are the most important perceptual benefits that door-closing sounds provide to customers. Quietness was also an important emotional benefit associated with these sounds. Understated sounds and sounds with rapidly damped energy seemed to be perceived as quieter. Major parts of a value evaluation's hierarchical structure evidently can inform the direction of design strategies for door-closing sounds. Factors found at the higher level of the structure may be regarded as concepts (or targets) for the design direction of product sound.

Experiments employing conjoint analysis showed product price to be the most important attribute, and improvement of sound quality and noise reduction capable of raising the partworth scale value. The results suggest that the appropriate design of product sound should help increase product desirability or attractiveness.

The CVM experiments revealed the indication of sound output from a product, and experiences of being distracted by noise from a product, affect customers' purchasing behaviour. This suggests that information about sound that a product emits should be appropriately communicated to customers. Although most customers are likely unfamiliar with the specificities of sound, including information expressed in dB, filling this communication gap should help enhance product value through the improvement of sound quality and sound design.

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