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# The Effects of Tactile Feedback on the Affective Evaluation of Switch Sounds

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**Abstract:** In a previous study, we examined the effects of listening standpoint on the affective evaluation of switch sounds through a psychoacoustical experiment. Three roles of listeners were set in that experiment: *operator*, *active listener*, and *passive listener*. We considered the difference between *active* and *passive listeners*' evaluations to be due to the listeners' attitude or attention to the sounds. On the other hand, the difference between *operators*' and *active listeners*' evaluations remains an outstanding question. In order to investigate this question, in this study we conducted an experiment on tactile evaluation of the same 15 switches as in the previous study. The experiment was carried out using the semantic differential (SD) method involving 14 adjective pairs with a 5-point category scale. Twenty-seven subjects, who were the *operators* in the previous experiment, participated in this experiment. The experimental results were analyzed using factor analysis; we obtained three factors of *activity*, *evaluation*, and *potency*. The three factor scores of the *operators*' auditory evaluation obtained in the previous study are estimated well by linear regressions with the factor scores of the *active listeners*' auditory evaluation and the *operators*' tactile evaluation. The results of regression analysis indicate that that *operator's* evaluation of switch sounds is based on the auditory evaluation and affected by the evaluation of tactile feedback.

**Keywords:** *Switch sound, Sound quality, Tactile feedback, Semantic differential method, Factor analysis*

## 1. INTRODUCTION

Sounds or clicks emitted by switches or buttons when they are pushed are a matter of interest because mechanical switches and electrical buttons are ubiquitous in our daily lives. Thus, some studies have evaluated these switch sounds [1-4].

Among them, we focused on the effects of listeners' standpoints on the evaluation of switch sounds [4]. Our study conducted a psychoacoustical experiment to evaluate the sound quality of 15 switch sounds by three roles, namely, *operator*, *active listener*, and *passive listener*: An *operator* is a person who pushes a switch and listens to its sound actively, an *active listener* is a person who listens to the switch sound actively by sitting in front of the operator, and a *passive listener* is a person who listens to the switch sound passively during a task (playing a video game) by sitting next to the active listener. The experimental results showed that the affective evaluations were different depending on the subject's role. The difference between *active* and *passive listeners*' evaluations was considered to be due to the listeners'

attitude toward listening to the sounds.

On the other hand, the difference between *operators*' and *active listeners*' evaluations remains an outstanding question. This study focuses on this question. These two roles are different as to whether they have or lack tactile feedback when listening actively to switch sounds. In order to determine the effects of the feedback, we conducted an evaluation experiment on tactile sense for the same 15 switches used in the auditory evaluation. Before describing the tactile evaluation experiment, we briefly summarize the auditory evaluation [4] in Sec. 2.

## 2. SUMMARY OF AUDITORY EVALUATION [4]

Fifteen switches were mounted on a circular board and covered with uniform caps to prevent visual information effects, as shown in Figure 1. In the semantic differential (SD) experiment, an *operator* continuously pushed a designated switch for 5 s (approx. 15 times), and the three participants, *operator*, *active*, and *passive listeners*, rated the sound using 26 pairs of adjectives on 5-point scales arranged in random order. The 81 participants were



**Figure 1:** Fifteen switches with uniform caps mounted on a circular board.

assigned to one of the three roles, thus forming 27 subject groups.

The evaluation results were analyzed using factor analysis, and three factors of *activity*, *evaluation*, and *potency* were extracted. Statistically significant differences in the factor scores were observed among the three roles. We considered that the difference between *active* and *passive listeners*' evaluations was due to the difference in the listeners' attitude or attention to the sounds. On the other hand, the reason for the difference between *operators*' and *active listeners*' evaluations remains an open question.

### 3. TACTILE EVALUATION EXPERIMENT

#### 3.1 Experimental method

After the auditory evaluation experiment, every *operator* participated in a tactile evaluation experiment. In the experiment, an experimenter designated one of the switches in random order. The *operator* rotated the board so that the designated switch was located at the nearest position, then continuously pushed it for 5 s (approx. 15 times) in the same way as in the auditory evaluation experiment. The subjects then rated the tactile feeling on 5-point scales using 14 pairs of adjectives (Table 1) arranged in random order.

Prior to the experiment, the *operator* wore headphones with high soundproof characteristics (Sennheiser, HDA 200). During the experiment, white noise was continuously reproduced from the headphones to mask the switch sounds.

#### 3.2 Factor analysis

The evaluated scores of all participants and switches for the 14 adjective pairs were analyzed using factor analysis (principal factor solution, varimax rotation); 405

**Table 1:** Factor loadings for 14 adjective pairs after varimax rotation. The largest factor loading in the absolute value for each pair is underlined.

Adjective pairs	TF1	TF2	TF3
Likable – Dislikable	<u>0.86</u>	-0.05	0.18
Bounding – Not bounding	<u>0.83</u>	0.03	-0.23
Interesting – Boring	<u>0.80</u>	-0.13	0.13
Crisp – Woolly	<u>0.74</u>	0.13	-0.07
Superior – Crummy	<u>0.71</u>	0.04	-0.13
Easy to push – Hard to push	<u>0.65</u>	-0.21	0.48
Elastic – Not elastic	<u>0.44</u>	-0.27	-0.26
Shallow – Deep	-0.05	<u>0.86</u>	-0.02
Hard – Soft	0.31	<u>0.55</u>	-0.49
With play – Without play	-0.15	<u>-0.63</u>	0.23
Easy to squash – Hard to squash	0.23	<u>-0.86</u>	0.04
Sinking – Not sinking	0.09	<u>-0.89</u>	0.07
Catchy – Smooth	-0.32	0.08	<u>-0.49</u>
Heavy – Light	0.42	0.19	<u>-0.65</u>
Contribution ratio (%)	29.9	22.6	9.8
Cumulative contribution ratio (%)	29.9	52.5	62.3

observations (27 participants  $\times$  15 switches) were analyzed for statistically significant associations. Based on the criterion that eigenvalues must be greater than one, we extracted three factors. Table 1 shows the factor loadings for every adjective pair, contribution ratios, and cumulative contribution ratios for the three factors. The cumulative contribution ratio up to the third factor was 62.3%.

In Table 1, all pairs are sorted by the largest factor loading in absolute value, which is underlined. All items loaded at least 0.4 on one or more factors. The first tactile factor, TF1, represented *evaluation* [5] because pairs such as “likable–dislikable” and “interesting–boring” had larger loadings on this factor. The second tactile factor, TF2, indicated *potency* [5] because pairs such as “shallow–deep” and “sinking–not sinking” had larger loadings on this factor. The third tactile factor, TF3, was termed *activity* [5] because pairs such as “catchy–smooth” and “heavy–light” had larger loadings on it. Although the order of the factors is different from that of the three auditory factors [4], we consider corresponding factors to have been extracted for the auditory and tactile evaluations. Thus, we examine the effects of tactile feedback on the auditory evaluation of switch sounds in the next section.

### 4. ESTIMATION OF OPERATORS' FACTOR SCORES BY MULTIPLE REGRESSION ANALYSIS

Our preliminary examination [6] indicated that “the difference in auditory factor scores between *operator* and *active listener*” and “the tactile factor score” are

**Table 2:** Partial regression coefficients after the multiple regression analysis. The coefficients of  $a_1$  and  $a_2$  refer to the auditory factor score of *active listener* and the tactile factor score, respectively.

	$a_1$	$a_2$
F1	1.14	0.12
F2	0.64	0.35
F3	0.85	0.29

correlated. This may suggest that the factor score of *operator* is expressed by the sum of the auditory factor score of *active listener* and the tactile factor score.

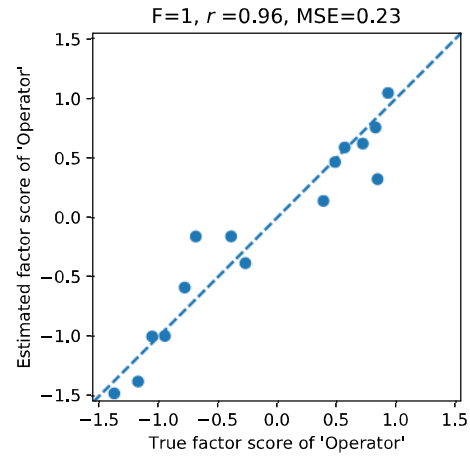
Thus, we conducted a multiple regression analysis with the objective variable  $y$  as the auditory factor score of *operator*, and the explanatory variables  $x_1$ : the auditory factor score of the active listener and  $x_2$ : the tactile factor score. The regression equation is as follows:

$$y = a_1 * x_1 + a_2 * x_2 + e \quad (1)$$

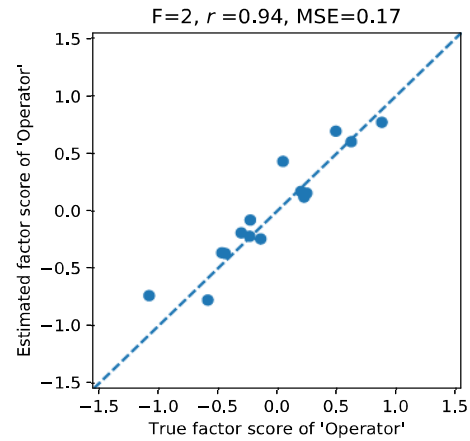
where  $a_1$  and  $a_2$  are partial regression coefficients, and  $e$  is an error term. This regression was carried out separately for each of the three auditory factors.

Even though the factors are common to the auditory and tactile evaluations, the axes of the auditory and tactile factor spaces need not correspond completely since varimax rotation was conducted separately in each space. Thus, prior to the multiple regression analysis, the space of the tactile factor space was rotated [7] so as to minimize the least squared error between “the *operator*’s auditory factor scores” and “the average of the tactile and the *active listener*’s auditory factor scores.”

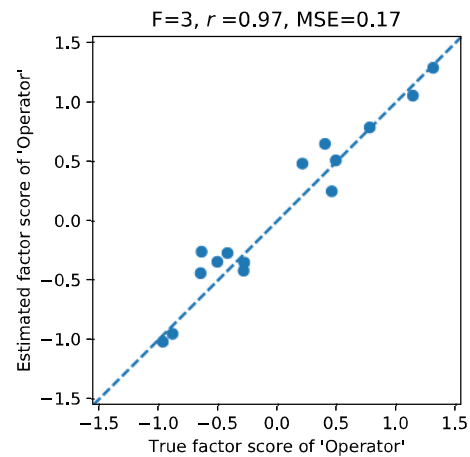
Figure 2 shows the relation between the true and estimated factor scores of *operator* based on Eq. (1) for each of the three auditory factors of F1: evaluation, F2: potency, and F3: activity. The multiple correlation coefficients ( $r$ ) shown in the figure are equal to or higher than those observed between the “true factor score of *operator*” and “factor score of *active listener*” (F1: 0.96, F2: 0.91, F3: 0.95). The mean square errors (MSEs) shown in the figure are smaller than those between the “true factor score of *operator*” and “factor score of *active listener*” (F1: 0.28, F2: 0.23, F3: 0.22). These indicate that the effects of the tactile information were successfully incorporated in the auditory evaluation: the auditory evaluation of *operator* was affected by the tactile feedback. Table 2 shows the partial regression coefficients after multiple regression analysis. The magnitudes of the coefficients suggest that the operator’s evaluation of switch sounds is basically determined by the auditory sensation and modified by the tactile feedback.



(a) Auditory F1: Evaluation



(b) Auditory F2: Potency



(c) Auditory F3: Activity

**Figure 2:** Results of the multiple regression analysis. The auditory factor scores of *operator* for the 15 switches were estimated using the auditory factor scores of *active listener* and the tactile factor scores.

## 5. CONCLUSION

This study focused on the difference in the auditory factor scores between the *operator* and *active listener* for switch sounds. The results of the multiple regression analysis suggest that the difference can be explained by the effects of the tactile feedback of pushing switches; the *operator's* auditory evaluation is based on the *active listener's* evaluation and modified by the tactile evaluation.

Further examination of this difference using a greater variety of switches is necessary. Our final goal is to establish a design method of switches having a variety of affective evaluations. Further studies of the mechanical and acoustical properties of switches will be needed to achieve that goal.

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