Backrest Designs in Meeting Chairs

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Abstract Our purpose was to design the backrest of meeting chairs. We investigated how a backrest structure influenced the sitting comfort of a meeting chair. Sensory values of sitting comfort were measured through a paired comparison method and body pressure distributions. Subjects were selected from a consumer group and an expert group who worked at an office furniture company. Body pressures and contact areas between the human body and the chairs were measured. As a market test, 663 people sat on the sample chairs. The sensory evaluation results were examined through a factor analysis. The results were as follows: (1) The sitting comfort evaluated by the consumers had a positive correlation with those of the experts. (2) Two factors were common and significant in evaluating sitting comfort of meeting chair in both groups: "soft at back" and "not tiring." (3) The adjectives related to "sitting comfort" had a relationship with the body pressure distribution and the bending properties of the backrest. (4) The "sitting comfort" of the meeting chair could be predicted by its physical properties. (5) The results of the market test conform with the results of the sensory test.

Keywords Sitting comfort • Sensory evaluation • Body pressure distribution • Factor analysis

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J. Watada et al. (eds.), *Industrial Applications of Affective Engineering*,
DOI: 10.1007/978-3-319-04798-0_12,

1 Introduction

Consumers are paying closer attention to the *kansei* elements of products, in addition to their functionality. Office furniture, which is essential for many jobs, requires many functions. While functions such as portability and storage are valued in meeting chairs, *kansei* elements such as “sitting comfort” are also important. Backrests and seats are the important parts of chairs that directly touch our body, so their designs are important not only as functional elements but also as *kansei* elements. Therefore, we have developed some chairs by focusing on their “sitting comfort.” Many studies have reported on the design of office and meeting chairs [1–3]. Obata et al. reported on the tendency of office chairs in postures and body pressure distribution. Matsuoka et al. reported on how a transverse radius of cushion can influence the sitting comfort of OA chairs. However, little attention has been paid to the relationship between backrest structure and “sitting comfort” during the design of meeting chairs. The subject panels in many sitting comfort studies consisted of only consumer groups or expert groups [4–6]; therefore, the relationship between the two groups was not investigated. Based on the relationship between the two, chair manufacturers could more efficiently develop sitting comfort the *kansei* element for consumers. Our primary goal was to develop a meeting chair that incorporated *kansei* elements. We studied methods for predicting the sitting comfort of chairs by through pressure distributions and other instrumental measurements for the efficient development of chairs. To obtain a basic knowledge of the predicting method, we investigated how a backrest structure influenced the sitting comfort through sensory evaluations and by measuring body pressure distributions. We also investigated the relationship between experts and consumers in regard to sitting comfort. A market test was also performed to verify of the validity of these methods.

2 Methods

2.1 Samples

We used five meeting chairs (Fig. 1) whose shape and size of frame were the same, and only backrest structures were different. Each backrest of the chairs was made with polypropylene or olefin resin, and the hardness of each backrest was different. Details of the backrest are shown in Table 1.

2.2 Sensory Tests

Sitting comfort of each chair was judged by tactile sensation using the Scheffe-Nakaya’s paired comparison method. Evaluation adjectives related to “sitting comfort” were “soft (at seat, at back),” “fitted (at seat, at back),” “oppressive (at

Fig. 1 Meeting chair. Sample chairs were composed of a same frame and a same seat, and only backrest materials were different

Table 1 Details of the backrest

Symbol	Material	Hardness by durometer
No. 1	Olefin	55
No. 2	Polypropylene	66
No. 3	Olefin	46
No. 4	Olefin	42
No. 5	Olefin	56

seat, at back)," "elastic at back," "stability at back," "tired," "stability of posture," "comfortable," "easy," and total judgment. These adjectives were chosen based on previous studies [3, 5–7]. Before sensory tests, these adjectives were described in Japanese, and the answers were obtained in Japanese. Ten pairs of test samples were randomized and presented to subjects. For evaluating sitting comforts, subjects sat on each sample for 2 min or longer and could sit on each chair by repeating. Sitting comfort of those five chairs was also evaluated using the ranking method. Subjects were 6 males and 1 female in the consumer group who worked at an office, and on what kind of chair they were sitting every day. And 17 males and 7 females in the expert group who worked at an office furniture company. Developers of these meeting chairs have been excluded from the expert group; therefore, the expert group did not know the details of the samples.

We calculated statistically mean preference scores of chairs for each adjective and used the factor analysis to study the sitting comfort, and the technique of the information theory [8] to study the evaluation structures of the sitting comfort from the calculated mean preference scores. The information theory to clarify structures of a response for stimulation was used for analyzing the hand evaluation of fabrics [9] or the evaluation of sitting comfort [7].

Transmitted information $T(X;Y)$ is that how much efficiency is transmitted into the received signal from the input and is defined by Eq. (1).

$H(X)$ is the entropy of the input to the channel or the input signal, $H(Y)$ is the entropy of the output of the channel or the received signal, $H(X;Y)$ is the joint entropy of input and output or co-occurrence information, $HX(Y)$ is the conditional entropy of *y* or the additional information, and $H_Y(X)$ is the conditional entropy of *x* or the equivocation. Each entropy is calculated as follows:

$$T(X;Y) = H(X) + H(Y) - H(X;Y) \tag{1}$$

$$H(X) = \log_2 n \tag{2}$$

$$H(Y) = \sum_{j=1}^{n} P_j \cdot \log_2 \frac{1}{P_j} \tag{3}$$

$$H(X;Y) = \sum_{i,j} P_{ij} \cdot \log_2 \frac{1}{P_{ij}} \tag{4}$$

$$H_X(Y) = H(Y) - T(X;Y) \tag{5}$$

$$H_Y(X) = H(X) - T(X;Y) \tag{6}$$

where *n* is the number of signals of samples. P_i is the probability of state *i,* and P_{ij} is the transition probability to state *j*.

2.3 Physical Properties

Bending properties of the backrest were measured in accordance with the determination of strength and durability by JIS S 1203. Details of the method are shown in Fig. 2. For measurement of displacements of the backrest as bending properties, legs of chair were fixed in a ground, and a load of 950 N was put on a seat. Then, we pressed a point at position from the upper at 100 mm and at the center of left and right of the backrest by any load of 200 N to 400 N. A change of position of the point in pressing direction and that of top point were measured. We defined the position of their point as the displacement and their top point as the deflection.

2.4 Body Pressure Distribution

Contact areas and pressure distributions between their bodies and a seat or a backrest of chairs were also measured by using the tactile sensor system (BIGMAT-2000, NITTA Co., Ltd.). The system consists of mats that are made up of thin flexible sensors, and the sensors were set on a seat and a backrest. Measuring area was 430 × 480 mm (2,064 points) for each mat. Subjects were 7 males in the consumer group.

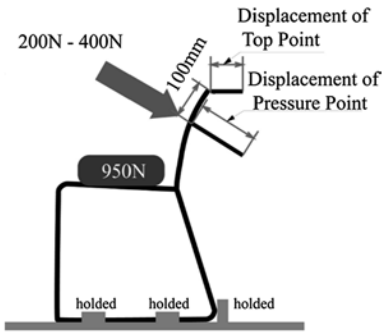


Fig. 2 Measuring method for bending properties of backrest

2.5 Market Test

The preference survey of the five above-mentioned chairs was performed at an exhibition show held in Mie Prefecture. For 663 people who were the visitors of the show, the five chairs were shown and sat on each chair. After sitting on five chairs, they made to choose one chair which it was comfortable to sit on as a meeting chair.

3 Results and Discussions

3.1 Subjective Measurements

From the results of the paired comparison method, we tested their judgments by the number of circular triads and the coefficient of consistency for each subject. Therefore, all subjects had their ability of judgment.

We calculated statistically mean preference scores of five chairs for each adjective and tested the main effect and combined effect of theirs. For the consumer group, main effect of “soft (at seat, at back),” “fitted at back,” “oppressive at back,” “elastic at back,” “tired,” and “easy” were significant at 5 % level and combined effect of all the adjectives were not significant at 5 % level. For expert group, main effect of all the adjectives except “stability” were significant at 5 % level and combined effect of all the adjectives were not significant at 5 % level.

Mean preference scores of each adjective evaluated by the consumer group are shown in Fig. 3 and those by the expert are shown in Fig. 4.

For the consumer group, sample No. 4 was evaluated as soft at back, fitted at back, elastic at back, and easy and No. 2 was as hard at back, oppressive at back, tired, and not easy. For the expert group, No. 4 was evaluated as soft at back, fitted at back, elastic at back, comfortable, and easy and No. 2 was as hard at back, not elastic at back, oppressive at back, tired, uncomfortable, and not easy.

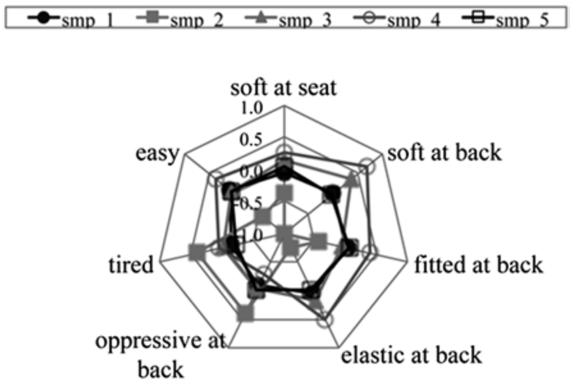


Fig. 3 Mean preference scores by the consumer group

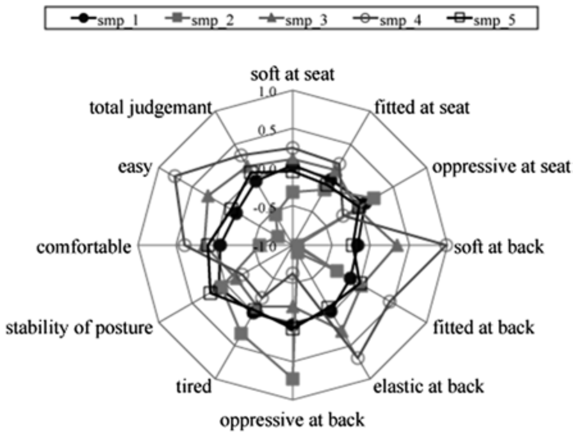


Fig. 4 Mean preference scores by the expert group

The results of the two groups were similar, though the experts judged more clearly than the consumers. Mean preference scores of seven adjectives evaluated by the consumer group had a positive correlation with those by the expert. For adjectives except "tired," there were significant correlations at 5 % level between mean preference scores of each group.

From the results of ranking method shown in Fig. 5, for the two groups, No. 4 was evaluated as high priority and No. 2 was as low. Therefore, we found that the backrest structures influenced sitting comfort of meeting chairs.

3.2 Factor Analysis

The sensory evaluation results were also examined by factor analysis. We obtained the factor matrices using the principal factor solutions without repeated

Fig. 5 Mean preference scores evaluated by ranking method

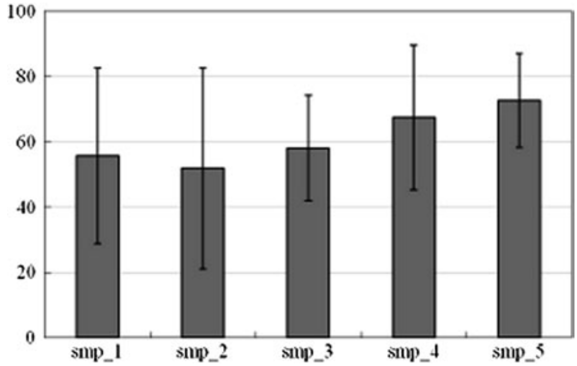
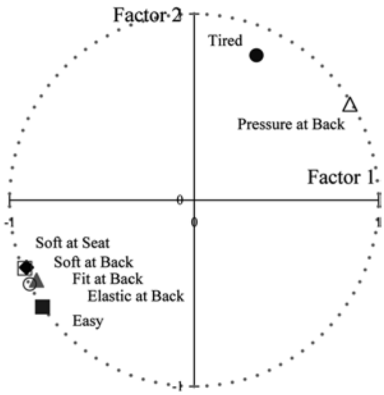


Fig. 6 Factor loadings of each adjective for the consumer group



assumption of communality, and the results of factor matrices were rotated using the varimax method.

From the results of factor analysis for the consumer group, two common factors were obtained (Fig. 6). Factor 1 is related to "soft at back," "fitted at back," "elastic at back," and "easy," and factor 2 is related to "tired" and "oppressive at back." It was found that the consumer evaluated sitting comfort using two adjectives, "soft at back" and "not tiring."

From the results for expert group, two common factors were obtained (Fig. 7), namely factor 1 is "not tiring," and factor 2 is "soft at back." Therefore, for the two groups, two factors—"soft at back" and "not tiring"—were common and significant in evaluating sitting comfort of meeting chair, whose backrest structure only was changed.

Figure 8 shows the factor loading scores of each chair evaluated by the consumer group (black symbol) and the expert group (gray symbol). It can be seen that No. 4 chair was evaluated as soft at cushion, and No. 2 chair was as tiring. The results of the two groups were very similar.

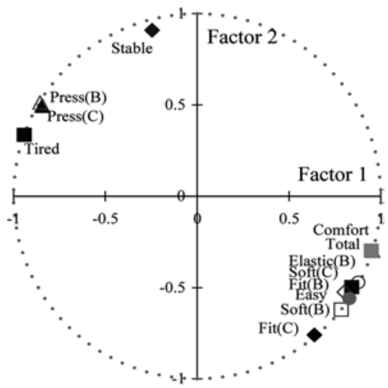


Fig. 7 Factor loadings of each adjective for the expert group

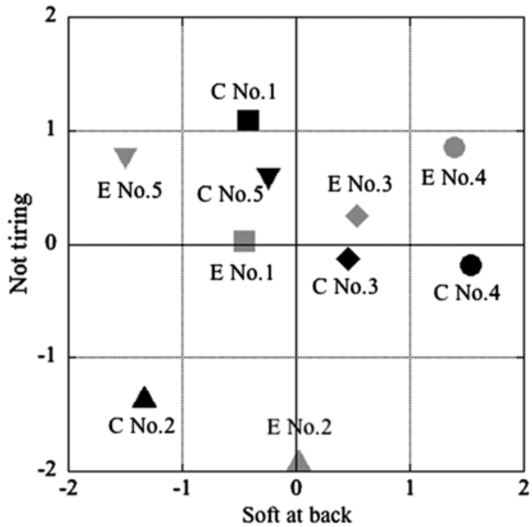


Fig. 8 Factor loading scores. *C* consumer, *E* expert

3.3 Body Pressure Distribution

We examined the standard deviation in the contact area of each sample, for excluding the influence of the individual variation. Figure 9 shows the result of the contact area between the backrest and the human back. As shown in Fig. 9, the contact area of No. 4 was the largest and that of No. 2 was the smallest. When the contact area at the backrest was large, the upper part of the body was supported by the backrest. So we examined the load ratio of backrests to seats. Figure 10 shows the load ratio of theirs. No. 2 was the lowest in sample; therefore, the backrest of

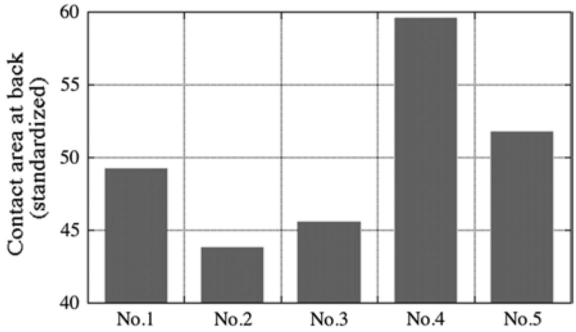


Fig. 9 Contact area of the backrest

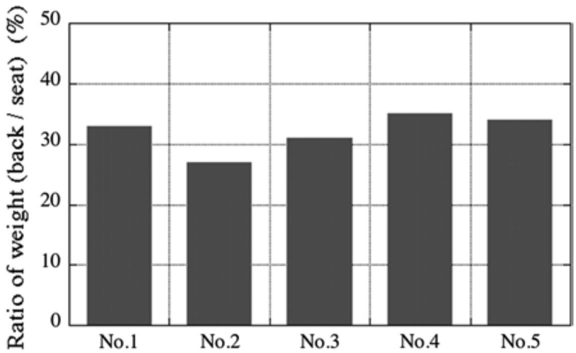


Fig. 10 Load ratio of seats and backrests

No. 2 was not used for sitting. We found that the backrest structures influenced the body pressure distribution between their bodies and backrests.

3.4 Correlation Between Sensory Evaluations and Body Pressure Distribution or Physical Properties

The correlation coefficients between sensory values and body pressure distributions were examined. The contact area at the back was closely related to "fitted at back" and "elastic at back," and the pressure at back was related to "tired" in the two groups. It was found that the adjectives "fitted at back" and "elastic at back" were judged by the contact area at the back, "tired" was evaluated by the pressure at the back. The displacement and the deflection were closely related to "soft at back," "fitted at back," and "easy."

We found that the body pressure distribution or physical properties had good correlation with sitting comfort of meeting chairs. The sitting comfort could be predicted by body pressure distribution or physical properties.

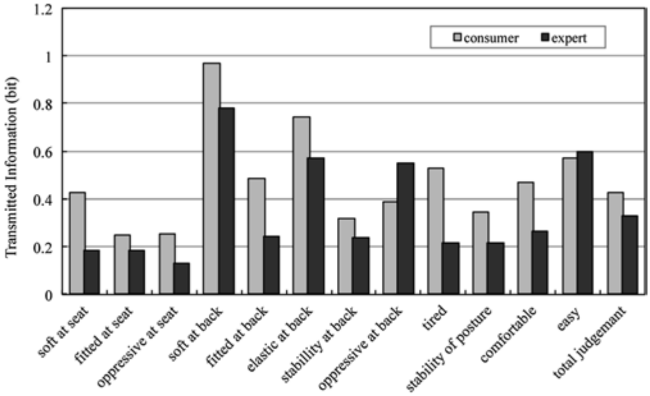


Fig. 11 Transmitted information of each adjective

3.5 Transmitted Information

Transmitted information calculated by the result of sensory evaluation is shown in Fig. 11. The transmitted information of consumers tended to be larger than those of experts. Therefore, we considered that experts group could evaluate sitting comfort of meeting chairs using the small amount of transmitted information.

3.6 Market Test

The results of market test for 663 consumers are shown in Fig. 12. No. 4 was the most preferred, and No. 2 was not most preferred. No. 4 was evaluated as soft at back, fitted at back, elastic at back, and easy by the sensory test for consumer and expert, and No. 2 was as hard at back, oppressive at back, tired, and not easy by the sensory test for consumer and expert. The results of market test have a correlation with the results of body pressure distribution. The contact area at the back was closely related to the preference of consumers.

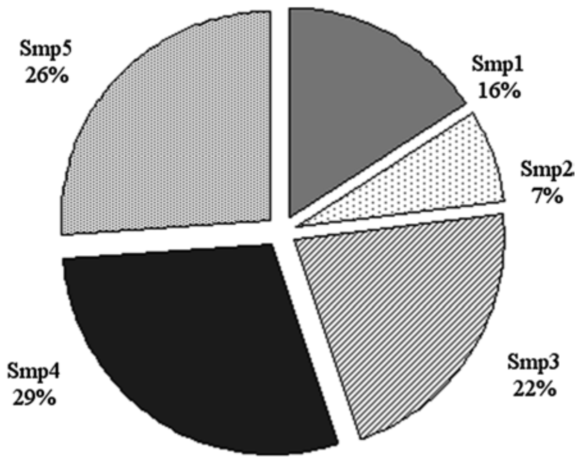


Fig. 12 Results of the market test

4 Conclusions

A backrest structure was investigated to determine its influence on sitting comfort thorough sensory evaluations and body pressure distributions. We also investigated the relationship between experts and consumers with regard to sitting comfort. The results were as follows:

1. The material of the backrest influenced the body pressure distribution and the sitting comfort of the meeting chair.
2. The sitting comfort, as evaluated by consumers, had a positive correlation with those of the experts.
3. Two factors were common and significant in evaluating the sitting comfort of meeting chair in the two group: “soft at back” and “not tiring.” Only the backrest structures were changed.
4. The adjectives related to “sitting comfort” had a relationship with the body pressure distribution and the bending properties of the backrest. The “sitting comfort” of the meeting chair could be predicted through its physical properties.
5. The expert group could evaluate the sitting comfort of the meeting chairs by using a small amount of transmitted information through sensory evaluation.
6. The results of the market test conform with the results of the sensory test.

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