

# Electronic Product Development with Kansei Engineering / Kansei Ergonomics

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**Abstract:** Successful products cannot be made with only ergonomic considerations, and Kansei engineering provides eloquent answers to the problems that arise. In this paper, we report Kansei ergonomics process of electronic products, shaver and washer-dryer from SANYO electronics. Both of the cases have ergonomic researches into detailed Kansei domain. New prototype of electric shaver has 80 degree bent head and shaped to pen grip. Electromyogram of fore arm and pressure to skin are both significantly lower. Washer-dryer has evaluated with subjective Kansei, working posture analysis and kinematic model. Control panel was also examined and improved. Research results of both projects have commercialized, and have got successes.

**Keywords:** Kansei Ergonomics, Product Development, Electronic Products, Measurements

## 1. INTRODUCTION

Along with the spread of the Kansei engineering applications, different approaches have been required to new aspects. From the last 1990s and during the first 10 years of the 21<sup>st</sup> century, novel measurement and analysis methods have been developed and used in Kansei engineering field. The major approaches are in below lines. 1. Novel analysis methods of non-linearity (Ishihara et al., 2007a, 2007b), discreet (combination) optimization analyses (Nishino et al., 2005,2006a,2006b, Tsuchiya et al., 2007), 2. Statistical analysis of shapes (Ishihara et al., 2008), 3. Brain wave measurement and analysis: Yoshida theory (Yoshida & Iwaki, 2000), 4. 3D measurement, computer graphics and virtual reality, 5. Kansei Ergonomics. In this paper, we show methods and applications on Kansei Ergonomics, which have been applied to different commercial products. Cases of SANYO electronics are shown.

## 2. KANSEI ERGONOMICS

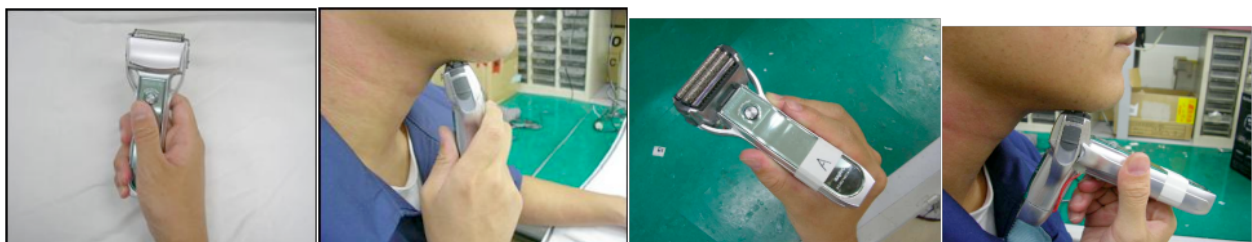
Research results produced during the early era of Kansei engineering, from the 1970s to the mid-1990s, were presented primarily in ergonomics societies. Since the end of the 1990s, we have been involved in the development of many more products, and have recognized that Kansei engineering and ergonomics are inseparable. Successful products cannot be made with only ergonomic considerations, and Kansei engineering provides eloquent answers to the problems that arise. We are fully convinced of the need for Kansei Ergonomics. Two cases are shown here.

### 2.1. Electric Shaver

Home electrical appliances are changing from low-price mass-produced items to higher-price higher-function items. One of main challenges for appliance manufacturers is continuously presenting innovative functionality.

The mechanism of a typical electric shaver involves an inner blade, which moves inside of the mesh outer blade. Thus, when more pressure is added to the face, the load is added to the inner blade and shaving becomes poorer. The conventional stick-shaped shaver tends to force users to add pressure to their faces. SANYO Electronics engineers thought that bending the shaver head and grasping it with a pen-grip, like a T-shape razor, would address this problem. We have verified the idea with experiments and measurements.

We examined two types of shavers: a conventional stick and a prototype of a new pen-grip shaver. These two shavers had the same grip part; thus, their grip length and diameter were identical. The stick shaver had its head at 15° from the grip and the pen grip prototype had its head at 80°.



**Figure 1:** Stick shaver (left) and pen grip prototype (right)

#### 2.1.1. Electromyogram (EMG) measurements and Pressure measurements

**EMG measurements:** The factor in this experiment was the difference in EMG between the NS1 (existing stick shaver) and the pen-grip prototype (based on the NS1). Electrodes were attached on the flexor digitorum superficialis and on the flexor digitorum profundus, with bipolar derivation. Measurements were conducted with two channels and the earth was taken on the elbow joint bone. The measurement device was a Biopac MP30 (Biopac Inc.) with a sampling rate of 500 Hz.

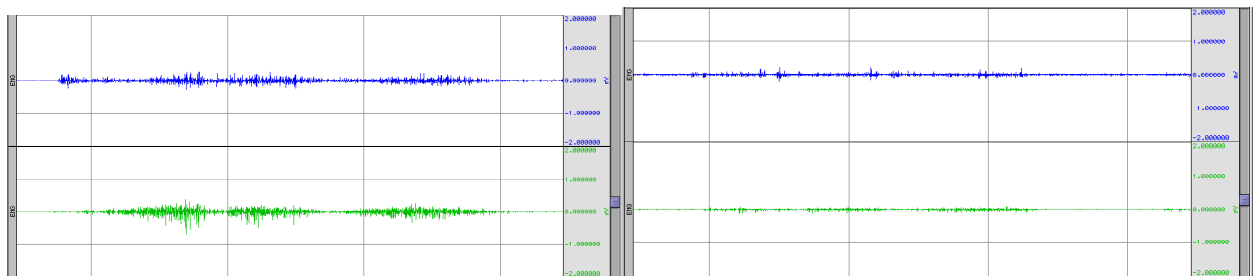
**Pressure measurements:** A piezo pressure sensor was attached behind the blade of the shaver. The factor in this experiment was the difference in pressure to the face between the stick shaver and the pen-grip prototype. Measurements were also made with the Biopac MP30.

*Instruction to the participants:* An instruction sheet with directions applying to the face and shaving direction was given to the participants. The task was to move the shaver three times at seven different sites: the middle under the chin, right and left of it, on the chin, under the nose, right cheek, left cheek. The subjects were seven men in their 20s.

### 2.1.2. EMG and pressure results

As shown in Fig.2, the pen-grip prototype had smaller EMG voltages. EMG integral values (mV×sec / 500 (Hz)) of the two shavers (sum of the seven sites) were compared using measurements from the seven participants. The ratios between the pen-grip prototype and stick (average between subjects) were 0.60 at the flexor digitorum superficialis, 0.95 at the flexor digitorum profundus, and 0.78 combining both muscles. Thus, a 22% EMG reduction was observed with the pen-grip prototype.

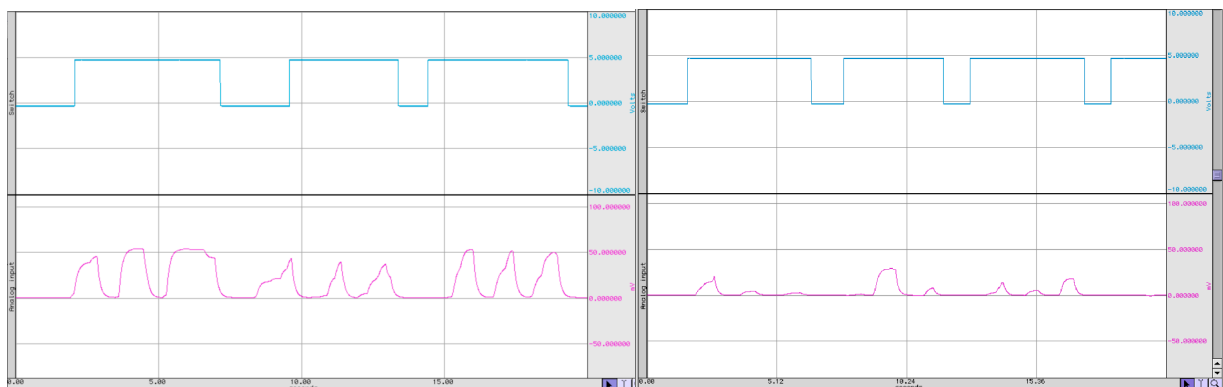
The statistical distribution of differences between pen-grip and the stick was not a standard distribution, according to the Shapiro-Wilk *W* test. These were paired data, because the same subject used both shavers. Thus, we used the Wilcoxon signed-rank test, a non-parametric test of paired data. Using this test, the difference in EMG integral value between two shavers was statistically significant ( $p < 0.0001$ ).



**Figure 2:** EMG examples in the middle, under the chin. The left panel shows stick shaver data and the right panel shows pen-grip prototype data for the same subject. The upper row corresponds to the flexor digitorum superficialis; the lower row corresponds to the flexor digitorum profundus. One tick on the y-axis is 1 mV; one tick on the x-axis is 2 s.

*Pressure to face measurement results:* As shown in Fig.3, the pen-grip prototype had a lower pressure. The pressure integral values (mV × sec/500(Hz)) of the two shavers (sum of seven sites) were compared in measurements from the seven participants. The ratio between the pen-grip prototype and the stick (average between subjects) was 0.15. Thus, an 85% pressure reduction was demonstrated using the pen-grip prototype.

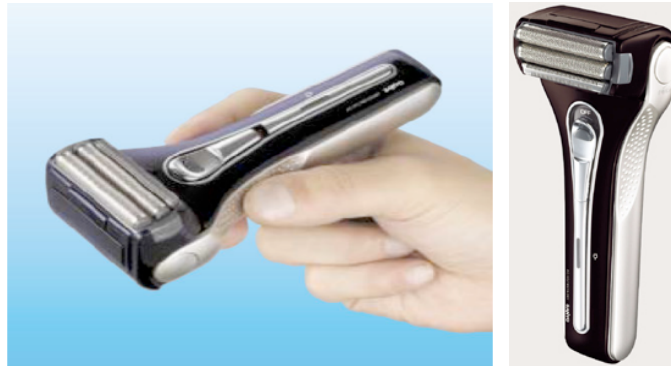
The statistical distribution of differences between the pen-grip and stick shavers was a standard distribution. Thus, we used the paired t-test; the difference in pressure integral value between two shavers was statistically significant ( $p < 0.0001$ ).



**Figure 3:** Example of pressure to the face; middle, right, and left under the chin. The upper row shows the moving period and the lower row shows the pressure. The left panel shows stick shaver data and the right panel shows pen-grip prototype data for the same subject. One tick on the y-axis is 50 mV.

### 2.1.3. Shaver results and product launch

From the experiment, the pen grip prototype reduced 22% of the forearm EMG and provided an 85% reduction in pressure to the face. Statistical tests demonstrated the significance of these reductions. As a result, the pen-grip shaver was developed and launched in March 2008, and has generated large sales at a fairly high price (around 9500JPY, 100USD) than before. Recently, two derived variations were added to a line-up.



**Figure 4:** Commercial realization of the pen-grip shaver (SANYO SV-GS1)

## 2.2. Washer-Dryer machine

Washer-dryer machines with slanted drums have recently become popular in Japan. Japanese washing machines have traditionally had vertical drums, and these are still quite common. The users of vertical-drum washers must bend their backs and stretch their arms to insert and remove laundry. In Europe, on the other hand, horizontal-drum washing machines have long been popular. This type of machine requires the user to crouch to insert and remove laundry because of its lower height.

The new washer-dryer combo machines have horizontal or slanted rotational drum axis. This has resulted in a significant change in shape, and the door position was changed to make loading and unloading easier.

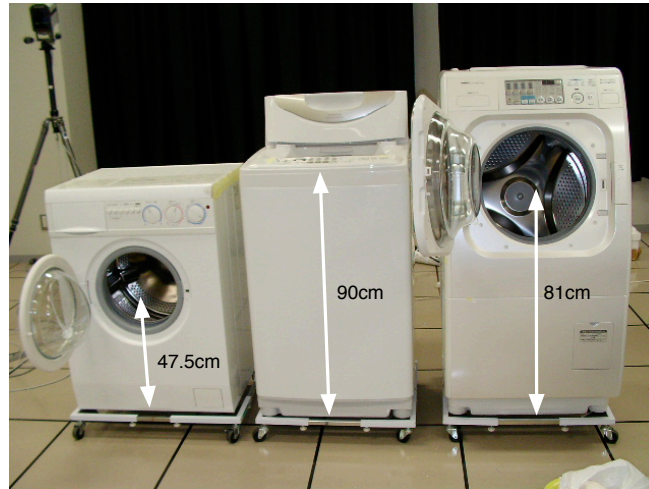
This research compared the physical loads and usability of the new generation of washer-dryer with traditional Japanese and European washing machines. This comparison was performed using subjective evaluations, three-dimensional (3D) motion captures, and estimates of the load on certain body parts using a human kinetics computer model.

### 2.2.1. Subjective Kansei evaluation

A subjective evaluation was carried out by asking the participants a set of questions each time they completed the task of removing laundry from a machine. Five questions were related to fatigue, five were related to usability, and one final question was related to the general usability of the washing machine. Table 1 lists the questions asked. Each question was answered on a five-point scale.

We used a one-way analysis of variance (ANOVA) to examine whether differences existed between the evaluations of the different washers. For post-hoc pair-wise comparisons, we used the Tukey-Kramer Honestly Significantly Different (HSD) test. Table 2 shows the results; washers are aligned by evaluations in rows. The slanted-drum machine received the highest evaluations for all questions.

Results show that 7 of the 11 questions were significant and that the European-type machine was statistically significantly inferior in terms of user fatigue and ease of use. The results also showed that the vertical-drum machine, which has been widely used in Japan until recently, was not suited for removing laundry from the drum (Q10). We next investigated the relationship between these results and the user's working posture using motion capture.



**Figure 5:** Laundry machines: European-type AWD-500 9 (left), vertical-drum washer ASW-800 (center), and slanted-drum washer-dryer AQ-1. The measurements on each machine are the heights to the center of the opening.

**Table 1:** Questions for Subjective Evaluation (left) and one-way ANOVA and Post-hoc Test Results (right)

1. How tired does your entire body feel?
2. How tired are your neck and shoulders?
3. How tired are your upper arms?
4. How tired is your low back?
5. How tired are your knees?
6. How easy was it to push the door open button?
7. How easy was to open and close the door?
8. How easy was it to check inside the drum?
9. How easy was it to insert your hand or arm inside the drum?
10. How easy was it to remove the laundry?
11. How easy was the machine to use?

Question	1way ANOVA significance	Good <-> NoGood, post-hoc test significance(*)
Q1	√	<div style="text-align: center;">           *            ┌───────────┐            │ slanted-drum, vertical-drum, European-type │            └───────────┘         </div>
Q2	√	same
Q7	√	same
Q8	√	same
Q11	√	same
Q10	√	<div style="text-align: center;">           *            ┌───────────┐            │ slanted-drum, European-type, vertical-drum │            └───────────┘         </div>
Q6	√	<div style="text-align: center;">           *            ┌───────────┐            │ slanted-drum, European-type │            └───────────┘         </div>

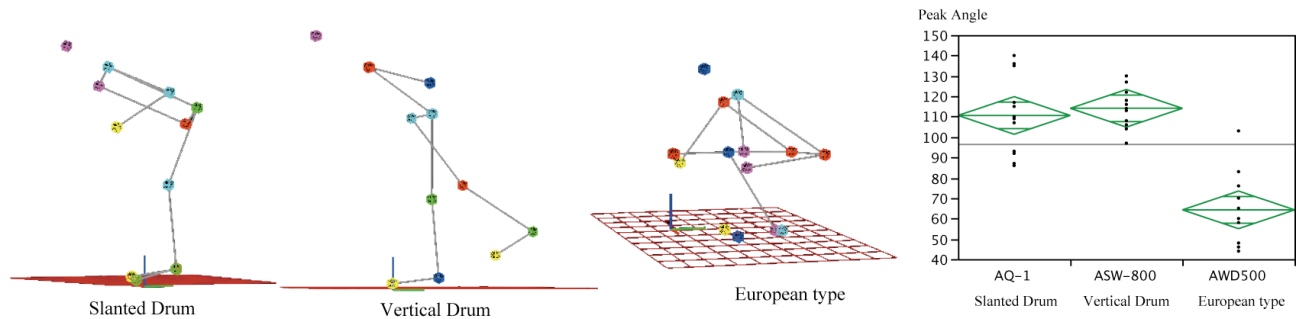
### 2.2.2. Working posture measurements using motion capture and analysis of joint angles

Slanted drum machine has excellent Kansei evaluations. We should know why these evaluations have achieved, and what the relations between body loads. Then, we have working posture analysis with motion capture system.

Figure 6 shows the posture of a participant with a height of 158 cm (the average for twenties to thirties Japanese women) during maximum bending of the body when removing a towel from the bottom of the drum. Using data from the motion capture, we measured and analyzed the angle formed by the knee, greater-trochanter, and shoulder. This angle was 110° (average of all participants) for the slanted drum, 114° for the vertical drum, and 64° for the European-type horizontal drum. Because standing posture is close to 180°, the larger angles are better. Slanted

drum has better (larger) angle than European type, but not the best. Single angle data is not enough for explaining the better Kansei evaluations on slanted drum.

We showed that the vertical drum required an unbalanced posture. The entire body load in such a position cannot be estimated on the basis of coordinates and angle data obtained through motion capture alone. The load on the lumbar vertebra that cannot be directly measured is also an important factor. Thus, to give due consideration to the mass of the various parts of the body, we attempted to estimate such loads using a kinematic model.



**Figure 6:** Posture during maximum bending of body (young 158-cm female) and graph of angles formed by the knee, greater-trochanter and shoulder for different machines

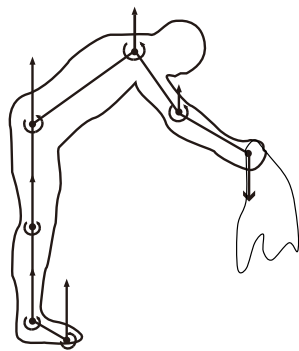
### 2.2.3. Static load estimates using a kinematic model

We estimated the load on various parts of the body using a kinematic model. To perform these calculations, we used the 3D Static Strength Prediction Program (3D SSPP) developed by a team lead by Prof. Don Chaffin at the University of Michigan. As shown in Figure 3(left), the Chaffin model features a human body with a basic structure consisting of seven links. These links are the forearm, upper arm, torso (shoulder to lumbar vertebra), sacral vertebra to pelvis, femoral head to knee, shank, and foot.

Using this model, we estimated the pressure (N) on the disk between the fourth and fifth lumbar vertebra and the maximum voluntary contraction (%MVC) for the muscles involved in the elbow, hip, knee, and ankle joints for the posture corresponding to maximum bending of the body for a 158-cm, 53-kg participant. The participant is most close to average height and weight of twenties to thirties Japanese women. Marker coordinates and the participant's height and weight were used for the parameters of load estimation.

Table 2 and Figure 7 (right) show that the slanted drum required less overall muscle strength, except for the hips. For the vertical drum, the pressure on the intervertebral disk was less than that of the other two machines, because the back was not bent as much. On the other hand, laundry cannot readily be removed from the bottom of a vertical drum without raising one foot, so that the load on the ankle of the other foot exceeded 100%. The load on the hip and knee was also high.

Summing individual %MVCs and comparing the overall %MVC for the different machines revealed that the slanted drum had the smallest value, with a muscle load about 60% less than that of the vertical drum. The European-type machine placed a smaller load on the hip than the slanted drum, but required 2.36 times the load on the knee because of the squatting posture required. These results demonstrate that the slanted drum permitted improved posture.



**Figure 7:** Body links (entire body) and SSPP calculation screen for the vertical drum (158-cm young female)

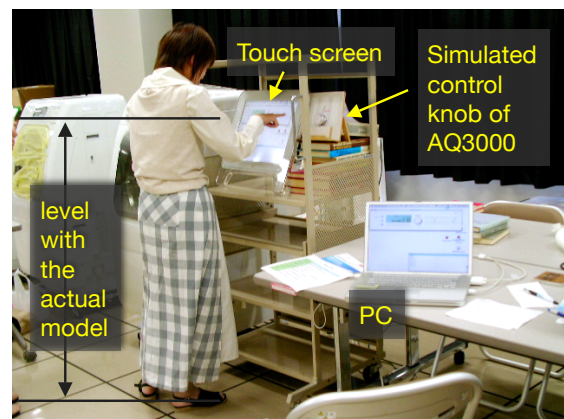
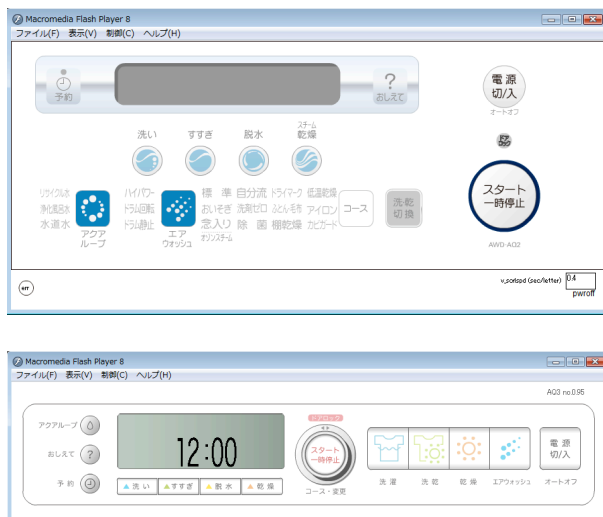
**Table 2:** Values estimated by the model (158-cm female)

Participant: 158 cm 53 kg	L4/L5 Comp (N)	Elbow (%MVC)	Hip (%MVC)	Knee (%MVC)	Ankle (%MVC)	Sum (%MVC)	Sum (%MVC)/ 400
Slanted drum	1732	12	54	25	25	116	0.29
European- type	1801	17	31	59	26	133	0.33
Vertical drum	1431	8	75	91	110	284	0.71

#### 2.2.4. Control panel improvement

After the working posture measurement and evaluation, we began a project to improve control panel of next generation of washer-dryer.

We compared the control panels of the existing model washer (SANYO AWD-AQ2000) and the proposed model prototype (AWD-AQ3000) that included a modified layout and a control knob. The both panels were implemented as two simulator programs.



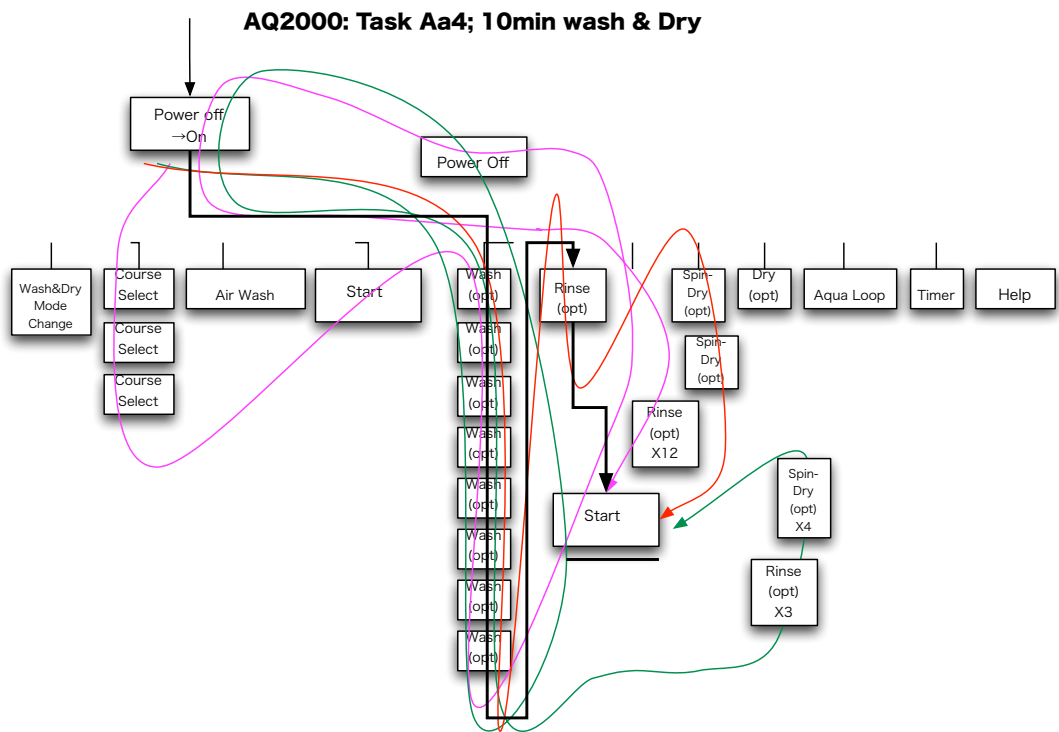
**Figure 8:** Control panels of the washer-dryers used in the usability experiment  
Upper Left: Simulated panel of AWD-AQ2000, Upper Left: AQ-3000, Right: Experimental setup

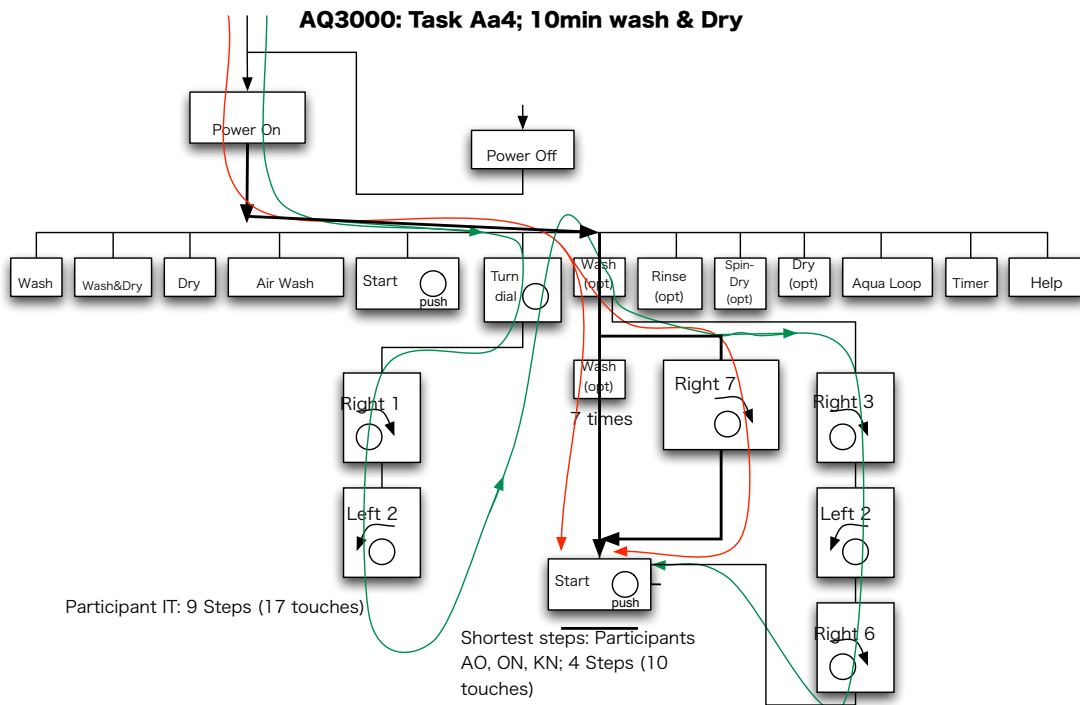
Figure 8 shows screen copies of the two simulated panels and an overall view of the experimental setup. The participants in the experiment were seven women all over the age of 30 who were accustomed to using automatic washing machines.

The required tasks were the following: turn on the power, select the wash or wash-dry mode, change the washing courses, adjust the wash settings, set the timer, set water-saving mode, and set the “air-washing” function. The instructions given to the participants were, for example, “Set to the machine to wash the wool sweater and then end without drying it” or “deodorize the leather shoes.”

The participants were asked to set the designated washing tasks by using two simulator panels. The time and the number of steps to complete each task were measured. Each turn of the control knob of the AQ3000 was counted as one step. The level of irritation on a five-point scale was reported by each participant. All steps were recorded on video tapes.

Hierarchical task analysis (HTA) (Stanton & Young, 1999) was performed (Figure 9) to find the erroneous steps of the tasks we conducted. The current alternatives were laid out horizontally and the participants’ actual operations were followed vertically. This permitted easy identification of the points where our participants became lost by comparison with the intended (optimal) operating sequence.





**Figure 9:** HTA example of a trial of “10 min wash and dry” task on AQ2000 and AQ3000 (simulator). Choice buttons and control knobs (AQ3000) are drawn as connected boxes. The shortest procedure and the sequence that the participant actually performed are indicated.

#### 2.2.5. Improvement of the AQ3000

Based on these results, we proposed to adopt the control knob and to isolate the mode-selection (wash-and-dry / wash / dry) buttons from the other buttons. The locations of the “Start” button and control knob were also changed. The “Power” button was placed at the right end and the “Start/Stop” button was placed just to its left.

The courses were differentiated from the program options. The courses were appeared in sequence when rotating the control knob. The detailed options were appeared when rotating the knob after pressing one of “Wash options,” “Rinse options,” “Spin-dry options” or “Dry options”. The control knob was also knurled to increase user control.

#### 2.2.6. Final verification with prototype models

Fifteen male and female washing machine users, aged 30-61, and 25 users about 20 years old participated in the usability experiment. They were asked to operate to the actual hardware of the conventional model (AQ2000) and the improved hardware prototype model of (AQ3000) to perform six of the seven washing tasks.

There was no significant difference in the total completion times for the two models, but the total number of steps and the total level of irritation were significantly reduced with the new model. We then focused on the performance of the participants 30 years and older, because they most closely represent our target market. We found that all measurements were significantly reduced for the new model. In particular, the change in layout and control knob facilitated the task of using the “Air-wash” function (disinfects and deodorizes using ozone instead of water), reducing the average completion time to 34.5% that of the conventional model.



**Figure 10:** Usability experiment with the hardware prototype models.

### 2.2.7. Improvements and results of Washer-dryer

Measurement of working posture showed the evidences of superiority of slanted drum design over the conventional vertical or horizontal drum machines. In our control panel study, small problems found during the experiment were fixed in the final production model. The colored line on the start button was changed so that it would be easily discriminated from the power button. The final design is shown in Figure 11. The improved new model AQ-3000 was released in February 2008 and became a success in the marketplace.



**Figure 11:** Production model of the SANYO AQUA AWD-AQ3000.

## ACKNOWLEDGMENTS

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## REFERENCES

Ishihara, S, Ishihara, K. & Nagamachi, M.(2007a), The graphical analysis method for non-linear relation between Kansei evaluation and design elements, *Ergonomia*, 29(2), 91-201.

- Ishihara, S., Nagamachi, M. & Ishihara, K. (2007b), Analyzing Kansei and design elements relations with PLS, Proceedings of The First European Conference on Affective Design and Kansei Engineering [CD-ROM], Helsingborg.
- Ishihara, S. (2008), Morphometrics と感性工学への応用, [Morphometrics and its applications to Kansei Engineering], 『感性工学』 [Kansei Engineering], Vol.8 No.1, pp.17-23 (in Japanese).
- Ishihara, S., Ishihara, K., Nakagawa, R., Nagamachi, M., Sako, H., Fujiwara, Y. & Naito, M.(2010), Development of a washer-dryer with Kansei Ergonomics, Engineering Letters, 18(3), 243-249.
- Nishino, T., Nagamachi, M. & Tanaka, H. (2005), Variable precision bayesian rough set model and its application to human evaluation data, In D. Slezak, G. Wan, M. Sezuka, I. Duntch and Y. Yano (Eds.), Rough Sets, Fuzzy Sets, Data Mining and Granular Computing, (pp.294-303). Berlin Heidelberg, Springer-velag.
- Nishino, T., Nagamachi, M. & Sakawa, M. (2006), Acquisition of KANSEI decision rules of coffee flavor using rough set method, International Journal of Kansei Engineering, 5(4), 41-50.
- Nishino, T., Nagamachi, M., Sakawa, M. & Tanaka, H. (2006), A comparative study on approximations of decision class and rule acquisition by rough set models, International Journal of Kansei Engineering, 5(4), 51-60.
- Tsuchiya, T., Maeda, T. Matsubara, Y. and Nagamachi, M.(2007), A fuzzy rule induction method using genetic algorithm, International Journal of Industrial Ergonomics, 18(2-3),135-145.
- Yoshida, T. & Iwaki, T.(2000), The study of early emotion processing in the frontal area using a two-dipole source model, Japanese Psychological Research, 42(1), 54-68.
- Stanton, A. and Young, M.S. (1999), A Guide to Methodology In Ergonomics, London, Taylor & Francis.

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