Research and products of Matsushita Electric Works for the aging society

This paper discusses Matsushita Electric Works' strategies for designing equipment from the viewpoint of Ergonomics and Kansei Engineering to assist the elderly. We refer to Universal Design philosophy related to the development of equipment to assist elderly people. We conducted ergonomic experiments in relation to the design of handrail and toilet. Using the evaluated Kansei data, we built the principle of body pressure scattering on toilet seat and applied that principle to find the most comfortable toilet set-up.

In 2005, Japan's aging ratio for over 65 years of age was 19.9% of the population and is predicted to be 27.8% in 2020. Japan functions as a super-aged society compared to the rest of the world. In addition, Japan's life expectancy is becoming larger. One prediction is that in the future 75% of 50 year olds will survive to 100 years of age.

The policy of 'Universal Design' emerged from the U.S.A. and has spread quickly throughout the world. This way of thinking affected Japan's business as to aging and it is now common sense to develop equipment to improve the welfare and well-being of the elderly. Matsushita Electric Works started early in implementing the Universal Design philosophy in product development for the elderly and began selling 'Iki-Iki Goods' (goods for activating the elderly) in 1991. These were related to developing equipment for the home, and then, in 1997 'Age-free Business' was established as one of the most important company strategies in providing the elderly home-based goods and related services. In 2001, Matsushita's company policy changed from the 'barrier-free concept' to 'universal design philosophy'. This became the fundamental strategy regarding home-based products and systems. The development of such equipment and systems has been based on human factors, ergonomics, and Kansei engineering.

Kansei engineering was founded by Mitsuo Nagamachi three decades ago at Hiroshima University[1]. It is defined as 'translating technology of the user's psychological and physiological demands into design specifications to develop the excellent goods fitting the user's demands'. Kansei engineering has been utilized to develop new products in Japan and in the world. It has the capability to create products that satisfy customers because the products are designed to match their feelings and demands. The technology has been and will be applied to the development of the welfare care equipment field and to the products for elderly people.

Approach to supporting the elderly

In 1997, Matsushita Electric Works began to help people who need special care under the company strategy named 'Age-free policy' that combined the concepts of 'barrier-free', 'stress-free', and 'care-free'. First, we provided new products for equipment to assist the elderly in their dwellings or homes. Currently Matsushita provides assistive services and home management services and other care services for the elderly, and equipment for sale to assist the elderly, remodelling elderly people's house, etc.

The universal design (UD) concept proposed by Professor Ronald Mace[2] has spread throughout the world and suggests that design should be created for all users. Therefore, products designed under the UD concept are to be easily operated and comfortable regardless of age, sex, race, human size, mental ability, etc. of the user. Matsushita began developing all products using this philosophy.

The founder of Matsushita Corporation, Konosuke Matsushita, used to educate employees under almost the same policy as UD. He said that Matsushita should produce products based on 'customer-orientation'. This has been the company's policy for a long time, so it proved not difficult to implement the UD concept on a company-wide basis.

We started the UD philosophy with the realization of symbiosis from combining manufacturing design, dwelling design and town-building design, and we reconstructed UD philosophy, unifying two directions of usability and contributions to more people. To reach these objectives, we focus on UD issues in a six-phase process, as follows:
(i) Understandable operations,
(ii) Clear display and explanation,
(iii) Comfortable posture and action,
(iv) Movement and space,
(v) Safety and security anxiety,
(vi) User environment.

Figure 1. An example of UD products, a toilet with arm stands named TRES

The UD issues are examined at each stage of idea building and planning, trial, manufacturing, design, and review.

A list of UD products in Matsushita Electric Works include:
(i) a staircase with firefly lighting: a low level lighting that automatically switches on when going to the toilet during the night, (ii) a sitting wagon in the kitchen, (iii) a kitchen that accommodates a wheel chair, (iv) a dressing table unit, (v) a dressing table accommodating a wheel chair, (vi) a clothesline in the room, and (vii) a toilet with arm stands (TRES, *Figure 1*).

Practical use of ergonomics or Kansei engineering

Aging affects human ability and function. Any decrease of brain cerebral function may influence many aspects such as muscular strength, physiological functions of vision, hearing and others as well as weakness of memory and judgment. Applications of ergonomics and the Kansei engineering to dwelling design have strong implications for UD considerations supporting quality of life (QOL).

Ergonomics of handrails

In this section, we focus on two assistive technology cases applied to dwelling design from the viewpoint of ergonomics or Kansei engineering. First, we conducted a survey about use of handrail at home. About 3,000 elderly people were asked and 1,165 people answered the questionnaire (*Figure 2*). The percentage of elderly using the staircase handrail at home will increase with advancing age. The staircase handrail is important in the prevention of falls[3].

We conducted several ergonomic experiments to identify the factors regarding the best handrail fit for the elderly. Aged subjects wore EMG (electromyogram) sensors on the legs and EMG was

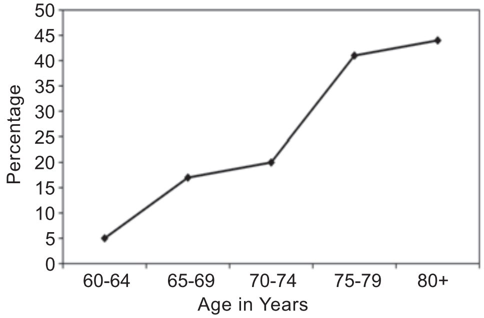

Figure 2. Distribution over age categories of the persons using a staircase handrail within the dwelling

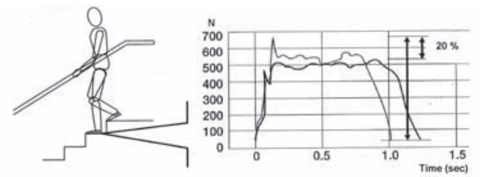

Figure 3. Using the handrail in stepping down resulted in 20% reduction of force used, as measured with a force plate

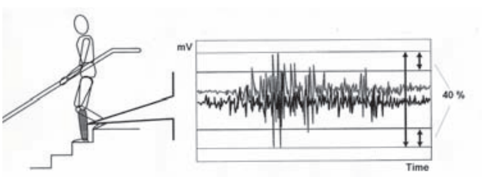

Figure 4. Using a handrail in stepping down resulted in 40% reduction of electromyogram oscillations in the legs

measured when stepping up and down the staircase. Force plates measured body swift. Comparing with and without handrail (*Figure 3*) shows that 20% force reduction was reached with the staircase handrail. In the next experiment, we set up EMG sensors on the subject's legs. The experiment showed that the use of a handrail was associated with a 40% reduction in the oscillations of the EMG (*Figure 4*).

Why can the usage of staircase handrail save force so much? When stepping up and down, especially when stepping down, standing on two legs is not stable and safe. The elderly have less muscular strength and they swing their body when stepping down. But if they grasp the staircase handrail, a three-point support arises: two feet and one grasp of the handrail. This increases elderly stability. The extra leg stability saves unnecessary expenditure of energy in keeping a stable body posture. Therefore, a staircase handrail is useful and effective for them for stepping down safely[4].

Entryway handrail

In a typical Japanese house, there is a small step (Kamachi) at the entrance, where people take off their shoes to go inside. When going outside, the elderly have difficulty putting on their shoes while standing up. If there is a vertical bar (handrail), they can use it when standing up.

We measured the body center of gravity of elderly subjects by means of the force plate when putting on shoes and standing up. The experimental results showed the large and the small swing in movement without and with handrail, respectively (*Figure 5*). Both horizontal and sloping handrails tilted 30-40 degree appeared effective for the elderly and facilitated standing-up.

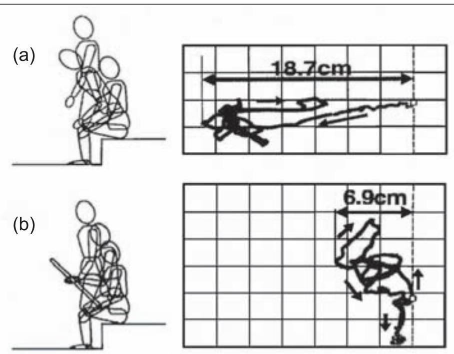

Figure 5. Oscillations of the center of gravity of the body when standing up without handrail support (a) and when using a sloping handrail (b) at the entry of a Japanese house; Starting from the open symbol at the right, arrows indicate the changes in time

Development of a new type of toilet

Our next activity was related to the development of a toilet fitting to elderly people.

An assisting device for toilet use by elderly people includes commonly an assisting mechanical system consisting of an oil-cylinder equipped to push up the bowl surface. That way the old person can easily stand up. But in general, mechanical systems are expensive, and regular maintenance is needed. Using Kansei engineering and the UD concept, we aimed at providing comfort and easy operation in toilet use:

(i) We first measured 20 students and two old people's hip shape and tried to illustrate it on three-dimensional computer graphics. The subjects consisted of male and female students and two female elderly persons, who suffered from a knee-joint injury;

(ii) We collected 6 toilet bowl surfaces from different manufacturers and compared the size, three-dimensional surface structure and other features. All subjects sat on the bowl surfaces and evaluated its fitness on a 5-point scale on an evaluation sheet with ten adjective words, called Kansei words, such as: easy to sit, comfortable, calm, wide;

(iii) Experiments were conducted to measure EMG on the forearm muscles, femoral muscle and gastrocnemius muscle. To create a better designed toilet that should be easy to stand up from, the new toilet was tilted 5 degrees in the front direction, and we equipped the toilet with arm rests on both sides (*Figure 1*). In this situation muscle contractions as measured with EMG were smaller with the new toilet, as compared to the old one. That is, the ordinal of EMG oscillations of the new toilet without arm rest, was larger than that of the new toilet with arm rest;

(iv) Each subject sat down on each bowl surface and their body pressure on the bowl surface was measured. The data of 3DCG (3 Dimension Computer Graphics) of hip shape, EMG and questionnaire results of 'comfort' and 'easy standing-up' were integrated in the design of the new type of toilet, which was named 'TRES' (Toilet related Ergonomics).

Evaluation of the new product 'TRES'

We aimed to produce a new product for all people, especially for the elderly. Therefore, we evaluated the resulting design with data concerning two elderly persons, who completed 2 trials each. EMG was measured from a forearm and a leg, as well as hip body pressure on the bowl surface.

An integral value of EMG

We calculated the integral value of EMG when each subject stood up from each bowl surface. In this case, we compared a TRES with and without arm support (*Figure 6*).

The EMG integral was calculated for each muscle on standing up from the new product with and without using the arms. The three EMG values from the forearm muscles, the femoral muscle, and the gastrocnemius muscle were set at 100% when standing up from a normal toilet.

Muscle activity of the forearm showed no decrease when using TRES without arm support. On the other hand, both TRES with arm and without arm support greatly decreased the EMG activity from the gastrocnemius muscle. The reason of this stems from the surface of TRES that slopes 5 degree forward. This supports easy standing up for the elderly. If a TRES with arm support is used the EMG integral decreases to 72% for the forearm muscles and 73% for the femoral muscle.

From this evaluation experiment we may conclude that the new toilet design eases standing-up behavior, without the need of an active mechanical support.

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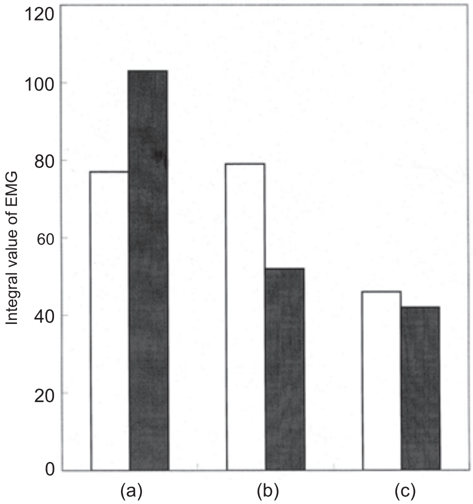

Figure 6. Comparison of integral value of the electromyogram (EMG) of the fore-arm muscles (a), femoral muscles (b), and gastrocnemius muscle (c); in white: complete TRES; in black: TRES without arm support

Body pressure

We conducted another experiment for evaluating the effectiveness of the new product as to toilet seat comfort. From the measurement of the subject hip shape, we concluded that:

(i) The backyard area of the seat should be wider to secure a safer feeling,

(ii) Both sides of front area of the seat that touches the lower part of the thighs should be lower and curved down, compared to the front center line; this curved discrepancy enables a soft touch to the lower part of thighs.

(iii) It used to be said that a good chair will have the body pressure centered at two points under the hipbone node (tuber ischiadicum). We changed this principle in a body pressure that is equally distributed around each node's center.

We imagined that the flattened distribution of body pressure, together with the soft touch with the lower part of thighs will make for increased sitting comfort.

Under these new principles, we re-designed the TRES toilet adding arm rests and the curved seat surface. To test this new design, we covered the TRES seat surface and the surface of an ordinary toilet seat with a body pressure mat from FSA Ltd, and seated two elderly female subjects on the mat (*Figure 7*).

The hip pressure using an ordinary toilet (upper part of Figure 7) shows the highest pressure spreading out from

(a)

9	8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	5.9	22	18	4.3	0	0
0	0	64	53	77	40	9.4	0	8.0
0	45	67	79	100	55	20	3.1	0
0	100	84	95	100	46	51	2.7	3.5
0	72	76	25	9.8	9	49	3.9	0
0	44	18	5.9	15	11	21	16	0
0	0.8	0	1.6	5.5	7.8	12	18	0
0	0	0	0	3.1	5.9	5.1	18	0
0	0	0	0	0	0	0	14	0
0	0	0	0	2	2.4	4.7	36	0
0	0	0	3.1	1.6	5.5	12	15	0
0	1.6	5.9	2.4	4.3	3.9	18	8.6	0
0	20	52	22	6.3	11	34	6.7	0
0	36	69	82	42	82	45	4.3	1.0
0	33	88	71	68	100	32	0.4	0.4
0	0.4	100	100	96	68	24	6.3	9
0	0	47	56	76	42	9	0.4	0.8
0	0	0	0	6.7	6.7	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

Measurement row

(b)

9	8	7	6	5	4	3	2	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0.4	0.4	5.9	14	6.3	0	0
0	0	25	40	40	38	17	0.4	0
0	16	23	36	60	57	30	9.4	0
0	13	33	51	100	100	96	18	0
0	13	47	83	20	24	43	29	0
0	5.5	23	2.7	12	15	5.5	29	0
0	0	2.7	1.2	10	11	3.1	28	0
0	0	0	0	0.4	5.5	0	24	0
0	0	0	0	0	0	0	25	0
0	0	0	0	3.9	2.7	0	13	0
0	0	0	0	5.5	7.5	2	14	0
0	5.5	0	2.7	8.6	11	2	24	0
0	7.8	10	2.7	11	12	9.4	17	0
0	16	50	11	8.6	7.5	73	24	0
0	21	34	100	62	51	66	30	0
0	7.8	22	65	100	100	40	18	0
0	0.8	20	35	45	100	36	4.3	0
0	0	0	0	0	1.6	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

Figure 7. Hip pressure on an ordinary toilet (a) and on TRES (b); Front of toilet to the left; The numbers represent the presure in mm Hg (1 mm Hg = 133 N/m²)

left to right under both thighs. This means that the whole toilet-seat surface touches the under surface of both thighs. This implies uncomfortable feelings, because the pressure to the thighs will disturb the blood flow to the legs.

On the contrary, with TRES (lower part of Figure 7), the highest pressure spreads only along the length of the thighs around the hipbone nodes, expressing a comfortable sitting.

Psychological evaluation
22 Subjects including two female subjects were requested to fill out a 5-point SD scale with Kansei words on 'comfortable', 'easy standing up', and so forth. On a 10-point scale as to 'comfortable sitting', they evaluated TRES in a positive way (average: 6.5 points), but were negative in relation to the ordinary toilet (average: 2.8 points).

Two female subjects expressed their feeling as 7.6 on 'comfortable sitting', and 8.5 on 'easy standing up'. The t-test showed a significant difference between the assessment of an ordinary toilet and the TRES toilet. Differences between elderly and young subjects were also significant. The TRES has sold very well in the market since beginning of manufacturing in 2004, and has been well-known for its excellent product fit to the elderly.

General remarks

Matsushita Electric Works has implemented the philosophy of 'Universal Design', and has used ergonomics and Kansei Engineering as their product development technology. We endeavoured to create a number of different kinds of products, from a shaver to a robot in the electrically powered products field, as well as from floor material to roof material in home equipment. We are always focussing on realizing QOL and assistive devices, and equipment for the elderly to use and feel comfortable.

In this contribution we described a few products that were created using ergonomics and Kansei Engineering. Many more dwelling devices have been produced for people of all ages, but we want especially to create useful products for the elderly in Japan's aging society.

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