A Study about the Effect of Space Size on the Individual Distance

Miyu Aoki¹ and Akiko Watanabe²

1. Eizo-System Co., Ltd., Tokyo 108-0014, Japan

2. Department of Architecture, Tokyo Denki University, Tokyo 120-8551, Japan

Abstract: This study is the design guidelines for the living space with robots. The study can be applied to the architectural planning and focused on the basic environmental primary factor. The authors focused on space size, specific distance from the wall in the front direction, position, and distance between an individual as factors affecting individual distance. The authors research the distances a small mobile robot moves to a six mats space compared with that toward a distance 5 m or more (space less physical factors). The following three results were obtained: (1) The individual distance is smaller than 30 cm in both the approach angle in the experiment space of six mats; (2) The distance from the wall in the front increased, and the individual distance between a participant and a robot also increased; (3) In terms of body position, the upright positioning was clarified and the individual distance was small.

Key words: Small mobile robot, individual distance, living space.

1. Introduction

The use of home cleaning robots is becoming popular. Some robots are equipped with a camera and voice communication capabilities. In Japan, such robots are expected for monitoring the health of the elderly. In addition, the issues for alone elderly is also a concern. For these reasons, the robot to help the lives of single persons is required in housing.

The authors conducted basic research to find design guidelines for those involved in architectural planning for living spaces with robots and focused on the basic environmental primary factor. This research focuses on the distances a small mobile robot moves to human. In related research, it is focused on the generation and sex of the subject. The authors conducted experiments to target adult male and female, the elderly person and the infant [1-7]. This is assumed the resident of living space.

Moreover, the influence of the space, the difference in ceiling height and the size of the plane of the space are considered to affect the act and mental evaluation

at the time of using the inside of space.

The authors researched the distance in gymnasium of the university where a physical factor was few (point 5 m or more away). This research focuses on the size of the space, and the authors aim to identify the distance at which the robot can approach individuals and clarify how the distances to individuals change as the space. The authors research the distances a small mobile robot moves to six mats space compared with that toward a distance of 5 m or more (space less physical factors). Moreover, at the apartment complexes in Japan, a living room of six tatami mats (9.9 m²) is common. Therefore, we focus on such a living space.

2. Methods

The experiment with adult males was done from October 9 to November 22 in 2012. People were selected for the trial aged 21-26.

The distance was measured close to the small mobile robot as subjects gradually looked at the small mobile robot and indicated when they did not wish to be approached any further.

Corresponding author: Miyu Aoki, M.A., research field: architecture planning. E-mail: aoki@eizo-system.co.jp.

The authors did this experiment to analyze 54 patterns per person when at an angle of the difference of male, three position standing/seated/seat on floor and one speed-setting—0.08 m/s, no function (the subject has been described that it is the moving object) and five directions—0°, 45°, 90°, 135°, 180°.

This experiment was performed in room at the university campus. The dimensions of the experimental room were set as 90 cm × 180 cm × 270 cm × 360 cm. This distance is based on the assumption that changes to 90 cm per space in Japan.

In addition, this experiment was set at a random pattern and got a wireless remote control to operate the subject which was tested in a way to stop the small mobile robot. In addition, there were not subjects who has a trauma or a failure that leads to avoidance or walking (Tables 1 and 2 and Figs. 1-3).

3. Result and Discussion of Experiment 1

From data obtained from the experiment, the authors considered the distance between adult male and the small mobile robot. In addition, the standard deviation was determined to be an indicator of the overall variability in the data because there was individual variation (Table 3).

This was verified by focusing on space size, specifical distance from the wall in the front direction, position and distance between an individual as factors affecting individual distance. The size of space to verify the impact changed the experiment space because that the living space of housing is assumed. In order to verify more impact, the distance from the wall in the front direction is the impact on an individual distance by the change in distance from the wall to clarify the effect by the human body feels narrower. In addition, this experiment sets three behaviors of attitudes, standing, chair sitting position, sitting position on the floor because of assumed living behavior in housing.

3.1 Effect of Size of Room for Individual Distance

The individual distances are compared from the outcome of an experiment by the change in the area of the space. The comparison is “the gymnasium of the university (point 5 m or more away) where a physical factor is few” and “the experiment space of six mats (central position in the laboratory)”.

In addition, the robot was the experimental conditions ever “size: small mobile robot”, the robot’s speed was 0.08 m/s and there was no setting function.

Table 1 Experimental settings.

Approaching angle (°)	Distance from the wall in the direction of the front (cm)			
0	90	180	270	360
45	90	180	270	360
90	90	180	270	360
135	90	180	270	360
180	90	180	270	360

Table 2 Average data of the subjects.

Adult males	Average	Standard deviation
Average age	21.7	±1.3
Average height (standing) (cm)	172.1	±5.4
Average height (seated) (cm)	84.5	±5.4
Average height (seated on floor) (cm)	84.5	±5.4
Average visual acuity (both eyes)	0.9	±0.4

Measurement (width × depth × height)
120 mm × 130 mm × 70 mm
Speed:
0.08 m/s
Function:
No function (no relationship)

Fig. 1 The robot conditions.

Fig. 2 Experimental venue 1.

Fig. 3 Experimental venue 2.

Table 3 Individual distance of front distance and each posture.

		Distance from the wall in the direction of the front (cm)			
		90 cm	180 cm	270 cm	360 cm
Individual distance	Standing	67.9	74.1	71.2	83.3
	Seated	79.6	84.2	80.4	88.9
	Seated on floor	78.2	84.2	80.2	91.6
Standard deviation	Standing	37.0	32.8	35.9	38.5
	Seated	31.8	29.3	32.3	37.0
	Seated on floor	34.7	29.8	30.6	39.0

Table 4 Effect of size of room for individual distance.

Posture	Space	Approaching angle (°)					Average distance	Standard deviation
		0°	45°	90°	135°	180°		
Standing	Gymnasium	122.4	145.7	142.6	153.7	157.0	144.3	65.2
	Six mats	67.1	75.3	76.9	79.7	71.4	74.1	36.1
	Range difference	55.4	70.5	65.7	74.0	85.6	70.2	
Seated	Gymnasium	161.6	164.4	137.5	152.1	144.0	151.9	65.6
	Six mats	88.6	92.0	80.2	84.6	75.9	84.2	32.4
	Range difference	73.0	72.5	57.3	67.5	68.1	67.7	
Seated on floor	Gymnasium	121.7	123.5	117.2	121.0	130.5	122.8	64.0
	Six mats	76.8	84.8	83.0	86.5	82.6	82.7	33.3
	Range difference	44.9	38.7	34.2	34.6	47.9	40.1	

The participants were adult males who were asked to stand, sit on a chair or sit on the floor.

Table 4 compares the measured individual distances with the experimental results.

The difference in individual distance for each position was 70.2 cm (in gym 144.3 cm $\pm$ 65.2, in six tatami mats 74.1 cm $\pm$ 36.1) for standing, 67.7 cm (151.9 cm $\pm$ 65.6, in six tatami mats 84.2 cm $\pm$ 32.4) for sitting on a chair and 40.4 cm (in gym 122.8 cm $\pm$ 64.0, in six mats 82.7 cm $\pm$ 33.3) for sitting on the floor.

Fig. 3 shows that every angle was common to all,

which revealed that the individual distance was less than 30 cm. Thus, the size of the room may affect the individual distance between a robot and on adult males.

Figs. 4 and 5 show the experimental results obtained when the participants were standing.

The individual distance for this study is based on Hall's phases of intimate distance (between 15-45 cm) and personal space (between 45-75 cm) [8]. Intimate distance is where one can easily touch someone else and personal space begins about an arm's length away.

Fig. 4 Effect of size of room for individual distance floor plan.

That is considered to be aware of the contact and the operation of the human body than the distance of the conversation in a confined space of six tatami mats.

3.2 Effect of Distance from Wall on Individual Distance

We studied the effect of distance from the wall surface of the front. We found that the standard deviation and individual distance increases when each

front distance increases from Fig. 6. Thus, the distance from the wall surface of the front affects individual distance.

As the distance (L) from the front wall surface increases, the proportion of I/L and individual distance (I) decreases. In particular, the distances can be considered to gradually change in 360 cm and 270 cm front distance. The impact on individual distance gradually becomes smaller.

3.3 Attitude toward Individual Distance

We clarified that it was common to the condition of all the front distances as a result of examining the influence at the individual distance by posture from Fig. 7 and the individual distance became small in “upright positioning (which is significant in $p < 0.05$)”.

Fig. 5 Effect of size of room for individual distance elevation plan.

Fig. 6 Comparison of individual distance of 0° angle.

Fig. 7 Comparison of individual distance of each position.

Moreover, the individual distance in “floor seat title” was smaller than when the participants were sitting on a chair in the front distances of 90 cm and 180 cm (which is not significant in $p > 0.05$). It is considered to be a reason that this was conscious of leg operation of the body in the direction of the front in 90 cm of front distance and 180 cm at the time of a chair seating position since distance with a wall was closer.

4. Conclusions and Future Prospects

The following four results were obtained:

- Individual distance is smaller than 30 cm in both the approach angle in the experimental space of six tatami mats and the current point away more than 5 m. The comparison is “the gymnasium of the university (point 5 m or more away) where a physical factor is

few” and “the experiment space of six mats (central position in the laboratory)”;

- The distance from the wall in the front increased and the individual distance between a participant and a robot also increased;

- In terms of body position, the upright positioning was clarified and the individual distance was small;

- Moreover, the individual distance when the participant sat on the floor title becomes smaller than chair sittings in the direction of the front because of the lower limbs operation of the body in the chair sitting.

The authors will continue research in order to develop for architectural planning technique living with robot. We will also conduct experiments in a living room of housing in future.

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