Walking Environments for the Visually-Handicapped : Recognition of Spaces in a Geometric Model Laboratory

WALKING ENVIRONMENTS FOR THE VISUALLY-HANDICAPPED : RECOGNITION OF SPACES IN A GEOMETRIC MODEL LABORATORY

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Abstract

In daily life it is not safe for visually-handicapped people to walk alone and often they have accidents or lose their way. In order to improve walking environments, it is important to show clearly how visually-handicapped people recognize spaces and their position in spaces, and what the clues to recognition are.

In this study, in order to clarify the characteristics of search behavior, experiments are carried out in 12 kinds of model spaces of geometric plan. The behavior of the visually-handicapped is analyzed by walking locus, and the recognition of spaces, by sketch map and interview.

1. Introduction

Recently in Japan, town planning which takes into account special needs has progressed, so that elderly people or handicapped people can now go out more easily. However, it is not safe for visually-handicapped people to walk alone, and often they have accidents or lose their way. Improvement of the walking environment is needed so that visually-handicapped people can reach their destinations safely by walking alone.

It is important for such improvements to show clearly how visually-handicapped people recognize spaces and their position in spaces, and what the clues to recognition are[1].

In this study[2,3], in order to clarify the characteristics of the search behavior of visually-handicapped people, experiments are carried out by producing 12 kinds of model spaces and treating these people as main subjects.

2. Outline of Experiments

2.1 Subjects

The subjects are seven visually-handicapped people between 19 and 27 years old, and nine eye-masked people with ordinary vision who are aged between 21 and 23 years old.

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Table 1 Attribution of the subjects (the blind)

Subjects	blind 1	blind 2	blind 3	blind 4	blind 5	blind 6	blind 7
age / sex	27years/male	20years/male	24years/female	26years/male	19years/female	22years/female	26years/male
occupation	self-employed business man	university student	domestic help	graduate student	university student	university student	technical college teacher
level of handicap	1st class, acquired blindness	1st class, congenital blindness	1st class, congenital blindness	1st class, congenital blindness	1st class, congenital blindness	1st class, congenital blindness	1st class, acquired blindness
age became blind	17 years	0 years	0 years	16 years	7 years	2 years	21 years
disease	glaucoma, cataract	cataract	premature retinopathy	congenital blackout	detachment of the retina	retinoblastom	retinitis pigmentosa
eyesight 1: right	light perception	0	0	light perception	0	0	0.01
: left	light perception	0	0.01	light perception	0	0	light perception
view	nothing	nothing	angle of 30 degrees	peripheral vision	nothing	nothing	angle of 5 degrees
eyesight 2 :light	△	×	○	○	×	×	○
:color	×	×	○	×	×	×	×
:shape	×	×	×	×	×	×	×
hearing	normal	normal	normal	normal	normal	normal	normal
training : age	17 years	6-18 years	6-15 years	13 years	8-15years	5-15 years	19-20 years
: contents	walking training daily life training braille training personal computer	walking training daily life training braille training	walking training daily life training braille training thread work	walking training	walking training daily life training braille training information technology	daily life training braille training	walking training daily life training braille training
braille reading	○	○	○	○	○	○	○
walking cane	all the time	all the time	all the time	all the time	all the time	all the time	all the time
education:primary	general course	school for the blind	school for the blind	general course	general course	school for the blind	general course
:junior	general course	school for the blind	school for the blind	school for the blind	school for the blind	school for the blind	general course
:high schoo	general course	school for the blind	school for the blind	school for the blind	school for the blind	school for the blind	general course
:university	general course	general course	general course	general course	general course	general course	general course
:professional education	none	none	none	none	none	none	none
destination	hospital, bank, customer	university, parents' home	station, super market	Umeda Osaka, Kawaramachi Kyoto	university, Namba Osaka, Umeda Osaka	university, supermarket, station	Umeda Osaka, Yotsubashi Osaka
frequency	3 or 4 times/week	every day	once /2 or 3 days	every day	every day	every day	every day
care-giver accustomed place unaccustomed place	with a care-giver with a care-giver	alone alone	alone alone	alone alone	alone with a care-giver	alone alone	alone alone
transportation	train, bus, taxi	train	train, bus	train, bus	train	train, bus	train
housing type	detached house	apartment house	detached house	apartment house	apartment house	apartment house	apartment house
dwelling style	with family	without family	with family	without family	with family	without family	with family
health condition	good	good	good	good	good	good	good

Table 2 Attribution of the subjects (the eye-masked)

Subjects	eye-masked 1	eye-masked 2	eye-masked 3	eye-masked 4	eye-masked 5	eye-masked 6	eye-masked 7	eye-masked 8	eye-masked 9
age / sex	23years/male	23years/male	21years/male	22years/male	22years/female	23years/male	22years/male	23years/male	23years/male
occupation	graduate student	university student	university student	university student	university student	university student	university student	university student	university student
eyesight 1: right	1.5	0.2	1	0.5	1.2	1.5	1.2	1.5	1.0
: left	1.5	0.2	1	0.5	1.2	1.5	1.2	1.5	1.5
eyesight 2 :light	○	○	○	○	○	○	○	○	○
:color	○	○	○	○	○	○	○	○	○
:shape	○	○	○	○	○	○	○	○	○
hearing	normal	normal	normal	normal	normal	normal	normal	normal	normal
housing type	detached house	detached house	apartment house	detached house	apartment house	detached house	detached house	detached house	apartment house
dwelling style	with family	with family	without family	with family	with family	with family	with family	with family	without family
health condition	good	good	good	good	good	good	good	good	good

There is also a team of nine staffs. They guide the visually-handicapped people, take photos on videos, record experimental data, conduct interviews, and so on.

Attribution of the subjects is shown in **Tables 1 and 2.**

2.2 Experimental spaces

Experimental spaces are created in a model laboratory. Situated in Kansai University (The lab measures 13m×18m, its CH=3m, and the floor is carpeted. Illumination is

fluorescent light). Individual experimental spaces are made of corrugated cardboard panels (1800×900, in vertical usage). Experimental spaces are shown in **Fig. 1**.

There are four kinds of experimental spaces of the square type, four kinds of the rectangular type and four kinds of the polygonal type:

(1) Square type: side length is 10m, 8m, 6m and 4m.

(2) Rectangular type: depth is 2m, and width is 10m, 8m, 6m and 4m.

(3) Polygonal type: equilateral octagon, equilateral hexagon, equilateral pentagon and equilateral triangle.
(Radius of inscribed circle is 3m)

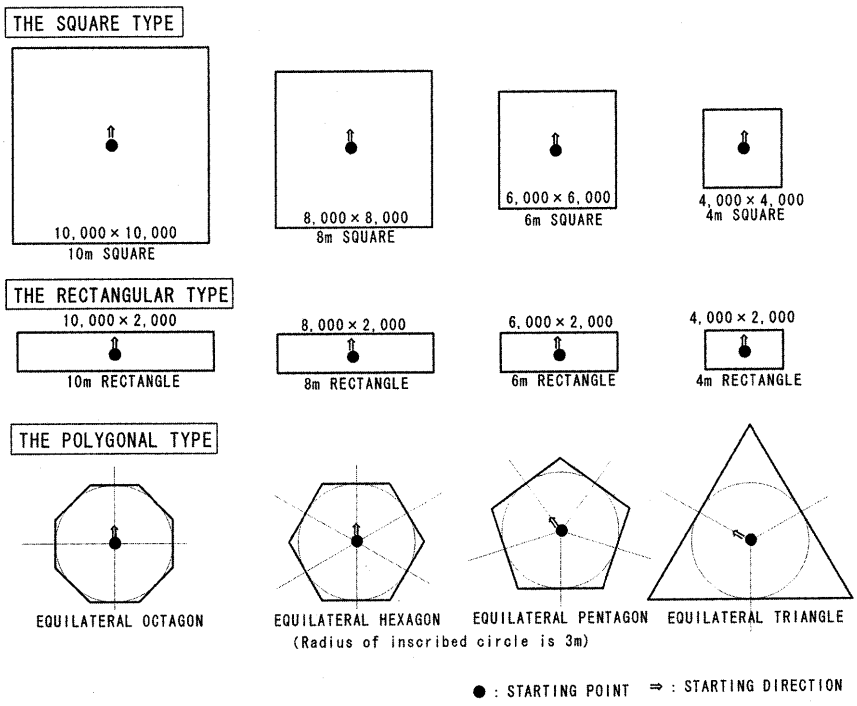

Fig. 1 Experimental spaces

2.3 Experimental period

The experimental period was from 5th to 7th December, 2003.

2.4 Experimental methods

First, the subjects receive directions from staff members at the starting-point in each experimental space, and in order to recognize the form and size of these experimental spaces, they walk around them for 2 minutes (searching walk). If this walk ends within the time limit, the subject signals to the staff member. otherwise, when 2 minutes are passed,

the staff member gives a signal to the subject.

Next, the subjects walk from the end point of the searching walk to the position that they think was the starting point (orientating walk). For this, there are no time limits. Their position after the orientating walk is recorded as coordinates whose origin is the starting point.

Furthermore, at the end of the orientating walk, the subjects are asked to turn to face in the same direction that they thought they started in. This "direction angle" is the angle between the starting direction and the direction the subjects actually turn to. The angle is shown in terms of a scale, $-180 \sim 180$ degrees.

The subjects all walk with the aid of a cane.

After this, the subjects come out of the experimental space, sit down in a chair and draw a sketch map at a desk near the experimental space. The instruction for drawing the sketch map is "Please draw how the space felt." The eye-masked subjects have to draw two sketch maps; the first with eye-mask, the second, without. There is no time limit for drawing a sketch map. After drawing is over, a member of staff asks the subject what form and size the space is, what criteria were used for deciding the direction of return to the starting point and when they got there, which direction had they started out walking in, and what they noticed. Another member of staff records the interview with a video camera.

The experiment is repeated using the same procedure in each different space.

3. Results and Considerations

3.1 Distance from the starting point

The distance from the starting point is the length of the straight line drawn from the starting point to the subject's position at the end of the orientating walk.

Distance from the starting point is shown in **Fig. 2.**

In the case of the blind subjects, distance from the starting point is long in the 10m square and in the 10m rectangle, and it is short in the 4m square. In such square spaces, distance from the starting point varies greatly, according to the size of the space. In both square and rectangular spaces, the smaller the space is, the shorter the distance from the starting point is. In the polygonal type, it is longer.

In the case of the eye-masked subjects, distance from the starting point is long in the equilateral pentagon and equilateral triangle, and it is short in the 8m, 6m and 4m rectangles.

Comparing the blind results with those of the eye-masked, differences are slight in rectangles of 8m, 6m and 4m, and ultimate distance from the starting point is short. Differences in these spaces are small.

With regard to the distance from the starting point, the results of the blind and the eye-masked are similar for the rectangular spaces. In rectangular spaces, it is relatively easy to recognize one's position, but in the polygonal type, difficult.

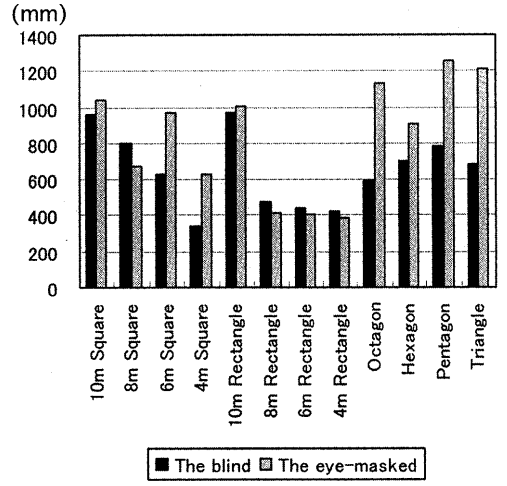

Fig. 2 Distance from the starting point

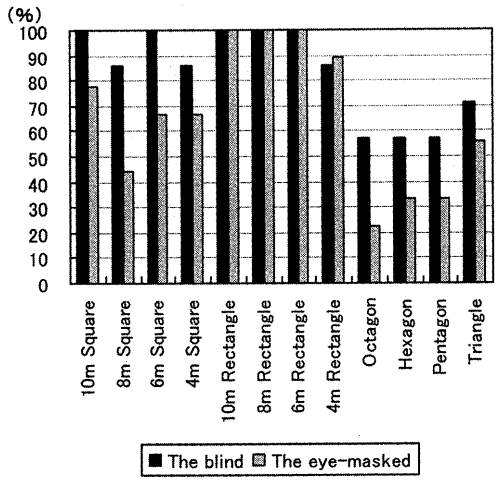

Fig. 3 Correct answer rate for the angle of direction

3.2 Angle of direction

Using the data of the angle of direction after the orientating walk, the correct answer rate is analyzed for each type of space. The correct answer of the angle of direction is given in terms of a scale, −22.5~22.5 degrees.

The correct answer rate for the angle of direction is shown in Fig. 3.

Correct answer rates of both the blind and the eye-masked are highest for the rectangular spaces, followed by the square and then the polygonal. The correct answer rate of the blind in the rectangular type is high. In the polygonal type, that of the blind in the equilateral triangle is highest, and the fewer the number of corners is, the higher the rate of the eye-masked tends to be.

For all of the square and rectangular spaces, the correct answer rate of the blind is higher than that of the eye-masked. But in the rectangular spaces, the difference is small and the rate is uniformly high.

This may be so because the short side of the rectangle is always 2m and there are both short and long sides. From this difference of side length it becomes easy to recognize the space and distance. In the 4m rectangle, the rates of the blind and the eye-masked are low, because the difference between short side and long side is small.

For both the blind and the eye-masked, the variation of direction is large in the polygonal type, and the correct answer rate is low. It is difficult to recognize the direction in a space without a right-angle corner or in one that does not generally feature in daily life.

3.3 Direction that they turn to first

"The direction that they turn to first" is the direction that the subjects turn to at the wall reached first in the searching walk. Using the walking locus figures created after the

end of the experiment, we have classified them into R (right turn), L (left turn), and B (back).

The factors governing the direction that they turn to are shown in **Table 3.** This is based on both interview and on observations of behavior.

Since the subjects use a walking cane in their right hand, the direction that they turn to is determined by whether they make sure of the wall with their hand or with the cane, but they often shift the walking cane into their left hand.

When they make sure of the wall with their hand, they use both the hollow of the hand and the back of the hand. Some of subjects show a body position with regard to the wall that is decided by risk aversion or by their habit in daily life. The direction that they turn to is also influenced by these two factors.

It is thought that the completely turning round to the back is to better ascertain the space.

Table 3 Factor of the direction that they turn to

direction	factor
turn to the right (R)	The subjects have a walking cane in their right hand and touch the wall with their left hand.
	The subjects avoid barricades or dangers with their left hand.
	The subjects tend to overlook some clues to the left hand space when they have a walking cane in their right hand.
	The subjects always walk with their left hand toward the wall.
turn to the left (L)	The subjects touch the wall with their right hand. In this case, there are two types. One is that they shift the walking cane into their left hand and touch the wall with their right hand. Another is that they touch the wall with their right hand keeping the walking cane in their right hand.
	The subjects are accustomed to walking on the right hand to the wall. They feel confident when the wall is on the right hand side.
	The subjects walk along the wall using a walking cane in their right hand.
return to the back (B)	The subjects make sure of the starting point.
	The subjects make sure of the size of space.
	The subjects make sure of the space form which they imagine.
	The subjects make sure whether the walls facing each other are parallel.
notes	Some subjects said that they always chose either left or right for the first turn.

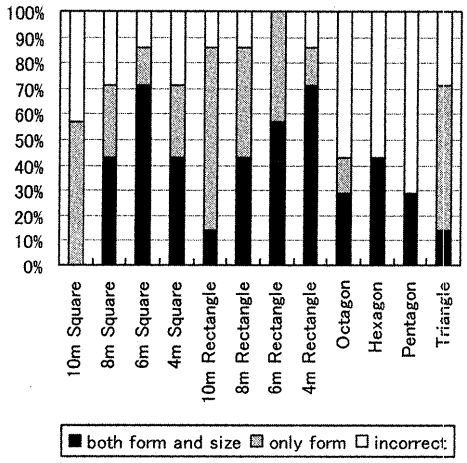

Fig. 4 Correct answer rate for recognition of the space (The blind)

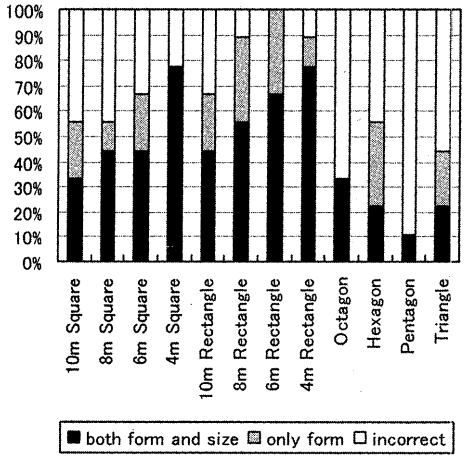

Fig. 5 Correct answer rate for recognition of the space (The eye-masked)

3.4 Recognition of the space

Recognition of the space is limited to that of the form and the size of the space plan, and the correct answer rate for this is derived from the results of the sketch map and interview.

The form of the space that they draw in the sketch map and the way they describe the form in the interview are taken as their answer. With the size, 20% is the allowable margin of error.

The correct answer rates for recognition of the space by both blind and eye-masked subjects are shown in **Figs. 4 and 5.**

1) The blind: The correct answer rate for 'both form and size' is high in the 6m square and the 4m rectangle, and it is low in the 10m square and the 10m rectangle.

   In the rectangular spaces, the rate for 'incorrect' is low, and it is high in the polygonal spaces. The rate for 'incorrect' is especially high in the case of the equilateral pentagon. In the rectangles, the smaller the space is, the higher the correct answer rate for 'both form and size'.
2) The eye-masked: The correct answer rate for 'both form and size' is high in both the 4m square and rectangle, and low in the equilateral pentagon. In both square and rectangular spaces, the smaller the space is, the higher the correct answer rate for 'both form and size'. The rate for 'incorrect' is low in the rectangular spaces and high in the polygonal type. This is the same as for the blind.
3) Comparing the blind with the eye-masked: For both the blind and the eye-masked, the smaller the space is, the higher the correct answer rate for 'both form and size' and 'only form' tends to be. But in the 4m square and the 4m rectangle, the rate tends to be low. It is thought that such spaces are too small for easy spatial recognition. The rate for 'incorrect' increases in the equilateral pentagon. It is thought that the pentagon is a difficult shape for spatial recognition. With rectangular spaces, the rate for 'incorrect' is low, especially for the 6m rectangle. For both the blind and the eye-masked, its rate for 'incorrect' is 0%. It is thought that in the form of a rectangle 2m×6m it is easy to recognize the space.

3.5 Search behavior and clues to recognition of space

Search behavior, clues to recognition of space and classification of walking are shown in **Tables 4 and 5.** They are based on behavioral observation and the interviews.

In the experimental spaces, the subjects mostly search for clues on the surface of wall because there are few clues in the space itself. Subjects try to make out the features of the wall itself, or of part of the wall or a corner. In some space types, there are psychological changes in their behavior; feeling uneasy, disturbed, confused, and so on.

Most of the subjects walk along the wall using either a walking cane or their hands, and others walk straight across the space. It is thought that walking straight across the space is mainly to make sure of the space. It is important that the blind can walk not only along the wall but also across the space.

Table 4 Classification of walking

walking along the wall	walk exactly around the space	The subjects find a base point and walk exactry around the space.
	walk less than all around the space	The subjects think that they walked all around the space. The subjects can't walk all around the space. The subjects don't think that they will try to walk all around the space.
	walk more than all around the space	The subjects don't think that they walked all around the space. Although the subjects walk all around the space, they do more than exactry once around as a check. The subjects don't think that they will try to walk all around the space.
walking straight across the space	across the space from wall to wall	The subjects make sure of the features of the form imagined in their mind. The subjects make sure whether the walls facing each other are parallel. The subjects make sure of the size of space.
	across the space from wall to corner	The subjects make sure of the features of the form imagined in their mind.
	across the space from corner to wall	The subjects make sure of the features of the form imagined in their mind.
	across the space from corner to corner	The subjects make sure of the features of the form imagined in their mind.

Table 5 Search behavior and clues to recognition

search behavior	walk along the wall walk straight across the space wander in the space stop and think search using minimal indicator to return to the starting point remember the first wall search the characteristics of the wall discover indicator on the wall expand the arms and search on the wall with the hands
how to walk along the wall	search the space tapping lightly on the floor with the walking cane search the space sliding the walking cane on the floor walk along the wall constantly touching the wall with the walking cane walk along the wall touching the wall with the walking cane at intervals walk along the wall constantly touching the wall with one hand walk along the wall touching the wall with one hand at intervals
how to walk across the space and behavior in losing the way	search the space tapping lightly on the floor with the walking cane search the space sliding the walking cane on the floor walk in the space holding the walking cane so as not to touch the floor walk in the space sticking the walking cane forward or holding on the walking cane to the side
base point of search	choose the base point on whole of the first wall panel choose the base point on the corner panel of the first wall choose the base point on a part of the first wall panel depend on the senses
make sure or memorize	memorize the number of steps memorize the number of wall panels memorize the length of walls based on that of the first wall memorize the number of corners memorize the number of sides memorize the number of turns or the direction of turns make sure of the angle of corners with a hand make sure of the angle of corners with the direction of the body make sure of the direction as often as he/she turns make sure of the direction constantly

imagine or predict	make a map in the mind imagine a form in the mind predict a form predict a form by the angle of corners predict a form by the number of steps and the angle of corners
clue of the wall	surface of the wall; a sense of touch tape binding panels; joint, length, wrinkles degree of fixation of wall panels length of walls
clue to the space's size	time of walking number of steps sense learned by experience echo of sound; the sound of the walking cane or wall panels expanding arms, hands, the walking cane
losing the way	lose the way in an unknown form lose the way by incorrect imagination lose the way through fixed idea lose the way by forgetting the number of steps lose the way by losing the first wall return to the starting point before losing the way lose the way in walking around too much not lose the direction if the corner is right-angled not lose the direction in walking around lose the starting point in walking around too much lose the direction in the same length of the walls not lose the way in the same corner angle even if the same length of walls lose the way in many corners
mental	uneasy if the same angle continues uneasy if the long wall continues easy if the next change can be checked by walking cane. get confused in expecting too much
etc.	The whole picture is difficult although each side is understood.

4. Conclusions

(1) If a space is smaller, it becomes easier to recognize one's position. It can be said that the blind are superior to the eye-masked in their sense of direction, but in the rectangular spaces the eye-masked recognize as well as the blind do. Rectangular spaces are easier to recognize than square or polygonal ones. The side length of a rectangle differs and

this difference becomes the clue to recognition.

(2) The aberration in angle of direction is large in polygonal spaces, and the correct answer rate is also low. It is difficult to recognize direction in a space without a right-angle corner, and to recognize direction in a space that is not generally encountered in daily life.

As the number of corners becomes fewer, the correct answer rate of the eye-masked tends to be higher, but that of the blind shows almost no change. The number of corners does not influence the correct answer rate of the blind.

(3) It is thought that the direction that the subjects turned to first is based on their own habits, but right turn, left turn and turn back has a reason, and these could be classified into groups. It is thought that such characteristics for the blind are different from those of the eye-masked in each space.

(4) The smaller the space is, the easier its recognition, but it is thought that if the space is too small, recognition becomes more difficult.

Certain types of spaces are easier or more difficult to recognize. Amongst the squares, the 10m square space is most difficult to recognize; amongst the rectangles, the 6m space is easiest; and amongst the polygons, the equilateral pentagon is most difficult.

(5) Because there are few clues to direction or shape of space in an experimental space, the subjects' behavior trying to get a clue from the wall could be seen.

Search behavior and clues to recognition could be classified into eleven categories, and within each category there are several scenarios.

Looking for a base point on the wall or at the corner and walking round the space was often observed during the subjects' searching walk. Some of subjects walked straight across the space in order to make sure whether it was the form predicted in their mind.

(6) There are two types of walking in this experiment; one is walking along the wall, another is walking straight across the space. "Walking along the wall" could be further classified into three types, and "walking straight across the space" could be further classified into four types. There is a rationale behind each one.

References

1) Y. Kametani, T. Takei, H. Hayase, K. Chibana and H. Araki, *J. Architecture and Planning*, **582**, 47-54 (2004) (in Japanese)

2) Y. Kametani, J. Kishigami, K. Chibana and H. Araki, *J. Summaries of Technical Papers of Annual Meeting of AIJ*, E-1, 885-886 (2004) (in Japanese)

3) Y. Kametani, J. Kishigami, K. Chibana and H. Araki, *J. Proceedings of AIJ Kinki Chapter Research Meeting*, **45 Planning**, 333-336 (2004) (in Japanese)