

A STUDY OF SPATIAL REPRESENTATION OF PEOPLE WITH IMPAIRED VISION

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1. Purpose of the study

In this paper, verbalized spatial representation of people with impaired vision is examined based on the experimental results. The environmental target of the experiment is actual large scale spaces such as urban streets of everyday use. Words used by people with impaired vision in the route description are classified and typical conceptual elements (schemata) constructing their sentences are extracted.

In order to fulfill the social requirements for realization of barrier-free traveling environments for people with impaired vision, we need to develop the system which assists the process of collecting the information of orientation as well as to reconstruct facilities fit for their accessibility. On one hand, the differences of mobility between people with impaired vision and sighted people should be clarified in detail from viewpoint of the latter. And on the other hand, from viewpoint of the former, terms for the communication between these two groups of people should be unified through the process of extracting common schemata underlying various detail expressions. The purpose of this study is to provide basic findings for actual resolutions of the communication, such as voice navigation systems.

2. Background of the study

Various experimental approaches were reported in previous studies on spatial cognition, or wayfinding, of people with impaired vision in actual large scale spaces. Passini et al. (1998) carried out the experiment with the subjects that had already attended two pre-experimental guided tours in the object building. And analyzed their protocols recorded during independent wayfinding, i.e. verbalized report on what they were doing and why they were doing it, the answers to the questions after wayfinding, and the result of the post-experimental cognitive mapping exercise. Whereas, in the experiments by Brambring (1982) and Rieser et al. (1992), the subjects were directed to pick up several places in the city where they often visit, and in the former paper, route descriptions were analyzed, and in the latter, accuracy in recognizing straight-line distances between the places and direction judgment.

For the detail examination of how people with impaired vision perform their wayfinding, the protocol analysis on the actual places, as Passini et al. did, should be described. In addition, it is preferable to carry out the experiment combined with other representational forms such as straight-line distances and direction judgment, or with the cognitive mapping exercise. In this paper, however, not the protocols of actual wayfinding but the oral route descriptions made in the laboratory are recorded as data as were done in Brambring's study, and, thus, the language is treated as external representation for communication. And also, we understand that only the named objects could be considered if we want to treat language as means of public communication, even though it is well understood that objects which are not named and represented with demonstrative words such as "this" or "there" are important clues for everyday wayfinding. However, the previous study by Yokoyama et al.(1996) of interviews to the orientation and mobility (O&M) instructors and of observational investigation of instructing scenes are referred additionally in order to assist the analysis by supplementing it with actual conditions of wayfinding by people with impaired vision.

As for the category of the subjects, Passini et al. experimented on congenitally totally blind people and

sighted people, and Brambring compared people with impaired vision with sighted people. Rieser carried out the comparative analysis in even more detail with blind people, acuity loss, and field loss, and also early and late onset groups of each of above mentioned impairment as well as sighted people.

As the purpose of this study is to extract common schemata among as many people as possible, we carefully conduct comparative analysis on reasonable number of impairment categories.

3. Experimental method

The whole processes of this experiment is conducted in Japanese language.

1) Subjects (See Table 1.)

Subjects were divided into two groups, that is, early onset(EO), and late onset(LO), and each of them were then divided into two groups, functionally blind(FB) and partially sighted(PS)¹. All the subjects were given O&M instruction beforehand. Sighted people were selected from those who lived near the LO subjects' houses so as to be able to orally express the same routes as those of people with impaired vision.

Table 1. Summary of the subjects and experimental routes, and the number of route descriptions.

Group	Nr. of Subjects	Age (Av./SD)	Experimental Routes	Distance	Nr. of Corners	Nr. of Sentences
Early Onset	19(11/8) *2	12-20yrs (15.9/3.1)	Dormitory > School	375m	2	13(8/5)*2
			School > Nearest station	1660m	2	13(8/5)*2
Late Onset	14(6/8) *2	23-64yrs (49.9/13.0)	Home > Nearest station/bus stop	Av. 533m	Av. 3.2	28(12/16) *4
				SD 305m	SD 1.7	
Sighted*1	14	*3	The same as above			14 *5

*1 Living close to the houses of the late onset subjects.

*2 (Functionally blind/partially sighted)

*3 Not yet investigated (all subjects are adults).

*4 Total number for both going and returning.

*5 Only one way

2) Experimental routes (Also see Table 1.)

The experiment was situated in the laboratory. The subjects of EO groups were asked to orally explain their everyday routes from the dormitory to their school and those from the school to the nearest station, both or one of these for each EO subjects. And LO groups were asked to orally explain their routes (going and returning) from their houses to the nearest stations or bus stops. The subjects were directed to explain their routes correctly enough that their friends with the same traveling abilities could follow the routes safely. All the subjects had already been given O&M instruction once on the route they were asked to explain, and actually travel on the route on their own.

3) Working hypothesis

Models for classifying words in oral route descriptions were determined prior to the analysis, as follows.

First of all, we hypothesized that wayfinding is explained with three general categories of words as shown in Fig. 1. "Element (E)" is defined as the name of stationary physical object constituting urban environments which is referred to during the travel. "Orientation (O)" as the word representing positional relation between elements or between the subject and the elements. And "movement (M)" as the word representing traveling behavior of the subject or the search for the elements. Route descriptions are considered to consist of the words of these three general categories.

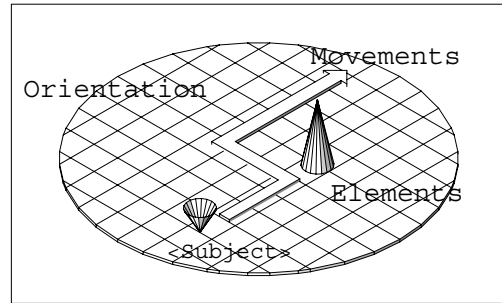


Figure 1. Basic model of wayfinding

Further divisions are set in E, O and M. Seven categories are set in E. First, elements are divided into those haptically recognizable with long canes and the others. Second, the former is divided into spot (E1) and linear (E2) elements according to the shape. Various objects are included in the latter elements that is recognizable without a long cane, which includes those recognized with auditory sense or olfactory sense, for e.g. noticing the existence of a large building or an open space from subtle air movement or from sound echo when tapping the ground with a long cane, noticing that of main streets from traffic sounds, of restaurants from the smells and so forth, and those recognized in O&M instructions or from visual memory of the past (for those of LO), those recognized with visual perception (for PS or sighted people) and the like. However, we cannot pinpoint from their route descriptions which senses they used to perceive the elements. In this study, therefore, the elements are divided into spot (E3), linear (E4), and two-dimensional (E5) elements according to its shape, and special category for sound (E6) according to the words such as “sound of <element>” indicating that the element is recognized as sound. While starting point and destination are arbitrarily elements in this experiment, they are included in another category(E7).

Table 2. Categories of words in route descriptions

Categories	Words (translated from Japanese into English)
Elements (E)	
Spot 1*(E1)	Post (of the Traffic lights), Tactile pavement(points), Gate, Utility pole, Roadside trees, Garbage bin, etc.
Linear 1*(E2)	Wall, Fence, Hedge, Guardrail, Step, Slope, Ramp, Gutter, Curb, Tactile pavements(lines), etc.
Spot 2**(E3)	Parking lot, Play ground, Bus garage, School, Fast food restaurant, Building, etc.
Linear 2**(E4)	Road, Street, Crosswalk, Sidewalk, Byway, Alley, Footbridge, Railway, Bridge, etc.
Two-dimensional(E5)	Intersection, T-intersection, Y-intersection, Irregular-intersection, Crossing, Rotary, etc.
Sound(E6)	Sound signal, Sound of drain, Sound of traffic, Sound of store, Sound of vending machine, etc.
Starting point/destination(E7)	Station, School, House, Dormitory, Bus stop, Hospital
Orientation (O)	
Order(O1)	next time, at the first(--th) time, once more, on the way, several times, lastly
Distance(O2)	<length> meters, near, up to, a little, <time> minutes, for a while, long/short (distance), <number> steps
Direction(O3)	right/left(side), straight, front/back, east/west/south/north(side), opposite side, proceeding direction, etc.
Shape(O4)	corner, edge, wide/narrow, broken off, large/small, right angles, curved, crooked, open, in line, inside/outside
Movements (M)	
Going(M 1)	going, walking, going up(down), proceeding, going along, trailing along, going straight, following, getting off
Crossing(M 2)	crossing, crossing over, passing, going across, passing over, cutting across, going through
Reaching(M 3)	reaching, entering, going out, going into, coming, touching, stopping, approaching
Turning(M 4)	turning, changing direction, returning, going around
Searching(M 5)	tapping, searching, looking, touching, listening, placing one's back to the wall

*Haptically recognizable with long canes, **Recognized with other means than haptic sense

Four categories are set in O, as order (O1), distance (O2), direction (O3) and shape (O4). As for M, most frequently used ten words, i.e. going, walking, going down, crossing, reaching, entering, turning, tapping (see

Table 2) , were categorized into five categories: going (M1), crossing (M2), reaching (M3), turning (M4) and searching (M5) .

4) Analyzing method

Words of the transcribed data were classified based on the criterion comprising of 16 categories mentioned above. Classification was independently performed by three encoders (agreement ratio was about 74%), and major opinions were adopted. An example from the encoded descriptions is shown below:

Example: After getting off(M1) the bus at “Matsueichou” bus stop(E7), cross(M2) the street(E4) to the opposite side(O3). Because it is very dangerous place, you had better to have someone assist your crossing (redundant explanation). After crossing over(repeated expression), follow(M1) the direction of the bus route(O3) for a few meters(O2), you reach an alley(E4). Proceed(M1) to the right(O3) into the alley (repeated expression). There is a ditch(E2) on your left side(O3) and trail along(M1) the ditch(repeated expression) for twenty to thirty meters(O2). Then, you touch(M3) the cover of the ditch(E1). Cross(M2) at the cover (repeated expression) and then turn(M3) to the left(O3). That is the apartment house(E7) I live in. (translated from Japanese into English)

5) Analyzing procedure

First, ratios of above mentioned categories are compared between groups of different impairment divisions, and differences and common tendencies are clarified (see 4. Analysis A). If consistent commonness is found out, then the working hypothesis should be regarded as effective for the purpose of this study, i.e. to identify typical expressions in route descriptions. The schemata are then extracted based on this commonness(see 6 Analysis B).

4. Analysis A

Out of the total number of 1968 words, 193 different words were identified within the total of 68 route descriptions of all the subjects. The subjects were divided into five groups of FB /PS of EO, FB/PS of LO, and sighted people. Average number of words per a route (one way) and the ratios of each category of words (E1 to M5) were calculated as Table 3 shows the result.

Table 3. The number of words and the ratio by 16 categories

Group		E1	E2	E3	E4	E5	E6	E7	Subtotal	O1	O2	O3	O4	Subtotal	M1	M2	M3	M4	M5	Subtotal	Total	Nr. of Words*
Early onset	Av.	7.9	6.2	1.3	2.8	2.8	1.5	6.7	29.2	3.6	6.9	20.0	2.8	33.3	19.0	3.8	7.2	6.9	0.5	37.4	100	25.9
Functionally blind	SD								4.2					6.8						4.3		8.3
Early onset	Av.	6.5	1.9	2.8	6.5	2.8	3.2	7.9	31.5	2.8	9.7	15.7	3.2	31.5	17.6	6.5	7.9	5.1	0.0	37.0	100	20.3
Partially sighted	SD								4.2					4.4						2.9		4.0
Late onset	Av.	4.8	5.7	2.6	6.3	5.8	2.6	3.6	31.3	6.8	6.3	16.6	4.5	34.2	9.8	9.4	9.1	2.9	3.3	34.4	100	48.7
Functionally blind	SD								1.9					1.4						3.2		15.6
Late onset	Av.	4.9	3.9	2.5	7.5	5.1	0.7	5.1	29.7	6.6	6.7	19.7	3.9	36.8	12.7	7.2	5.8	6.9	1.0	33.5	100	39.1
Partially sighted	SD								4.7					4.8						2.2		9.3
Sighted	Av.	5.9	0.0	9.2	13.3	1.4	0.0	6.0	35.8	2.8	5.5	22.3	1.7	32.3	9.5	4.3	0.0	15.7	2.4	31.8	100	7.6
	SD								7.9					8.7						5.4		3.4
Z**		7.4	5.3	11.9	14.9	8.3	2.1	10.0		7.4	10.4	13.6	5.1		8.4	7.4	7.4	12.6	9.5			

*per one way **Criterion analysis of two groups with LO and Sighted

As Brambring pointed out, the number of words uttered increases as the number of corners of the route does. Therefore, only the groups with similar route condition should be compared here: in this paper, 1) comparison of groups with LO impairment (including FB and PS) with that of sighted people, and 2) comparison

between FB of EO and PS of EO, were taken into account. The number of words uttered per one way by LO groups are, in average, 5.6 times more than the number of those uttered for the same route by sighted people. In addition, the FB of EO group use significantly more words than PS of EO group ($p < .05$)².

In order to examine the differences between each groups, taking the number of the words for each of 16 categories as variations, Wilks criterion test were undertaken for following 3 couples of groups; (1) sighted people and LO group, (2) FB of EO group and PS of EO, (3) EO group (FB and PS) and LO group (FB and PS)³.

As the result, significant difference was recognized ($p < .05$) only in case (1). In case (3), the fact that there is no significant difference between the groups shows that the result was not affected by differences in route conditions between EO and LO groups. As for case (1), it was clarified in discriminatory analysis (accuracy ratio, 91.5%) that the values of E3, E4, O3 and M4 are large enough to contribute to the significant difference(see Table 3.).

As for case (2) and (3), differences between individuals were larger than those between groups, that might have brought insignificant difference in the test. However, we should note here that no large difference was observed between each subtotal of E, O and M⁴, and ratio of three general categories was almost the same ,about 30% for each.

5. Comparison of route descriptions by 5 groups with different impairment

According to Passini, people with impaired vision need more information in wayfinding and thus make more wayfinding decisions than sighted people. In this experiment, people with impaired vision of EO also used more words than sighted people, which is considered to support Passini's finding.

Results of comparative studies of the contents of the route descriptions show that sighted people tend to omit certain midway information by referring to distant landmarks as the following example shows:

Example: 'Turn(M4) to the left(O3) and go(M1) straight(O3) on the street(E4), then you reach the footbridge(E4)'.

On the contrary, PS group of EO refer to more elements and details on the way while walking on the same route, as follows:

Example: 'After going out(M3) of my house(E7) and turning(M4) to the left(O3), you reach the irrigation channel(E6). Then cross over(M2) the bridge(E4) and go(M1) straight(O3) for a while(O2), you find(M5) the parking lot for bicycles(E3). Passing through(M2) it and crossing(M2) on the footbridge(E4) over the train railroad(E4)'.

People with impaired vision frequently express small crossroads or byways, for, possibly, they have to stop once to confirm safety. While sighted people seldom refer to those on the way.

Among people with impaired vision, especially when FB groups refer to an element, they tend to add smaller elements around it in order to make it sure that they could find it out. And that should be a reason for the experimental result that FB people of EO tend to use more words than PS people of EO.

Significant difference in ratio per categories of words was observed only between sighted people and people with impaired vision of LO. This difference is mainly caused by the facts that sighted people mostly express visually confirmed elements of E3 and E4 and scarcely do small elements haptically recognizable with long canes such as E1 and E2, and also that they exclusively use combination of O3 with M4 (e.g. "turn to the right" and so on). Rieser pointed out that blind people and people with field loss of early onset have difficulties in recognizing straight distance or direction. In this experiment, however, no significant difference was observed between FB people of EO and PS of the same, and no large difference was observed between ratio of O2 or O3 of the FB group of EO and the others. In this experiment, however, not the quantitative accuracy of cognition but

the usage of the terms was examined. Therefore, relative expressions like “much more” or “a little”, walking time such as “a few minutes” and the like are included in classification of O2, and laterality and also directionality are altogether included in classification of O3 in this study. For that reason, it might be inappropriate to consider the results of this experiment to be contradictory to those of Rieser.

It was found to be common to the route descriptions by all the five groups that each subtotal of E, O and M reaches almost the same ratio (about 30%). For instance, see the example of 3.4) with the same ratio of E, O and M(counting 7, 7, 8 in number, respectively). In the following sentences sampled from the essay written by a famous Japanese novelist, however, the frequency of appearance of E, O and M are 8, 10, and 1 respectively, and thus the frequency of appearance of M is much smaller than that of route descriptions:

Example: The ground rises high(O) at one side(O) of the road(E), and, on the side, there are a lonely temple(E) with a flight of stone steps(E) and a ruined shrine(E). The road separates into two branches(O) a few blocks ahead(O). One branch(E) is connected to fairly steep(O) slope(E) towards a hill(O), and the other branch(E) becomes low(O) and continues into(O) the rice fields(E) towards the hill(O) seen(M) over(O) them.

From “Katsushika Miyage” written by Kafu Nagai.

This shows the fact that, among sentences expressing space, route description has the consistent strategy which not only people with impaired vision (FB/PS, of EO/LO) but also sighted people select for oral expression. The feature of this strategy is that ratio of words showing “movement (M)” is relatively high, as high as to be the same as those of reference element (E) and orientation (O). The words classified into M correspond to verb (phrase) grammatically, and particularly the verbs expressing actions. Such verbs meaning states (“exist”, “be” and the like) were not counted in this analysis as seen in sentences of the example of 3.4). Making combined expression of “reference element (E)” or “orientation (O)” with “movement (M)” is considered to be the strategy employed in route descriptions.

Brambling reported that sighted people perform environment-oriented description, while people with impaired vision perform person-oriented description with words for time, distance and rotation of the bodies with which correct estimates independently of the environment. In our experiment also, frequency of using reference elements is slightly higher within sighted people’s description. However, as described above, when comparing the number of words expressing movement(M) with those of the essays representing spaces, it is rather reasonable to interpret that both sighted people and people with impaired vision employ similar strategy in the route descriptions.

6. Analysis B

Now we found, the common strategy with all the groups from the analysis A based on the working hypothesis. Here in analysis B, cognitive contents of the common strategy, schemata, are extracted. For the purpose, we identify which categories of E and O strongly related to each of 4 categories of M by counting the number of modification of the words in M categories by each word of either O or E. E3, E7 and M5 are excluded from this analysis, for the reason of low appearance frequency in the case E3 and M5⁵. And E7, for the fact that the contents were arbitrarily selected. Also data of sighted people were excluded in this analysis aiming at extracting the schemata of people with impaired vision.

Upper row in each cell of Table 4 shows frequency that words of E1 to O4 modify those of M1 to M4 ($\chi^2=268.9$), and lower row shows standardized residuals calculated based on this contingency table. Dark areas mean cells with significantly large numbers ($p<.05$), and where the row and the column are suggested to be strongly related. Fig. 2 shows the pictograph of Table 4. As for the relation between O and E, 70% of M1O2, 71% of M4O3 and 50% of M4O4 were independent combination not accompanied by E, while M2O1 was always

accompanied by E, e.g. cross (M2) the second (O1) intersections (E5).

7. Extraction of schemata

Thus, pictograph of Fig. 2 is considered to be typical conceptual elements for the route descriptions, that is schemata. Followings are typical examples of each schema.

1) M1E2: “going along the wall”, “going up the steps” and so on.

2) M1O2: “going <length> meters”, “going for a while” and so on.

Although M1O2 actually means “going <length> meters on the street” which is combined with E4, E4 is usually omitted in oral expressions.

3) M2E1: “crossing at traffic lights”, “passing the post” and so on.

4) M2E4: “crossing over the street”, “crossing over the bridge” and so on.

5) M2E5: “crossing the intersection” and so on.

6) M2E6: “crossing at the sound signal” and so on.

7) M2O1: “Passing over the second <element>”, “crossing at the next <element>” and so on,

where <element> means words of E1, E4, E5 and the like.

8) M3E4: “reaching the street”, “entering the byway” and so on.

9) M3E5: “reaching the crossing” and so on.

10)M4O3: “turning to the right” and so on.

11)M4O4: “turning around the corner” and so on.

Table 4. Frequency of the appearance of E and O per classification of M

	M1	M2	M3	M4	Total
O4	16	9	5	14	44
	-0.47	-0.80	-0.60	1.96	
O3	116	35	26	100	277
	0.89	-6.08	-2.95	8.09	
O2	77	11	12	3	103
	7.77	-3.70	-0.86	-4.69	
O1	6	25	8	11	50
	-4.14	4.09	0.32	0.32	
E6	5	14	3	3	25
	-2.05	3.55	-0.35	-1.04	
E5	7	32	18	13	70
	-5.32	4.05	2.81	-0.36	
E4	25	41	23	6	95
	-2.85	4.19	2.88	-3.60	
E2	48	7	8	3	66
	5.71	-2.91	-0.56	-3.31	
E1	22	33	14	11	80
	-2.36	3.39	0.82	-1.52	
Total	322	207	117	164	810

Note: Upper/lower row shows frequency/standardized residual, respectively. Dark area shows cells with significantly large number (p<.05).

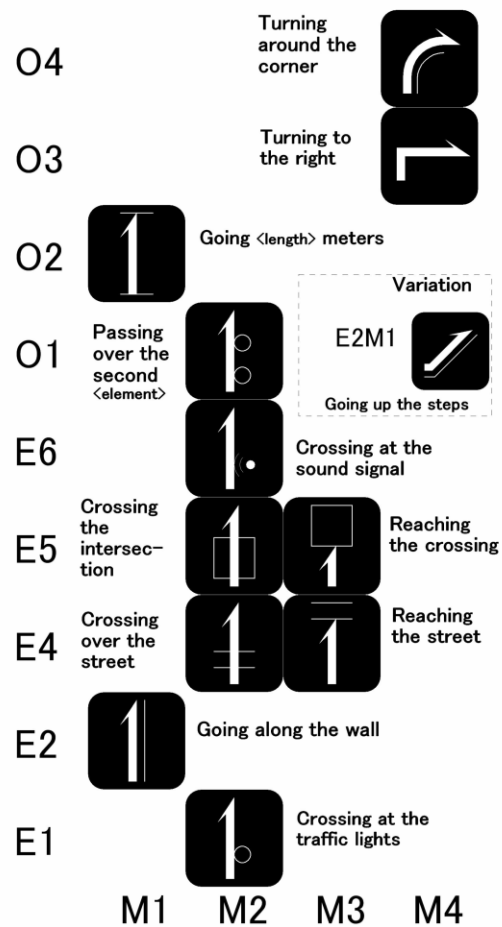


Figure 2. Schemata of the route descriptions of the people with impaired vision

However, presence of other schemata than these can not be denied. For instance, as for M1O3 cell of which frequency is maximum nevertheless the standardized residual is not so large, one of the typical samples spoken as “going to the right” could be summarized with the words “turning to the right”, while the schema correspondent to “going on the right side (of the street)”, another typical sample, was not extracted. The reason for this could be that the variation of the experimental routes were not sufficiently controlled. Although there is a case where people with impaired vision recognize right and left side of the street as different streets, many streets selected within our experiment were narrow ones in residential areas and only a few streets have sidewalks.

Next, comprehensiveness of the extracted schemata is examined by comparing them with the elements proposed in Lynch’s study (1960) which is the pioneering study of spatial representation. According to Lynch, the image of the city for sighted people comprises of major five elements: “paths” are the channels along which people customarily, occasionally, or potentially move, “edges” are the linear elements not used or considered as paths by people, “districts” are the medium-to-large sections of the city, conceived of as having two-dimensional extent, “nodes” are places which are the intensive foci to and from where people are traveling, and “landmarks” are a point-reference which people do not enter within them, they are external.

Among reference elements in this study, “paths” corresponds to E2 of 1), linear element haptically recognizable with long canes, and relate to the movement of M1, i.e. going; “edges” corresponds to E4 of 4) and 8), linear elements haptically recognized with other senses than haptic one using long canes, and relate to the movement of M2 and M3, i.e. crossing, passing and reaching; “nodes” corresponds to E5 of 9), two-dimensional elements on which direction of the movement can be changed, and relate to the movement of M3, i.e. reaching and entering; “landmarks” corresponds to E1 of 3), spot element haptically recognizable with long canes, or E6 of 6) , sounds, and relate to the movement of M2, i.e. passing, , respectively. Reference elements corresponding to “districts” are not extracted here. For people with impaired vision, however, it may be interpreted that they correspond to E5, two-dimensional elements, relating to movement of M2 of 5) ,crossing.

8. Discussion and Conclusions

The application of the schemata presented above to actual navigation systems is discussed below.

According to Leonard and Newman (1970) we can decrease the mapping errors of dog guide users within people with impaired vision by using “portable maps”. Three types of maps using ‘Disk’ with Braille letters, tape-recorded description of the route, or spatial diagrammatic were equally examined and all of them were evaluated to be effective in reducing errors.

First of all, we must note that the important point here is portability of the means used. As Neisser(1976) and Gaerling et al. (1991) argue; spatial cognition is built upon the interaction between person and environment. In other words, it is necessary to construct interactive relations between actions and environments in order to support wayfinding, and the schemata extracted in this paper, that integrate the reference elements or orientation with movement, is to be useful as portable and continually provided wayfinding information⁶. However, it will be necessary of the same time to prepare a stationary information transmission system which supplements the portable information enabling checking it up of with elements in actual environments.

The second most important point we must argue is “modality” of information. For instance, Braille letters can never be used if people cannot read. Although speech can give more detail information, it requires much more time for reconfirmation. Also detail information might be omitted from spatial diagrams. From the viewpoint of universal design, the provision of information using various sense modalities is required, and it is desirable that different modalities of “maps” are simultaneously provided as actual systems(see Blasch B.B. et al.,1973).

It is easier for people with impaired vision to understand schematized tactile maps in necessary areas than plans. It is said that various difficulties exist in utilizing maps for patients of EO especially for FB of EO. Some of them can not acquire concept of figures, e.g. “square” and the like. Others can not understand the

meaning of scale, in other words it is hard for them to learn the correspondence between small figures on the maps and large elements in real worlds.

The pictographs shown in this paper only illustrate experimental results and haptical recognizability of it was not studied this time. The authors, however, expect that the realization of the comprehensive tactile map by combining with schemata partially extracted in this paper is even possible by applying the pictographs.

Application of these results to auditory map or tactile map systems and further confirmation of classification of schemata or words should be worked out in near future. However, realization of barrier-free traveling environments only by hardware means is difficult. Also in this experiment, individual differences were observed in detail of spatial representation, as shown in the frequency of the categories of E or O. Preparation of environments unified with software, e.g. rehabilitation programs by O&M instructors and the like, is also indispensable.

references

- Blasch, B. B., Welsh, R. L., and Davidson, T. (1973), "Auditory Maps: An Orientation Aid for Visually Handicapped Persons", *The New Outlook for the Blind*, Vol.67, No. 4, pp.145-58.
- Brambring, M. (1982), "Language and Geographic Orientation for the Blind", In Jarvella, R. J. and Klein, W. (Eds.), "Speech, Place, and Action", John Wiley & Sons Ltd., pp.203-18.
- Gaerling, T., Lindberg, E., Torell, G., and Evans, G. W. (1991), "From Environmental to Ecological Cognition" In Gaerling, T. and Evans, G. W. (Eds.), "Environment, Cognition, and Action : an Integrated Approach", p.338.
- Leonard, J. A. and Newman, R. C. (1970), "Three Types of 'Maps' for Blind Travel", *Ergonomics*, Vol.13, No.2, pp.165-79.
- Lynch, K. (1960), "The Image of the City", the Massachusetts Institute of Technology and the President and fellows of Harvard College.
- Neisser, U. (1976), "Cognition and Reality -Principles and Implications of Cognitive Psychology", W.H.Freeman and Company.
- Passini, R. and Proulx, G. (1998), "Wayfinding without vision, An Experiment with Congenitally Totally Blind People", *Environment and Behavior*, Vol.20 No.2, pp.227-52.
- Rieser, J. J., Hill, E. W., Talor, C. R., Bradfield, A. and Rosen, S. (1992), "Visual Experience, Visual Field Size, and the Development of Nonvisual Sensitivity to the Spatial Structure of Outdoor Neighborhoods Explored by Walking", *J. of Experimental Psychology: General*, Vol.121 No.2, pp.210-21.
- Yokoyama, K., Nomura, M., and Suzukawa, K. (1996), "Study of Barrier-free Traveling Environments for People with Impaired Vision", *Proceedings of 34th Conference of the Japanese Association of Special Education*, pp.50-1 (in Japanese).

Note:

¹ No people with secondary complication was included. Early and late onset are defined as onset of impairment before five years old and that after six years old, respectively. The partially sighted are defined as those who has learned or been learning readings and writings, and rehabilitated with assisting devices. Others with impaired vision are included in the functionally blind. None of people with field loss was included in the subjects here.

² Wilcoxon Rank Sum Test.

³ Wilks' Criterion Test ($\lambda = 0.176$, $F = 8.79$, $df = (16, 30)$).

⁴ Cramer's Contingency Statistic ($\chi^2 / (N + \min(r-1, c-1)) = 0.16$, $\chi^2 = 50.8$, $N = 1968$, $\min(r-1, c-1) = 2$), χ^2 were calculated based on the number of words for all the subjects by each of three general categories.

⁵ M was counted repeatedly when plural number of Es and Os modified M.

⁶ It is not asked whether objects carried become receivers or transmitters (whether recording of information is done at the portable device side or in the structures in the environment).