Object's width and distance distinguished by the blind using auditory sense while they are walking

Takahiro Miura[a], Kazutaka Ueda[b], Teruo Muraoka[b], Shuichi Ino[b] and Tohru Ifukube[b]

[a]Graduate School of Information Science and Technology, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, 113-8654 Tokyo, Japan
[b]Research Center for Advanced Science and Technology, University of Tokyo, 4-6-1 Komaba, Meguro-ku, 153-8904 Tokyo, Japan
miura@human.rcast.u-tokyo.ac.jp

Mobility aid has recently become important for the blind because of increasing their outgoing opportunity. It is necessary for the blind to acquire "obstacle sense" by which they can recognize surrounding objects auditorily. In particular, it is indispensable to investigate the characteristics of the obstacle sense while they are walking. However, training method for the mobility has not been systematically proposed yet because factors regarding the obstacle sense while walking remain unknown. Final goal of this study is to propose a systematic training method for their mobility using the obstacle sense. In this study, the authors particularly focused on a relation of interaural differences between both ears to the ability of the obstacle sense while walking toward the obstacles. In the experiments, the blind subjects were asked to answer when they find the obstacle made of wooden plate with various widths in both conditions of head moving and head fixing. Auditory discrimination ability of the obstacles was measured as a function of the obstacle's width and the distance from the blind subject. From the experimental results, it was found that blind people generally can recognize the obstacles better in the head moving case than the head fixing case.

1 Introduction

Helping walking and trivial movement of the blind, it has been proposed many special education methods and aids for mobility and communication[1, 2, 3, 4]. Walking training is divided into two steps; the orientation, knowing their own relative position against the circumstance, and the movement, moving toward target or target direction[5]. The blind cannot depend on the optical sense, but they can orientate by "obstacle sense" which is the ability that enables them to perceive objects only by hearing[5, 6, 7, 8]. According to many of the conventional studies, the blind can recognize the distance from the object, size, shape, and materials of the object with this sense[9, 10].

The obstacle sense is effectively used when the blind are searching and approaching the obstacle. It is assumed the reason why the blind can intelligibly recognize the objects while walking is because they unconsciously use the tiny acoustic change in the temporal sequence. However, the transitional acoustical change and its perception while moving have not been discussed in the past report regarding the dynamical obstacle sense. If the mechanism of the dynamical obstacle sense is clarified, the findings would be useful in order to construct a systematic rehabilitation method for the blind mobility aid. Simultaneously, the findings will be useful to design an auditory display system by which sighted subjects as well as the blind can virtually perceive the obstacles. A purpose of this study is to clarify the acoustic factors and the perception/recognition process of the dynamic obstacle sense.

We compared of the localization accuracy of obstacle distance between the static and dynamic condition and obtained the results of higher accuracy and low variation of localization distance in dynamic condition[11]. It is assumed that the sensitization of the dynamic obstacle sense during walking was caused by acoustic changes associated with a head rotation. While walking toward an obstacle, temporal interaural difference changed result from continuous changes of the angle formed by interaural axis and obstacle's surface. When the experimental participants were approaching toward the obstacle, the change of the interaural difference would increase. Thus, the subject would be able to more easily recognize the existence of obstacle when the subject is close to the obstacle than when the subject is far from the obstacle.

In addition, Pettorossi et al. stated that subjects can localize sound sources quickly when the head rotating is done actively than passively [12]. Loetscher et al. suggested that head movement aroused attention to spatial perception[13]. Therefore, it is hypothesized that head rotation contributes to high localization accuracy in distance as well as direction.

Whereas, Nakamura-Funaba et al. reported that the blind have difficulty in recognizing thin objects such as utility poles or antenna supports[14]. This can probably be because interaural difference change accompanied by head rotation in walking is not recognizable for the blind when they approach the narrow-bodied object. Obstacle width which the blind hardly recognize while walking is decided, the concept of the design for blind mobility aids which can help the ability of obstacle sense by the blind can be proposed.

Thus, Comparable experiment was carried out for the difference of obstacle perception accuracy between the condition of head rotation and non head rotation in variable obstacle width and distance.

2 Experiments

Due to investigate the difference of obstacle certainty and localization between the condition of head rotating and non head rotating, following experiment was carried out.

2.1 Subjects

Three congenital blind and two acquired blind aged 22-35 (average: 30.2) years old participated in the experiment. All of them are totally blind. Three of them are females and two of them are males. All of subjects have normal hearing; within normal limits in the pure-tone audiometry (Rion AA-75).

2.2 Experimental Setup

Experimental Environment is shown as illustrated by Figure 1. Experiment was carried out in the 6m× 6m× 6m half-anechoic room. Loudspeaker (Tanoi System 800) was set at 3.0 m from the center of half-anechoic chamber. Subjects were placed at the center of chamber with the loudspeaker located at their back in each trial and were faced to the obstacle. Obstacles were 3 kind of 67 cm×1.0 cm wooden boards which width were 10,

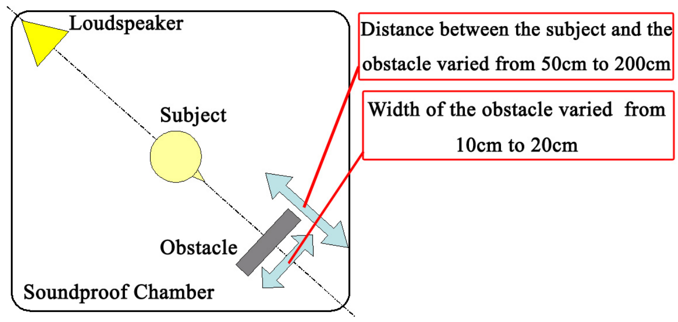

Figure 1: Experimental environment for localization accuracy of obstacle distance.

15, and 20 cm and were placed at the height of subjects' head. The distance between the obstacle and the subject could be variable. Subjects could set the sound intensity of loudspeaker at a comfortable level before finishing the practice.

2.3 Method

Before experiment started, subjects asked to wear a headphone not to hear the environment sound. Simultaneously, experimenter changed the obstacle distance at 50, 75, 100, 150 or 200 [cm] from the subject randomly. Then, the subject answer the localization certainty and the localization distance after pink noise generated from the loudspeaker. The localization certainty meant how strong subject perceive the obstacle existence and is answered by an ascending scale of 1 to 5. Subjects answered scale 5 when they felt 80 - 100 % presence of obstacle in front of them. Falling a scale of the localization certainty means 20 % presence of obstacle was decreased. The localization distance is answered by the centimeters. In addition, the localization certainty and distance were answered by fingers and parol, respectively.

Subjects asked to do aforementioned task with these four condition: binaural localization with/without head rotation and monaural localization with/without head rotation. In the monaural condition, an earplug was inserted to subject's worse ear in the pure-tone audiometry.

The experiment was composed of 30 - 35 sets for training and 30 sets in each condition for actual tests.

2.4 Result

Results of localization certainty is illustrated by Figure 2. Each graph describes the result at the condition of binaural with head rotation, binaural without head rotation, monaural with head rotation and monaural without head rotation in descending order. The change of localization certainty accompanied by the distance change is higher in the condition with head rotation than without head rotation in both binaural and monaural hearing when obstacle width is 10 cm. Moreover, binaural hearing tends to be higher in the localization certainty at 10 cm in obstacle width than monaural hearing under the condition with head rotation. Whereas, under the condition without head rotation, variation of localization certainty is more considerable in monaural hearing.

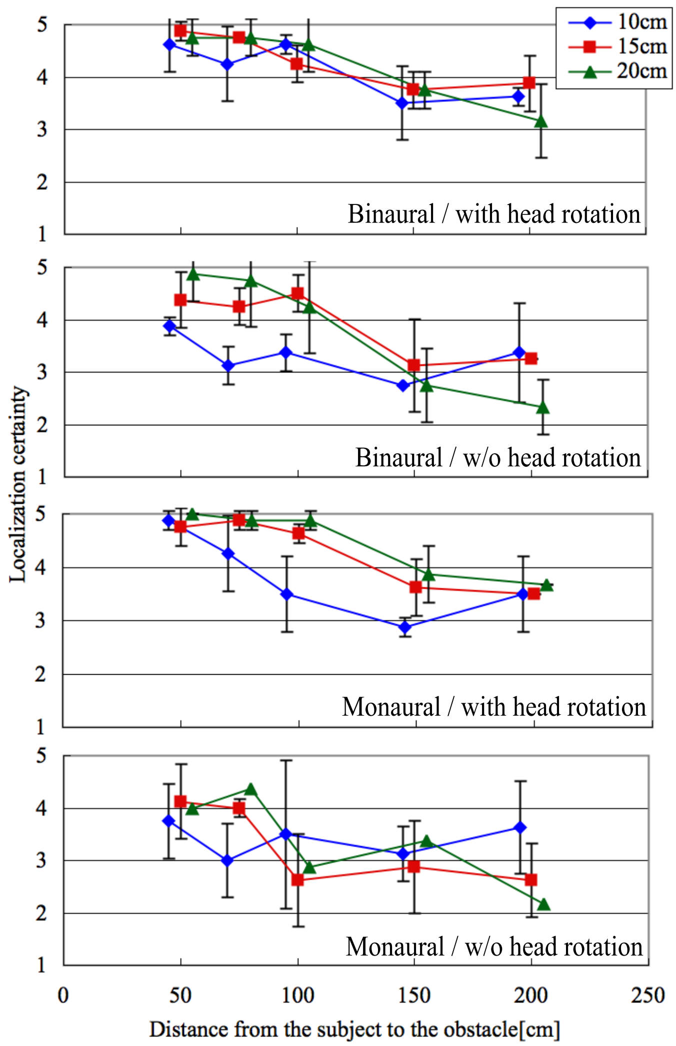

Figure 2: Results of localization certainty as a function of distance between the subject and the obstacle. The parameter is obstacle width. In addition, marks in case of 10cm or 20cm obstacle width are plotted ±5cm points from the set of experimental configured distance in the transverse each other due to facilitate visualization.

Figure 3 shows results of localization distance. Graph order is the same as figure 2. Aqua blue lines in these graphs is added for visualizing the difference between the localized distance and actual distance. It appears that the condition without head rotation varied more widely in both binaural and monaural hearing.

According to the introspection of subjects, the binaural with head rotation is 1st in the ease of task, followed by the binaural without head rotation, the monaural with head rotation and the monaural without head rotation. Whereas localization ease of evaluation for obstacle presence and distance are the binaural with head rotation, the monaural with head rotation, the binaural without head rotation and the monaural without head rotation in that order.

3 Discussion

According to the localization certainty represented by Figure 2, change of the localization accuracy in the con-

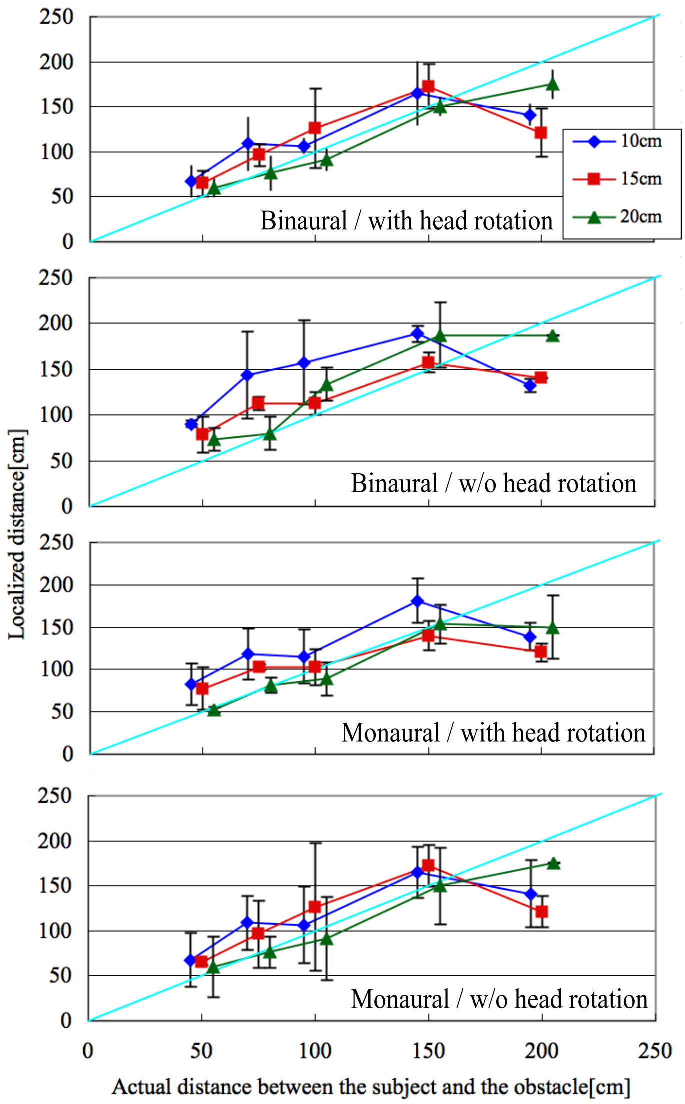

Figure 3: Results of localization distance as a function of the distance between the subject and the obstacle. The parameter is obstacle width. In addition, marks in case of 10cm or 20cm obstacle width are plotted at ±5cm points from the set of experimental configured distance in the transverse each other due to facilitate visualization. Aqua blue lines mean the actual distance between the subject and the obstacle.

dition without head rotation is flat when the obstacle width equals to 10 cm. The average head width (bitragion breadth) of Japanese people is 14.86 ± 1 cm in general [15]. When the obstacle width is smaller than this range, intensity of reflected sound from the obstacle significantly decreases due to the head shadow[16]. Thus, obstacle presence when the obstacle width was 10 cm is not varied because the sound intensity change between the far and near from the obstacle is almost the same.

Change of the localization accuracy in the condition with the head rotation, however, tends to be decrease monotonically. Head rotation results in the change of ear position against the reflected surface of obstacle. Thus, intensity loss of reflected sound due to diffraction during head rotation decreases more than the case interaural axis is parallel to the obstacle surface. Therefore, it can be assumed that change of interaural difference during head rotation contributes to more sensitive perception of obstacle presence.

As specified by the localization distance represented by Figure 3, the condition with head rotation varied less widely than the condition without head rotation. It can also be assumed that the change of the interaural difference plays an important role to obstacle distance localization.

Therefore, head rotation which generates interaural difference contributes to more sensitive obstacle presence and distance localization. This can apply to the training method of the orientation: it is more effective for localizing the circumstances to pay attention to change of interaural sound during head rotation.

Almost all of blind people are binaural hearing in ordinary environment, thus binaural hearing condition is focused. According to Figure 3, there observed wider variation of localized distance at 10 cm in obstacle width than at 15 and 20 cm. Obstacle distance is difficult to localize for the blind when the obstacle surface width is smaller than the head width. Therefore, the design of blind mobility aid should be developed to enable users to easily recognize the obstacle whose width is narrower than their head width.

4 Conclusion

Head rotation contributes the presence and the distance perception of obstacle. This is because of change of interaural difference during head rotation. In addition, it is more effective for localizing the circumstances to pay attention to change of interaural sound during head rotation. The design of blind mobility aid should be developed to enable users to easily recognize the obstacle whose width is narrower than their head width.

Acknowledgments

This work is supported by JSPS Grant-in-Aid for Scientific Research (S), 17100009.

References

[1] T. Ifukube and T. Sasaki and C. Peng, "A blind mobility aid modeled after echolocation of bats", *IEEE Transactions on Biomedical Engineering*, 38, 461-465 (1991).

[2] N. Pressey. " Mowat sensor, " *Focus*, 3, 35-39 (1977).

[3] L. Kay, "The design and evaluation of a sensory aid to enhance spatial perception of the blind", *Dep. Elect. Eng., Univ. Canterbury, New Zealand, Rep.*, 21 (1973).

[4] S. Shoval, and I. Ulrich and J. Borenstein, "NavBelt and the GuideCane [obstacle-avoidance systems for the blind and visually impaired]", *IEEE Robotics & Automation Magazine*, 10, 1, 9-20 (2003).

[5] Y. Seki, "Acoustical design of city for the visually handicapped", *J. Acoust. Soc. Jpn.*, 54, 5, 387-392 (1998).

[6] M.Supa, M.Cotzin K.M.Dallenbach: "Facial Vision": The Perception of Obstacles by the Blind, *The Amer. J. of Psychol.*, 57, 2, 133-183 (1944).

[7] P. Worchel and K.M.Dallenbach,"" Facial vision: " perception of obstacles by the deaf-blind ", *Proc. of the Int Congresss on Technology and Blindness*, 60, 4, 502-553 (1947).

[8] M. Cotzin and K.M. Dallenbach," "Facial vision: " the role of pitch and loudness in the perception of obstacles by the blind ", *The Amer. J. of Psychol.*, 63, 4, 485-515 (1950).

[9] W.N. Kellogg, " Sonar system of the blind ", *Science*, 137, 3528, 399-404, (1962).

[10] C.E. Rice, " Human echo perception ", *Science*, 155, 656-664 (1967).

[11] T.Miura, S.Ino, T.Muraoka, T.Ifukube, "Contribution of interaural di?erence to obstacle sense of the blind during walking", *Proc. 124th Audio Engineering Society*, (2008).

[12] V. E. Pettorossi, M. Brosch, R. Panichi, F. Botti, S. Grassi and D. Troiani, "Contribution of self-motion perception to acoustic target localization", *Acta Oto-Laryngologica*, 125, 524-528 (2005).

[13] T. Loetscher, U. Schwarz, M. Schubiger and P. Brugger, "Head turns bias the brain's internal random generator", *Current Biology*, 18, 2, R60-R62 (2008).

[14] H. Nakamura-Funaba, M. Ueda, S. Iwamiya, "Questionnaire survey of the use of sound to support the mobility of the visually impaired", *J. Acoust. Soc. Japan*, 62, 12, 839-847 (2006).

[15] http://www.dh.aist.go.jp/AIST91DB/.

[16] D. S. Brungart and W. M. Rabinowitz, "Auditory localization of nearby sources. Head-related transfer functions", *J. Acoust. Soc. Am.*, 106, 3 pt 1, 1465-1479 (1999)