TRAINING EFFECT OF A VIRTUAL AUDITORY GAME ON SOUND LOCALIZATION ABILITY OF THE VISUALLY IMPAIRED

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ABSTRACT

It is essential for a visually impaired person to correctly identify the position of a sound source because such identification enables him/her to recognize his/her surroundings, including obstacles. We developed training equipment to help the visually impaired to improve their ability to identify the position of a sound source by applying a auditory display technique. Training for ten days with the system was conducted. As a result, the ability to identify a sound source position was improved.

1. INTRODUCTION

The authors have developed a virtual auditory display (VAD) which is responsive to head movement. Furthermore, an action game named "Hoy-Pippi" was developed with the VAD system for application to the welfare field. This game was actually played by pupils of a school for the blind [1] [2]. As this game became popular with those who played it, we are confident of its potential as a new mode of entertainment for visually impaired persons.

The characteristic feature of this game is "touching sound," namely, positioning a hand at the position of a sound source. In other words, in order to play this game, a player needs to recognize the position of a sound source, and must be able to correctly position his/her hand in that position.

Then, we hypothesized that the ability to identify a position of the sound source near the body would be improved by repeatedly playing this game. For the visually impaired, improvement in the ability to identify a sound source position not only facilitates perception of the position of the object which emits sound, but is useful in others ways. For example, it may enable them to turn their faces toward the conversation partner, as well as to perceive obstacles and to avoid them, and to recognize the space and environment in which they are standing. These are indispensable requirements for improvement of the QoL (Quality of Life) of the visually impaired. In this study, we trained ten listeners using this game for ten days, in order to confirm this hypothesis.

2. OVERVIEW OF AUDITORY DISPLAY

The VAD convolves head related transfer functions (HRTFs) [3] according to the position of a sound in real time, the sound being presented through headphones (Figure 2). The head movement of a listener is tracked by a 3D tracker system (Polhemus 3SPACE FASTRAK) to change HRTFs so that the position of the emitting the sound object can be virtually fixed in a space. The listener can then reduce the front-back error in a sound localization by head movement, which results in improvement of the localization accuracy. The receiver of the 3D tracker system was fixed to the top of the headband of the headphones. The HRTFs used for the experiment were the non-individualized, rather those of another person were used.

3. OUTLINE OF THE GAME SOFTWARE

The game software for training which the authors developed has the following specifications. If a game is started, a virtual creature called Hoy-Pippi will appear in a random position, and shout "Hoy-Pippi." Then, it flies around the head of a player for about 2 seconds horizontally at the height of the player's ears. If a player can strike it with a rod having a 3D receiver made of polystyrene foam, he/she can get a point(Figure 1). That is, it is a kind of mole panic game using 3D sound. The Hoy-Pippi appears 20 times per game.
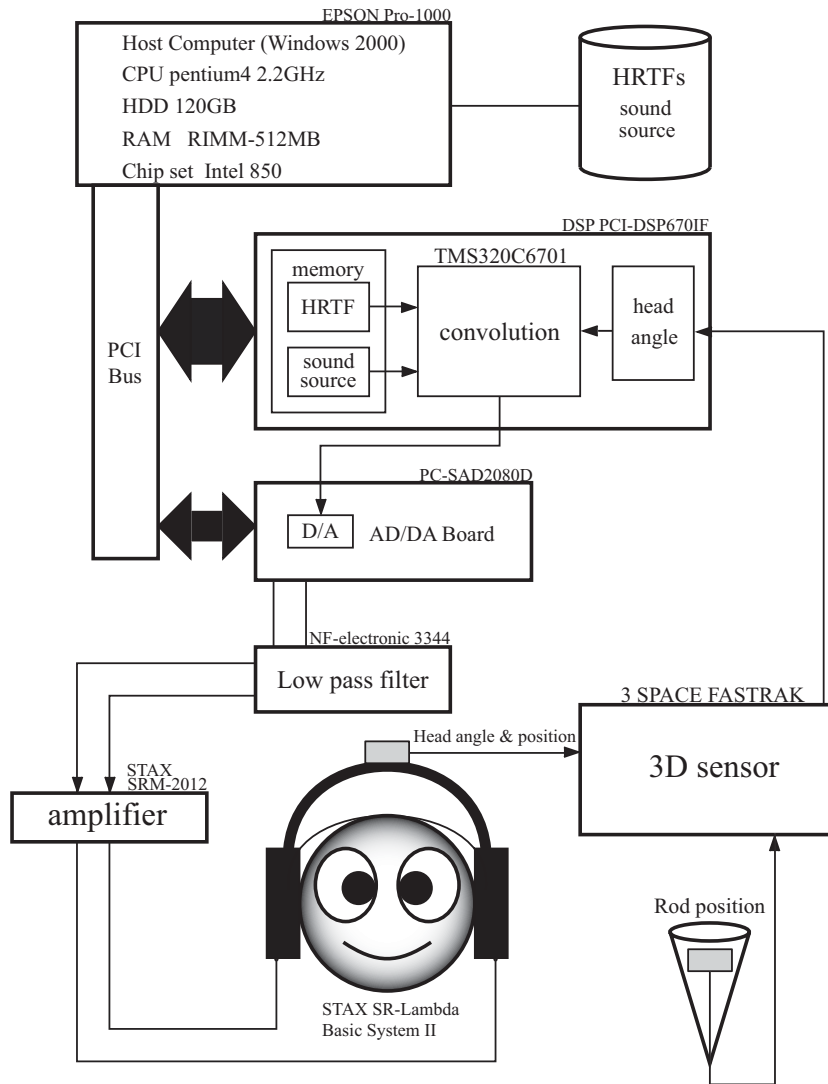

Figure 1: *A listener playing the game Hoy-Pippi.*

EPSON Pro-1000

Host Computer (Windows 2000)
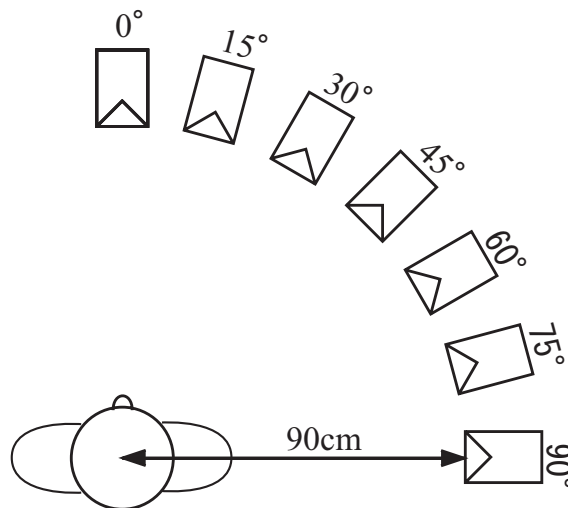
CPU pentium4 2.2GHz

HDD 120GB

RAM RIMM-512MB

Chip set Intel 850

HRTFs sound source

DSP PCI-DSP670IF

memory
HRTF
sound source

TMS320C6701

convolution

head angle

PCI Bus

PC-SAD2080D

D/A   AD/DA Board

NF-electronic 3344

Low pass filter

3 SPACE FASTRAK

Head angle & position

3D sensor

STAX
SRM-2012

amplifier

STAX SR-Lambda
Basic System II

Rod position

Figure 2: *The auditory display system.*

0°
15°
30°
45°
60°
75°
90°

90cm

Figure 3: *Loudspeaker arrangement for the measurement of the ability to identify sound source positions.*

4. MEASUREMENT OF THE ABILITY TO IDENTIFY SOUND SOURCE POSITIONS

4.1. Method

To measure the difference of the ability to identify a sound source position between pre-training and post-training, the following experiment was conducted. As shown in Figure 3, seven loudspeakers were arranged around the circumference of a circle (horizontal plane) with a radius of 90 cm from the center of the listener's head.

A pink noise of 70 dBA is presented for 2 seconds from one of the loudspeakers as a stimulus, and the listener points to the position of the sound source with his/her right index finger. The difference between the position the listener points to and the center of the correct speaker is counted as a sound localization error. A stimulus was randomly presented from each speaker 5 times, and the average of the sound localization errors for each speaker was calculated.

This experiment was performed before and after training using Hoy-Pippi, and the effect of training was confirmed by comparing those sound localization errors. Since listeners were sighted persons with normal hearing ability this time, they were blindfolded before entering the laboratory.

4.2. Listeners

Ten listeners participated in the experiment. Five of them were chosen at random and given training for 15 minutes every day for ten days. They are called the "trained group." The other five persons were a control group and underwent only a pre-test and a post-test without training. They are called the "non-trained group."

4.3. Results

Figure 4 is a scatter diagram of the sound localization error for every azimuth in the trained group. It can be seen that the sound localization error is decreased in almost all azimuths in the trained group. Figure 5 is a scatter diagram of the sound localization error in the non-trained group, which shows that there was scarcely any difference between results of the pre- and post-test.

Figures 6 and 7 show a comparison of the absolute value average of the sound localization error of the pre-test and post-test in the trained group and the non-trained group for every azimuth. In the trained group, the sound localization error of 15° to 90° showed a decrease after the training.

The analyses of variance (ANOVAs) were performed with regard to the absolute value of the localization errors. Three factors, i.e., TRAINING (trained or non-trained), PRE (pre or post), and AZIMUTH (0° to 90°) were treated as factors.

As a result, the second order interaction among TRAINING, PRE, and AZIMUTH was significant ($F_{(1,6)}=2.63$ $p<.05$). Therefore, analysis was sliced for each TRAINING condition. The interaction between the pre- vs. post-condition and the condition of the sound source azimuths was significant only in the trained group ($F_{(1,6)}=2.22$ $p<.05$). In the non-trained group, however, this interaction was not significant. Errors for each azimuth were then tested, which showed that the errors of the post-condition at 60° ($F_{(1,48)}=5.45$ $p<.05$) and 75° ($F_{(1,48)}=5.26$ $p<.05$) were significantly smaller than those of the pre-condition. On the other hand, in the non-trained group, no significant difference between azimuths was found. This result shows that the sound localization error of only the trained group decreased.
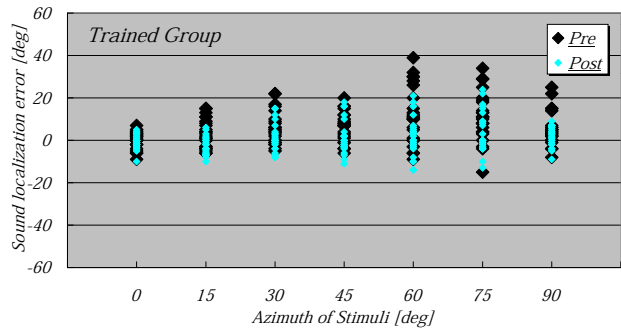

Figure 4: *Scatter diagram of the sound localization error in the trained group.*
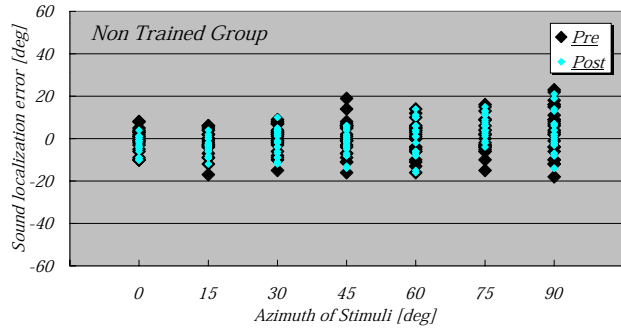

Figure 5: *Scatter diagram of the sound localization error in the non-trained group.*
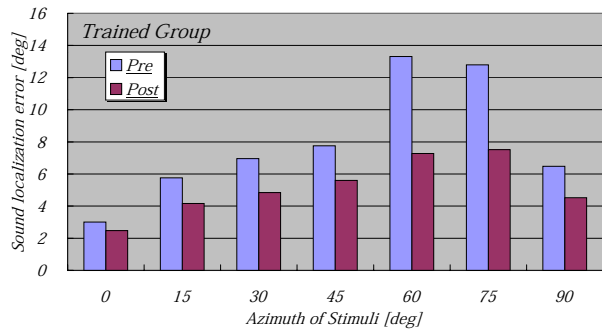

Figure 6: *Comparison of the absolute value average of the sound localization error of the pre-test and post-test in the trained group.*
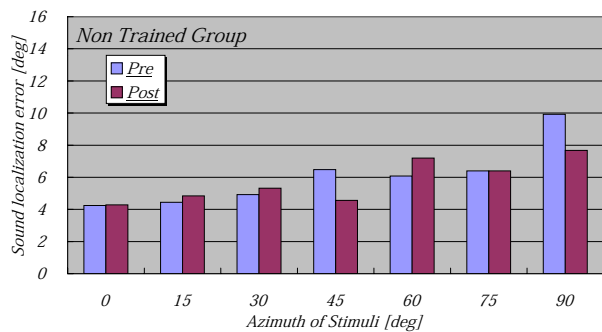

Figure 7: *Comparison of the absolute value average of the sound localization error of the pre-test and post-test in the non-trained group.*

5. DISCUSSION

In the trained group, although the ability to identify the sound source position after training improved in all the azimuths, the rates of the improvement of 60° and 75° were especially remarkable. Since the sound localization ability for the azimuth near the median plane for humans is originally excellent [4], even with training, no remarkable improvement could be expected, but since the ability in the 60° to 75° azimuths is low, our experiment showed remarkable improvement by the training using Hoy-Pippi.

However, when the localization error of the trained group and that of the non-trained group in the pre-test were compared, that of the trained group was significantly large in the 60° azimuth, while that of the non-trained group was significantly large in the 90° azimuth. This indicates the possibility that the trained group and the non-trained group were not samples of the same quality statistically. Thus, further experiments with the training of many more listeners are required.

In this research, although training for the ten days was performed, the authors did not investigate how many days were required for the appearance of the training effect nor the type of growth curve. However, analysis of the transition of the average score of the game Hoy-Pippi by ANOVAs showed that a significant difference appeared in the score on the 7th day of training. To obtain points in the Hoy-Pippi game, a player must be able to recognize the sound source position, as well as to be physically able to move the rod to that position. Therefore, it can be said that the ability of sound source position identification improved significantly on the 7th day from the start of training.

Finally, in this research study, only sighted subjects participated and thus the results may not match those of the visually impaired with generally good ability of sound source position identification. However, this equipment should be extremely useful in attempts to improve the ability of sound source position identification in visually impaired children or the non-congenital blind.

6. CONCLUSIONS

A 3D sound game called "Hoy-Pippi" was developed with the technique of virtual auditory display. It was hypothesized that the ability of sound source position identification improves with use of the game. Training with the game was conducted for the ten days. The listeners were ten sighted persons with normal hearing, five assigned to the trained group, and the other five assigned to the non-trained group. The ability of identifying the sound source position of each listener was measured before the training and after the training, results being compared after the training.

As a result, the ability of sound source position identification of only the trained group improved. This indicated that the 3D sound game Hoy-Pippi was effective in improvement in the ability of sound source position identification.

In the future, the authors intend to modify the game as an interactive type on a network so that two players living in different places can play each other. Moreover, the authors will further improve the application software and develop a training simulator of a mental map for the visually impaired [5] [6] [7].

7. ACKNOWLEDGMENTS

8. REFERENCES

[1] M. Ohuchi, Y. Iwaya, Y. Suzuki, & T. Munekata, "A game for visually impaired children with a 3-D virtual auditory display," ICAD2003, pp. 309, 2003

[2] M. Ohuchi, Y. Iwaya, Y. Suzuki, & T. Munekata, "Prototyping of sound VR game for children with visual impairment," The 23rd Asia-Pacific international seminar on special education, pp. 39, 2003

[3] M. Morimoto & Y. Ando, "On the simulation of sound localization," J.Acoust.Soc.Jpn., Vol.1, pp. 167-174, 1980

[4] A. W. Mills, "On the minimum audible angle," J. Acuust. Soc. Amer., vol.30, pp. 237-246 , 1958

[5] J. Sánchez, "Interactive 3D sound hyperstories for blind children," Proceedings of ACM-CHI , pp. 318-325, 1999

[6] R. G. Golledge, M. Blades, R. Kitchin & D. Jacobson, "Understanding Geographic Space Without The Use of Vision," NSF Peport SBR95-14907(Final Report), 1999

[7] O. Lahav & D. Mioduser, "Multisensory virtual environment for supporting blind persons' acquisition of spatial cognitive mapping, orientation, and mobility," Proc.4rd Intl Conf.Disability, Virtual Reality & Assoc.Tech., pp. 213-220 , 2002