PERFORMANCE EVALUATION OF BLIND PERSONS IN LISTENING TESTS IN DIFFERENT ENVIRONMENTAL CONDITIONS

György Wersényi

Széchenyi István University,
Department of Telecommunications,
H-9026, Győr, Egyetem t. 1, Hungary
wersenyi@sze.hu

József Répás

Széchenyi István University,
Department of Telecommunications,
H-9026, Győr, Egyetem t. 1, Hungary
repas@sze.hu

ABSTRACT

Visually impaired people are often in target groups of various investigations, including basic research, applied research, research and development studies. Experiments in the development of assistive technologies - navigation aids or computer interfaces (auditory displays) - aim to incorporate the results of testing with blind subjects during development. Listening tests concerning the localization performance of blind subjects can be installed in various environments using different excitation signals. Generally, results can be collected only from a small number of participants and they are compared with results of blindfolded sighted subjects. The goal of this study was to include different environmental conditions (virtual reality, real life, free-field), different localization tasks and a larger number of participants both blind and sighted for comparison. Results indicate that blind subjects' performance is generally not superior to sighted subjects' performance from the engineering point of view, but further psychological evaluation is recommended.

1. INTRODUCTION

Everybody knows the "fact" that blind people can "hear better" than sighted. This issue is far more complicated than one short statement, which can be true or false under different environmental and measurement conditions. Although this is a basic research question about human perception, results can also be exploited in the applied sciences [1, 2]. Firstly, it has to be clearly defined what "hearing better" means: a better hearing threshold, more correct judgments on a virtual audio display, an increased localization performance in the anechoic chamber or a better usage of reflections during outdoor navigation (echolocation)?

In general, research in this field includes only a small number of blind subjects (2-5) due to the relatively difficult procedure to recruit participants. Results are compared with blindfolded sighted subjects performing in the same test, where statistical significance and equal distribution (number of subjects, gender, age etc.) is hard to realize. Furthermore, experiments are designed to a unique task so results from different experiments can be hard to compare. In the field of engineering sciences, blind subjects are usually involved if they are targeted with the research: development of electronic travel aids (ETAs) [3], text-to-speech applications, auditory displays and interfaces [4, 5], and only seldom if basic perceptional questions are investigated. Research in psychology or medicine aiming at blind persons' abilities focuses on non engineering aspects such as effect of different medications, adaptation methods, cognitive and behavioral effects etc. Thus, these results are hard to compare with each other and with engineering goals.

The goal of our study was to establish a series of blind-sighted comparative experimental and evaluation procedures to do with localization that covers almost all possible environmental conditions [6, 7]. Furthermore, by recruiting a larger number of participants, statistical significance can be increased. This paper presents briefly the comparative results supported by statistical analysis, mainly from the audio engineering, sound design, and practical point of view. Future evaluation is about to include perceptual, psychological and cognitive aspects as well.

2. MEASUREMENT SETUPS AND INSTALLATIONS

2.1 Audiometric screening

Audiometric screening of participants in listening tests should be a requirement for proper evaluation of measured results. Detectable hearing loss on one or both ears could affect localization performance depending on the importance of the hearing loss. Even carefully conducted tests often skip this procedure to save time and money. Usually, excitation signal levels exceed background noise levels significantly; volume can be adjusted to be comfortable and if the investigation does not aim especially low-level perception or sensitivity, the results obtained will be accepted without the high cost and time demands of standardized audiometric screening.

In our case, our multi-level comparative evaluation required the correct measurement of the hearing thresholds. The sensitivity (hearing threshold) of hearing is related to the peripheral hearing system, from the movements of the eardrums to the inner ear's functionality. It is assumed that if blind people's sensitivity is not superior to sighted people's sensitivity levels, any differences in the hearing abilities, localization etc. are not on the peripheral level, but are related to higher level processing in the nervous system and thus, it is something that has to be, and can be, learned.

The blind participants in our survey were invited to a standardized audiometric screening following the ANSI standard [8]. Only blind subjects were tested, the only part in the survey that is not comparative. The measurement setup included the Oscilla-USB350BS computer-based clinical audiometer, the accompanying driver software and the anechoic chamber. 15 male and 15 female subjects between the ages of 22 and 71 years participated. 22 of them were totally blind, the rest with 75-90% blindness. The scanned frequency range was 125 to 8000 Hz, using sinusoidal pure tones in 5 dB steps. Figure 1 shows mean results of all measured values for the left and right ear respectively. The averaged audiogram does not differ (in dBHL) from those audiograms we usually measure of healthy sighted subjects in clinical audiometry.

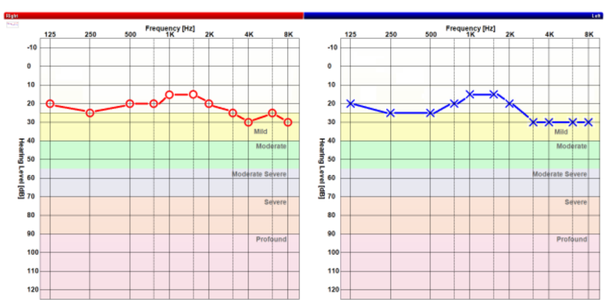

Figure 1: Audiogram shows frequency in Hz increasing from left to right as a logarithmic scale while intensity in decibels increases downward in a linear scale. Thresholds for the right ear are drawn as circles, in red, and are connected with red solid lines, while thresholds for the left ear are drawn as X's, in blue, and are connected with blue solid lines.

2.2 Outdoor navigation tasks

Two experiments were designed for testing outdoor navigation skills, simulating real-life situations. They were selected following the recommendations of the local blind community. 120 blindfolded sighted and 34 blind persons participated.

2.2.1 Walking straight experiment

The task to walk along a straight line without visual feedback has been used in experiments for a long time [9-21]. People veer from the straight line shortly after the start, even ending up walking in circles. A 40-m concrete playfield was used for the tests, both with and without acoustic beacons. Acoustic signals (click-train and white noise) were played back from a loudspeaker (the target) that had to be approached [22-26]. Statistical analysis showed that the mean absolute error in meters from the target left and right are same for both groups. For walks without acoustic beacon, both groups veered enormously. For walks using any of the acoustic beacon signals, all but one participant in both groups reached the target.

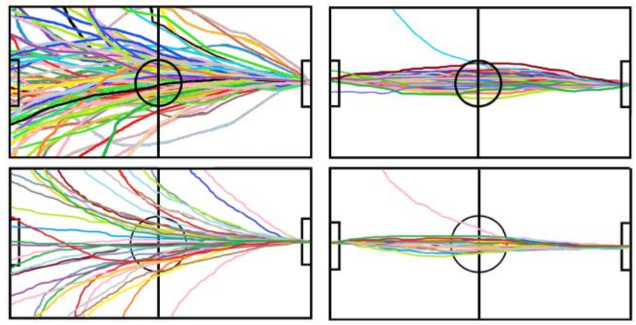

Figure 2: Walking trajectories based on GPS tracking during the first try without sound for 120 blindfolded sighted (top left) and 34 blind subjects (bottom left). On the right, walking trajectories based on GPS tracking in the case of white noise excitation for sighted (top) and blind subjects (bottom).

2.2.2 Echolocation

The term echolocation refers to the ability to detect reflections in order to avoid collision with obstacles or to detect the distribution of obstacles in a space. Blind people take advantage of echolocation during navigation in unfamiliar spaces, e.g. on streets where they attempt to detect the existence or absence of cars, buildings, doors, corners etc. [6]. Our experimental setup included an outdoor sidewalk next to a building on a university campus (Fig. 3). Cancelling all other parameters (weather, shadows, cars passing by, touching the wall etc.) the task was to walk along the wall, tapping on the pavement with the white cane and listening to the reflections in order to find the corner (the missing reflections). Cancelling the effect of these parameters means that the measurement was repeated if any of these parameters changed or affected the trial. Statistical analysis showed significant difference between the two groups. While blindfolded sighted subjects had large errors both after and before the corner, blind subjects had no negative error (that would cause hitting the wall if they turned) and could almost perfectly detect where they had to stop. No subjects were trained prior to the experiment for this dedicated task, however, blind users were already comfortable with using the white cane as most of them were 'early blind'.

2.3 Free-field experiment

Free-field experiments, tests were carried out in an anechoic chamber. 50 sighted and 36 blind subjects participated.

2.3.1 Front-back reversals

The audio playback system included two identical loudspeakers in the diagonal of the chamber with a listening position half way in between. Subjects were led blindfolded in the chamber, facing one of the loudspeakers in a standing position. White noise bursts were radiated in random order from the "front" or from the "rear" loudspeaker and subjects had to determine the direction by calling "front" or "rear". Statistical evaluation of error rates showed no significant difference between the groups.

Figure 3: Blindfolded subject during the experiment to detect the corner by tapping with the white cane.

2.3.2 Absolute localization

Using only one of the speakers with a frame around it showing the coordinate system for the evaluation, another listening test was installed (see Fig. 4). Subjects sat on a chair with a laser pointer on a finger. After losing orientation (by randomly turning the chair back and forth), source directions of 0, ±45, and ±90 degrees were set by rotating the chair. The subject had to point with the pointer to the sound source while it was radiating a white noise signal. Errors in degrees were collected in the horizontal and vertical plane. Statistical evaluation of error rates showed no significant difference between the groups.

Figure 4: Subject in a test installation pointing with the laser pointer mounted on a finger. The coordinate system is painted on the white board, sound source is in the origin, error rates can be recorded easily in degrees both in horizontal and vertical plane. "Out-of-frame" error can occur if the red dot is outside the board, i.e. the error is greater than 10 degrees in both planes.

2.4 Virtual localization

For experiments in virtual reality, a computer-based playback system with a good quality headphone is needed and a simulation of sound source directions has to be implemented. This is usually done with digital filtering of the Head-Related Transfer Functions [22].

The details of our experiment have already been published [7]. 28 blind and 40 sighted persons were involved using a 2-D virtual audio display in front of the listener. The measurement setup included a Beachtron rendering card and software, Sennheiser HD540 headphone, 300 ms white noise excitation and human HRTFs from a pre-recorded database in 30 degree spatial resolutions. Localization tasks included:

- Localization of static images in front and back of the listener in an absolute measurement to reveal in-the-head localization and front-back errors.
- Identification of a (virtually) moving sound source around the head (direction of circling) as well as of movements of the sound source up and down in the median plane.
- Source discrimination task within a Minimum-Audible-Angle (MAA) including two 300 ms white noise burst separated by silence. MAA values were determined for a moving source left, right, up, and down compared to a static source in the origin in front of the listener.
- A sound source discrimination task on a 3 × 3 grid in a 2-D Virtual Audio Display.

Based on T-tests (5% significance) blind subjects delivered better results on a 3 × 3 grid and in localizing static frontal sources. Reason for the latter is the decreased number of front-back reversals. In the case of moving sources, they were more accurate in determining movements around the head in the horizontal plane. On the other hand, sighted participants performed better during tests in which the task was to listen to ascending movements in the median plane and to identify sound sources in the back. Results of an MAA measurement in front of the listener (measuring their ability to detect descending movements and in-the-head localization rates) are almost identical for the two groups. In general, blind subjects performed at least as well as sighted subjects on this virtual audio display. Other factors, such as gender, age, having a musical background or even absolute pitch, or being born blind had no statistically significant influence on the results.

3. DISCUSSION

We only examined the experimental results from the engineering point (application level) point of view, not from a psychological perspective.

In non-virtual environments, blind subjects performed better only in the echolocation task. Devices, ETAs and applications using reflections and echo are recommended in the development of future equipment in assistive technology. In virtual audio in general (except frontal localization), and in other navigation and localization tasks, subjects from both groups performed almost equally proficiently. This suggests that any development targeting the visually impaired may include sighted subjects for testing if only localization performance is an issue. Because recruiting blind subjects is always a huge demand on experimental resources, using blindfolded sighted subjects can be a satisfying alternative for selected experiments. In addition, while blind people tend to be better in musical tasks and in echolocation, they have a low tolerance of headphones.

4. SUMMARY

Results of listening tests in different environmental conditions were briefly presented in a comparative manner between blind and blindfolded sighted participants in order to contribute to answering the question of whether blind people are superior to sighted people in their hearing abilities. There is no statistically significant difference in the hearing threshold levels, in the outdoor navigation task during "walking straight", in the front-back-reversal and absolute localization error rates in the anechoic chamber and during most of the virtual localization tasks. On the other hand, blind persons performed significantly better using echolocation during outdoor navigation and they had less front-back errors in virtual localization. The everyday general statement about blind people hearing "better" was not supported. Future work will include psychological and perceptual evaluation of the experiments.

5. ACKNOWLEDGEMENT

This research was realized in the frames of TÁMOP 4.2.4. A/2-11-1-2012-0001 „National Excellence Program – Elaborating and operating an inland student and researcher personal support system" The project was subsidized by the European Union and co-financed by the European Social Fund.

6. REFERENCES

[1] E. Hojan, and E. Skrodzka, "Polish Research on Acoustical Assistance for Blind and Visually Handicapped Persons," *in Proc. of ICAD13*, Lodz, Poland, pp. 13-16, 2013.

[2] N. Lessard, M. Paré, F. Lepore and M. Lassonde, "Early-blind human subjects localize sound sources better than sighted subjects," *Nature* 395, 278-280, 1998.

[3] M. Bujacz, P. Skulimowski, and P. Strumillo, "Naviton—A Prototype Mobility Aid for Auditory Presentation of Three-Dimensional Scenes to the Visually Impaired," *J. Audio Eng. Soc.*, vol. 60, no. 9, pp. 696-708; September 2012.

[4] D. K. Palladino, and B. N. Walker, "Efficiency of spearcon-enhanced navigation of one dimensional electronic menus," *in Proc. of ICAD 08*, Paris, France, 2008, 6 pages.

[5] T. Dingler, J. Lindsay, and B. N. Walker, "Learnability of Sound Cues for Environmental Features: Auditory Icons, Earcons, Spearcons, and Speech," *in Proc. of ICAD 08*, Paris, France, 2008, 6 pages.

[6] Gy. Wersényi, and J. Répás, "The Influence of Acoustic Stimuli on "Walking Straight" Navigation by Blindfolded Human Subjects," *Acta Technica Jaurinensis*, vol. 5, no. 1, pp. 1-18, 2012.

[7] Gy. Wersényi, Virtual localization by blind persons, *J. Audio Eng. Soc*., vol. 60, no. 7/8, pp. 568-579, 2012 July/August.

[8] ANSI S3.21-1978 (R-1992)

[9] H. S. Bracha, D. J. Seitz, J. Otemaa, and S. D. Glick, "Rotational movement (circling) in normal humans: Sex difference and relationship to hand, foot and eye preference," *Brain Research*. vol. 411, no. 2, pp. 231–235, 1987.

[10] B. Gurney, "Leg length discrepancy," *Gait & Posture*, vol. 15, no. 2, pp. 195–206, 2002.

[11] J. J. Rieser, D. H. Ashmead, C. R. Taylor, and G. A. Youngquist, "Visual perception and the guidance of locomotion without vision to previously seen targets," *Perception*, vol. 19, no. 5, pp. 675–689, 1990.

[12] J. L. Souman, I. Frissen, M. N. Sreenivasa, and M. O. Ernst, "Walking Straight into Circles," *Current Biology*, vol. 19, no. 18, pp. 1538-1542, August 2009.

[13] T. Uetake, "Can we really walk straight?," *American Journal of Physical Anthropology*, vol. 89, no. 1., pp. 19–27, September 1992.

[14] J. W. Philbeck, J. M. Loomis, and A. C. Beall, "Visually perceived location is an invariant in the control of action," *Perception & Psychophysics*, vol. 59, no. 4., pp. 601-612, 1997.

[15] Y. Takei, R. Grasso, and A. Berthoz, "Quantitative analysis of human walking trajectory on a circular path in darkness," *Brain Research Bulletin*, vol. 40, no. 5-6, pp. 491-495, 1996.

[16] Y. Takei, R. Grasso, M.-A. Amorim, and A. Berthoz, "Circular trajectory formation during blind locomotion: a test for path integration and motor memory," *Experimental Brain Research*, vol. 115, no. 2, pp. 361-368, 1997.

[17] C. Mohr, T. Landis, H. S. Bracha, M. Fathi, and P. Brugger, "Human locomotion: levodopa keeps you straight," *Neuroscience Letters*, vol. 339, no. 2, pp. 115-118, March 2003.

[18] C. S. Kallie, P. R. Schrater, and G. E. Legge, "Variability in stepping direction explains the veering behavior of blind walkers," *J. Exp. Psychol. Hum. Percept. Perform*., vol. 33, no. 1, pp. 183–200, 2007.

[19] D. Guth, and R. LaDuke, "The veering tendency of blind pedestrians: An analysis of the problem and literature review," *J. Vis. Impair. Blind*., vol. 88, no. 5, pp. 391–400, 1994.

[20] D. Guth, and R. LaDuke, "Veering by blind pedestrians: Individual differences and their implications for instruction," *J. Vis. Impair. Blind*., vol. 89, no. 1, pp. 28–37, 1995.

[21] S. A. Panëels, D. Varenne, J. R. Blum and J. R. Cooperstock, "The Walking Straight Mobile Application: Helping the Visually Impaired avoid veering," *in Proc. of ICAD13*, Lodz, Poland, pp. 25-32, 2013.

[22] J. Blauert, *Spatial Hearing*, The MIT Press, MA, USA, 1983.

[23] J. M. Terhune, "Localization of Pure Tones and Click Trains by Untrained Humans," *Scandinavian Audiology*, vol. 14, no. 3 , pp. 125-131, 1985.

[24] H. Babkoff, C. Muchnik, N. Ben-David, M. Furst, S. Even-Zohar, and M. Hildesheimer, "Mapping lateralization of click trains in younger and older populations," *Hearing Research* vol. 165, no. 1-2, pp 117-127, 2002.

[25] A. D. Brown, and G. C. Stecker, "Temporal weighting of interaural time and level differences in high-rate click trains," *J. Acoust. Soc. Am*., vol. 128, no. 1, pp. 332-341, July 2010.

[26] D. S. Brungart, and B. D. Simpson, "Effects of temporal fine structure on the localization of broadband sounds: potential implications for the design of spatial audio displays," *in Proc. of ICAD 08*, Paris, France, 2008, 5 pages.