

INFLUENCE OF LEAD AND LAG DIFFERENCES ON LOCALIZATION

PACS REFERENCE 43.66.QP

Kristian Jambrošić Bojan Ivančević

Department of Electroacoustics, Faculty of EE and Computing, University of Zagreb

Unska 3

HR-10000 Zagreb

Croatia

Tel: +38516129640

Fax: +38516129680

E-mail: kristian.jambrosic@fer.hr

ABSTRACT

The precedence effect explains the ability of our hearing system to locate a sound source in a reverberant room. However, there are still many unknowns about how the occurrence of the effect depends on the differences of the lead and lag. In this paper, lead and lag signals were not reproduced only through one sound source, but simultaneously through two. Thus, the precedence effect was simulated using two phantom sound sources rather than two real sources. Cross-correlation function between left and right ear signals of a dummy head was calculated in order to find the relation to subjective tests.

INTRODUCTION

The precedence effect, also called in some special cases the 'Haas effect' and the 'law of the first waveform' is a well-known phenomena in psychoacoustics where men's hearing mechanism shown the ability to localize a sound source in a reverberant environment where the direct sound is followed by multiple reflections, [1-3]. More general, it refers to all phenomena issuing in various time delays between the direct sound (lead) and the reflection (lag) as well as in amplitude or spectral differences between these signals.

The most popular experiment is to measure the perception of the source direction having one lead and one lag signal (the lead signal arrives first to the listener by a defined and variable time span) coming from two (or more) spatially distributed sources, fig. 1. This is the simplest simulation of a direct sound followed by a strong reflection with equal amplitude. There are three main regions in the graph showing the perceived location of the sound vs. time delay between the stimuli. The stimuli signals used for the measurements are often simple rectangular positive pulses (clicks) because they have a rich spectral content, they are transient and easy to repeat. When there is no delay between the signals, the perceived location is heard as a phantom image between the lead and the lag source position at half distance (0°). Between 0 and 1 ms the phantom image shifts toward the leading signal (first region). The second region is the region of the leading dominance where the precedence effect becomes obvious. The time delay is usual between 1 and 5 ms and the perceived location equals to the leading signal. At about 5 ms, depending on the stimuli signals, two sound sources are perceived, one at the lead position, and the other shifting to the lag position as the time delay rises. At bigger delays, two signals are clearly heard as an echo.

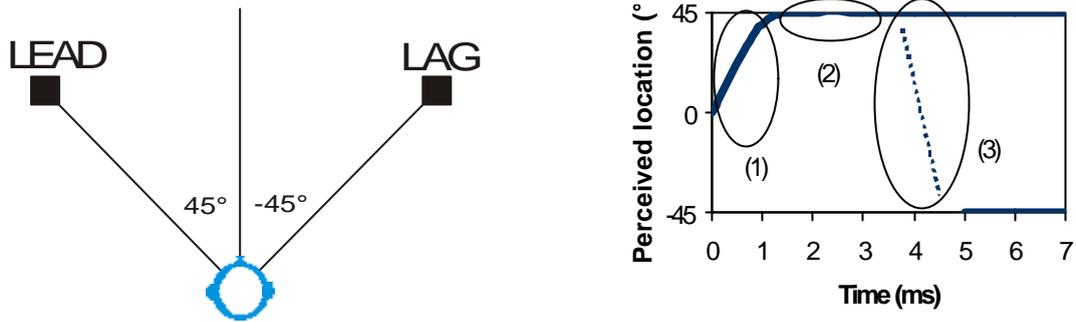


Fig. 1. Left – stimulus configuration, Right – perceived location with three characteristic regions.

The best place to make the measurement is an anechoic room to avoid possible unwanted reflections that could alter the controlled experimental environment.

MEASUREMENTS

Scope of the measurement

This paper deals with subjective and objective measurements of sound source fusion (summing localization) and dominance of the leading signal. The classic experiment uses one lead and one lag source which are spatially staggered (typical $+45^\circ$ and -45° from the zero azimuth line in the horizontal plane, fig.1). The fused image perceived by the listener can be considered as the phantom image.

Our experiment did not include real, but phantom lead and lag signal sources. Each phantom source was created from a pair of real sources (speakers) reproducing the signals at the same time and at equal distance from the listener. The leading speakers were positioned at -45° and -90° and the lagging speakers at 45° and 90° , fig. 2.

The intention was to create a hyper virtual (phantom) image that would behave in the same manner as when created by two real sound sources. In other words, the precedence effect was simulated using phantom sources rather than real ones. 7 subjects participated in the subjective tests. Afterwards, a dummy head was used to measure cross-correlation in the same listening place.

Measurement setup

The measurements were made in a room with dimensions $10.20\text{ m} \times 7.05\text{ m} \times 3.20\text{ m}$. It was acoustically designed as a music listening room, for subjective tests of loudspeakers, psychoacoustic research and for smaller recordings, fig. 2. There are absorption materials on the walls and floor in order to reduce the reverberation time to approximately 0.5 s at medium frequencies.

For the measurements of precedence effect, an anechoic room is the best choice as the reflections from the surrounding walls, floor and ceiling could influence the measurement results. In our case, the time span of the measurement (5 ms) was shorter than the time at which the first reflections after the direct sound would arrive to the listening spot. The loudspeakers were also shielded with acoustic absorptive material to reduce the sound energy that would spread toward the walls.

The loudspeakers were near-field active monitors of the same characteristics. They were driven using a multichannel PC sound system that had zero latency between the four measuring channels. The stimuli signals used in the measurement were positive rectangular pulses digitally generated. Three pulse durations were used: 50 μs , 100 μs and 200 μs . Using these pulse widths, differences in spectral content and transmitted sound energy were achieved. Time

difference of the lead and lag signal was set to following: 0 μ s, 100 μ s, 200 μ s, 300 μ s, 400 μ s, 500 μ s, 600 μ s, 700 μ s, 800 μ s, 900 μ s, 1 ms, 2 ms, 3 ms, 4 ms, 5 ms respectively, all together 15 signals in three measurement series.

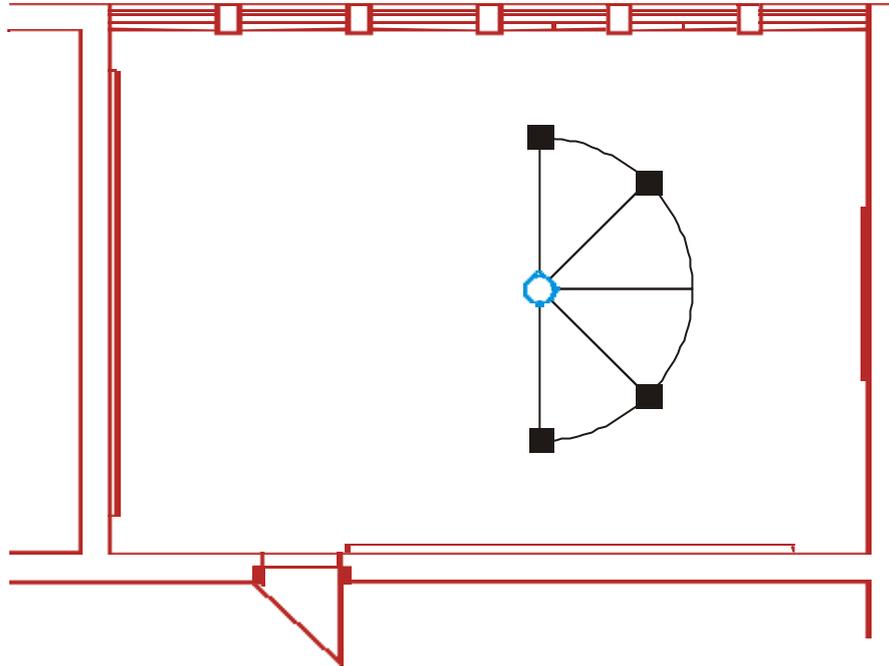


Fig. 2. Plan view of the listening room with loudspeaker arrangement and listening spot.

Localization measurements

Localization of the virtual image was determined using 7 subjects with normal hearing, all skilled listeners from 25 to 55 years. They were sitting in the central listening spot (fig. 2) and were told not to move their head during the experiment. There was a mechanical pointing device in front of them, which was used to point and note the perceived direction. The results of the experiment are shown in fig 3. (50 μ s pulse width), fig 4. (100 μ s pulse width), fig. 5 (200 μ s pulse width) and fig. 6 (average results for all subjects).

The results show a very good agreement with the data found in literature for real lead and lag source measurements. However, it is interesting to examine the average slope of the measured results – as the width of the stimuli pulses becomes smaller, the perceived direction of the sound moves toward the leading source slightly quicker.

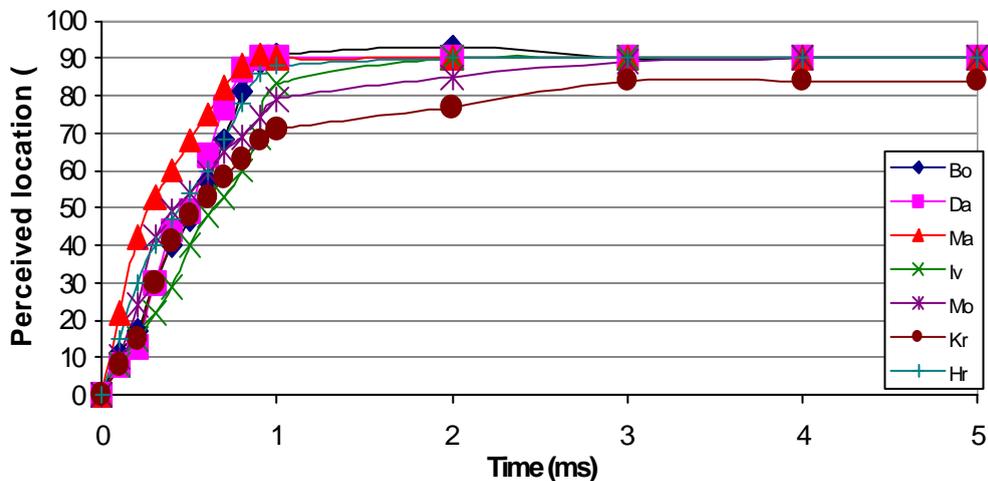


Fig. 3. Perceived location of the sound stimuli for 50 μ s lead and lag signals.

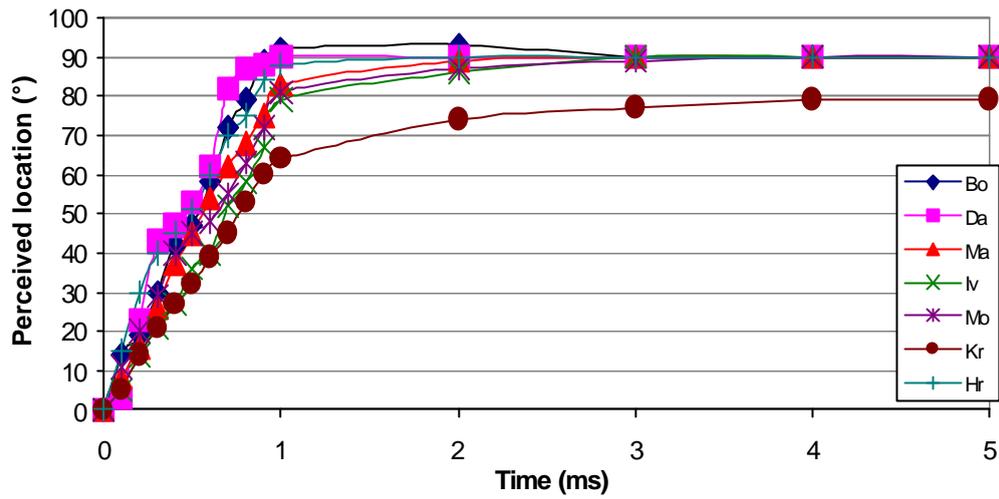


Fig. 4. Perceived location of the sound stimuli for 100 μ s lead and lag signals.

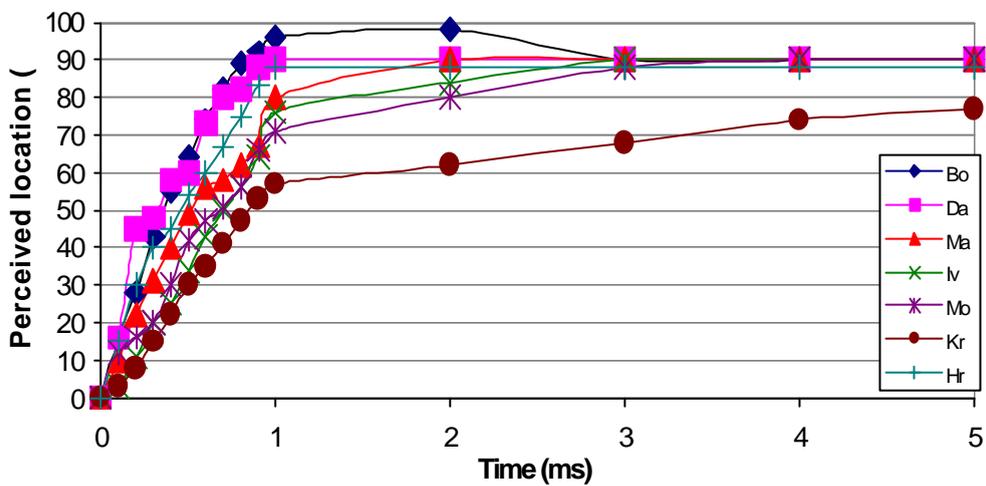


Fig. 5. Perceived location of the sound stimuli for 200 μ s lead and lag signals.

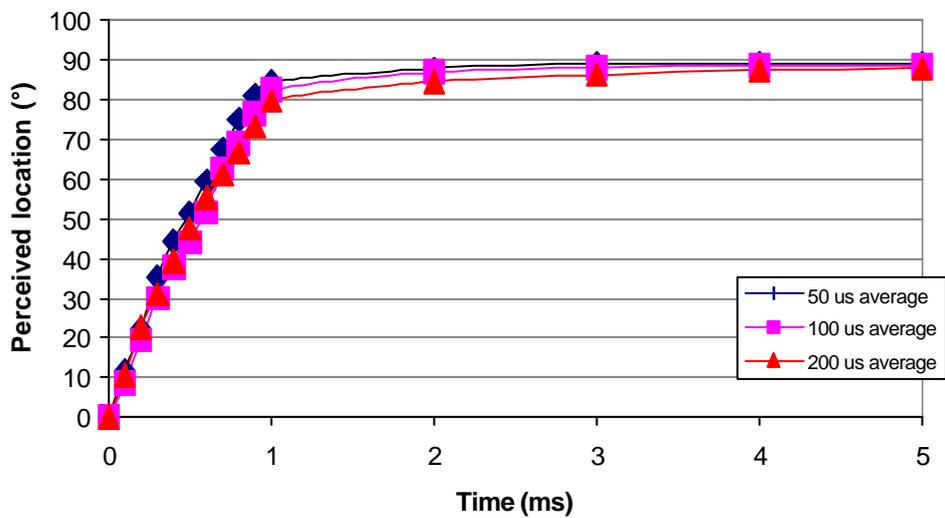


Fig. 6. Average perceived location for all subjects.

Artificial head measurements

Cross-correlation analysis was done using the B&K dummy head type 4128. First, the stimuli signal was recorded binaural, as shown in fig. 7. There are no strong reflections inside the 5 ms time span.

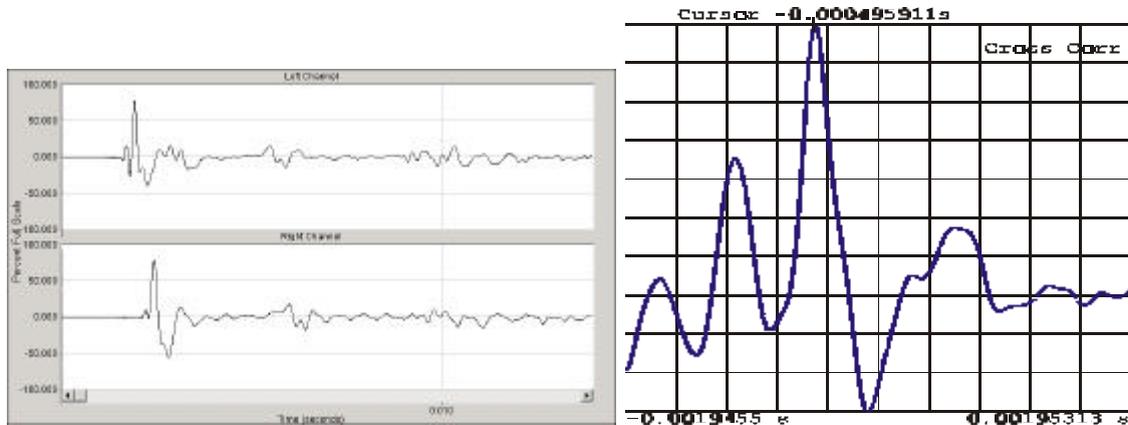


Fig. 7. Left – left and right ear signal of the precedence measurement stimuli, 500 μ s time difference; Right – cross correlation of the two signals

Cross-correlation function was measured between the left and right ear signals. Maximum peak of this function showed the time delay between the lead and lag signals, fig. 7. This was true for all stimuli signals with no exception – every maximum peak of the cross-correlation function equaled to the time difference between the lead and lag stimuli.

CONCLUSION

This paper tried to produce the summing localization and precedence effect using virtual, phantom sources rather than using real sources. It is obvious that these psychoacoustic phenomena occur equally when using real or phantom sources. The results obtained by subjective tests showed good agreement with the results of other authors. There was almost no difference in using stimuli of different pulse width except a slight difference in the perceived direction (moving quicker toward the lead when using shorter pulses). Cross-correlation measurements of the hyper virtual sound source test system using a dummy head showed exactly the time difference of the lead and lag stimuli.

REFERENCES

- [1] Litovsky, R.Y., Colburn, H.S., Yost, W.a., Guzman, S.J., The precedence effect, J. Acoust. Soc. Am., vol. 106, no. 4, 1999, 1633-1654
- [2] Blauert, J., Spatial Hearing: The Psychophysics of Human Sound Localization, MIT Press, Cambridge, 1997.
- [3] Moore, B.C.J, An Introduction to Psychology of Hearing, Academic Press, San Diego, 1997.