Reduced Localizability in Sequences of Narrowband Noise Bursts

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Introduction

The precedence effect describes perceived localization dominance of a sound event over a sound event arriving 2 ms to 50 ms later. It is known to have dynamic aspects in the sense that it needs some time to build up and that this build-up is direction-specific [3], which has also been interpreted as a breakdown [2]. Even though there are several models that may explain certain aspects of the precedence effect [5, 1], no comprehensive model exists to explain all of its aspects.

Under the point of view that the precedence effect may just be an aspect of some more global functionalities of binaural hearing, we were looking for related phenomena where some sound event is less localized due to the presence of other sound events.

In this article we present the results of an experiment using stimuli that are very similar to those of classical precedence effect experiments, but with a lead/lag delay of 100 ms, which is normally outside the scope of the precedence effect. It is shown that small modifications of the stimulus leads to reduced localizability, despite the fact that the localizability is nearly perfect for a corresponding classical precedence effect setting.

Experiment

Seven unpaid listeners (one female, six males) participated in this experiment.

Stimuli

The stimuli consisted of repeated sequences of four narrowband noise bursts and two pauses. They were presented using loudspeakers in three different frontal positions, L, C and R, as illustrated in Figure 1. At any time instant, only one noise burst was played from one of the loudspeakers was (i.e. no temporal overlap). The noise bursts were frozen and had a duration of 100 ms (including 30 ms attack and release ramps), a center frequency of 500 Hz and a bandwidth of 100 Hz (roughly one critical band on the Bark scale).

To characterize a stimulus, we specify the basic sequence using the following notation: a noise burst is written as the letter corresponding to the loudspeaker from which it was played (L, C, R). A pause is written as a dash (–) and the length of the pause is specified in milliseconds. "LC–RC–/50 ms" therefore means that a 100 ms noise burst is played from the left loudspeaker and immediately after the same noise burst is played from the center loudspeaker, followed by a 50 ms pause. Then a noise burst is played from the right, followed by a noise burst from the center and a 50 ms pause.

Each basic sequence was repeated several times such that the overall stimulus lasted at least 9 s. It is assumed that this is long enough for the auditory system to adapt to the stimulus, such that transient behavior can be neglected.

The main stimuli tested were based on LC–RC– with pause lengths of 0 ms (i.e. LCRC), 50 ms, 100 ms, 200 ms, 500 ms and 1000 ms. As a reference, LC–LC–/100 ms and LL–RR–/100 ms were tested as well. LC–LC–/100 ms is particularly interesting since it corresponds to a precedence effect experiment with a lead/lag delay of 100 ms. It was expected (and verified) that for such a long delay the precedence effect is not active.

During the experiment each 9 s stimulus was played 12 times, making a total of 96 stimuli presentations. Out of the 12 repetitions of each stimulus, 6 randomly chosen ones had the L and R channels switched. After each stimulus presentation, the subject had to decide whether he or she heard noise bursts coming from the proximity of the center loudspeaker or not.

Setup

The experiment was conducted in a room specifically designed for psychoacoustic experiments which is slightly reverberant in order to avoid the unnatural feeling of an anechoic chamber. To reduce unwanted reflections, additional absorbing panels were placed around the loudspeakers and behind the listener (see Figure 1).

The loudness of the noise bursts was 75 dB(A), measured at the position of the listener.

Results

For the main set of stimuli, where LC–RC– sequences with different pause lengths were played, most subjects heard the noise bursts from the center loudspeaker least often for a pause length of 100 ms. Both for LCRC (no pause) and LC–RC–/1000 ms, the noise bursts from the center are heard significantly more often than for a pause length of 100 ms. The results averaged over all subjects are shown in Figure 2.

For the reference sequences, the results are very clear: with the LC–LC–/100 ms stimulus, the noise bursts from the center were almost always heard, whereas for the LL–RR– stimulus only once a subject heard a noise burst from the center (which may simply be an error due to negligence).

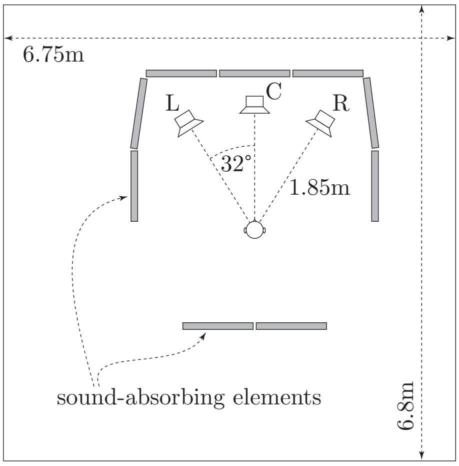

Figure 1: Setup for the psychoacoustic experiment (drawn to scale). The wall on the top of the drawing contained windows. In order to avoid reflections from the windows sound-absorbing elements, placed behind the loudspeakers, were used. The reverberation time RT60 of the room is 0.5 s.

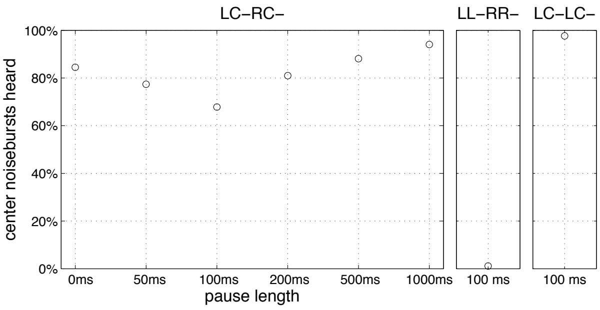

Figure 2: Results averaged over all subjects. *Left*: percentage of LC–RC– stimuli where noise bursts from the center loudspeaker were heard, as a function of the length of the pauses. *Right*: Results for the LL–RR– and LC–LC– reference cases.

The results given in Table 1 indicate that with a very high probability (>0.95) the LC–RC–/100 ms stimulus is less often localized than the LC–RC–/1000 ms stimulus or the LC–LC–/100 ms stimulus. Still likely with a probability of 0.81, there is a difference in localizability between the LC–RC–/100 ms and LCRC stimuli.

Discussion

One interesting result of this experiment is that alternating the position of the lead sound event decreases the localizability of the lag sound event (LC–RC– vs. LC–LC– case).

For the alternating sequence (LC–RC–), it is observed that there is an optimal delay between lead/lag pairs which leads to minimal localizability of the noise bursts emitted from the center loudspeaker. This may be interpreted as a superposition of two trends: for very short delays, the lead/lag pairs are so close to each other that the lead and lag sound events could actually be confused. Therefore lead nor lag should dominate the localization. However, for very long delays, build-up effects [3, 2] may play a role, in the sense that for long delays between a lead/lag pair and the next, each pair would be perceived as a single stimulus where no build-up has happened. On the other hand, localizability increases already for pauses of 200 ms, which seems short for a build-up effect to decrease.

Table 1: Numerical results averaged over all subjects. For the four chosen stimuli, the percentage of "noise bursts heard from center loudspeaker" responses is given and the probability that this percentage is statistically different from the percentage for the LC–RC–/100 ms stimulus. This probability was determined using a pairwise t-test.

Sequence	Pause	Heard	T-Test
LCRC	0 ms	85 %	0.81
LC–RC–	100 ms	68 %	n/a
LC–RC–	1000 ms	94 %	0.95
LC–LC–	100 ms	98 %	0.98

The cue selection model [4] may explain why in the LC–RC–/100 ms case the noise bursts from the center are less localized than in the LCRC (no pause) case, because a pulse after a pause results in higher interaural coherence than a pause directly following a pulse from a different direction. On the other hand, it is not clear how to explain that LC–RC– results in less localized center bursts than LC–LC–.

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