Some New Experiments On The Precedence Effect

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In a standard arrangement with one lead and one lag loudspeaker in anechoic space, simulated by a virtual auditory environment, a measurement of the "echo threshold" (ET) took place for each one of a pair of auditory streams. A second measurement of the ET of each stream followed, but this time the two streams were presented to the listeners simultaneously. The obtained results indicate that it is possible that two simultaneous streams may have different ETs for the same loudspeaker set-up. Additionally the results reveal an "interaction" occurring between the streams since the ETs measured in the second case were different to the ETs measured in the first one. Further studies of the "interaction" were based on the measurements of JNDs for the delay of the lag loudspeaker (absolute threshold of perceptibility). The JNDs are affected in the case of high-frequency band-pass-filtered noise burst when a continuous low-frequency band-pass-filtered noise is added, but not the other way around.

1 Introduction

The "precedence effect" (PE) (Wallach et al., 1949) describes a group of auditory phenomena that are thought to account for listeners' abilities to function in reverberant auditory scenes. One of the widely used methods for the "measurement" of the PE is through the "echo threshold" (ET) for one lead and one lag loudspeaker (Figure 1).

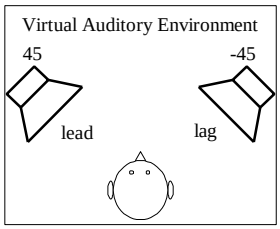

Figure 1: Experimental Paradigm

Apart from the delay of the reflection, the ET depends strongly on the type of signal, the level, the duration and the direction of the sound incidence (Blauert, 1996). Nevertheless many of the studies do not directly address "real-world" issues concerning the type of stimuli used and also concerning the acoustic environments (Litovsky et al., 1999). For the better understanding of the ET's dependence on the type of the signal, a series of pilot experiments was initiated using "real-world" stimuli. In one of these experiments, a 12sec portion of instrumental music was spatialized as depicted in figure 1. The portion of music contained three instruments: (a) piano (b) strings and (c) drums. For this experimental set-up and for a range of delays of the lag loudspeaker, the listeners perceived the three instruments as three auditory streams at different positions in space and not in one common position. The results of the two series of experiments that follow confirm these observations. They additionally reveal an "interaction" occurring between the streams, affecting their ET.

2 Experimental set-up

All the experiments reported here, were carried out using virtual sound sources. The experimental virtual auditory environments were created with PC-based software developed by the authors. The signals were presented with headphones (STAX LAMBDA PRO), using catalogues of individual head-related transfer functions (HRTFs). The listeners were placed in an anechoic chamber.

3 Experiments I: ET measurement for two simultaneous auditory streams

In the experiments reported here, two different types of pairs of auditory streams were used: music and noise. The ET of each stream was measured twice; once when the stream was presented separately and once when the stream was presented simultaneously, in a mixture, with the second stream.

3.1 Method

A 2AFC paradigm was used. The direct sound and its reflection were spatialized as depicted in figure 1. A two-down, one-up adaptive tracking rule was used to estimate the 71% correct point on the psychometric function (Levitt, 1971) measuring the ET. After each presentation the listeners should respond, with a "yes" or "no" answer, to the question: "do you perceive an echo?". For the purposes of this work, the term "echo" was defined as following: "a clearly audible second auditory event, which is distinct in time and space, and perceived as a repetition of the first auditory event, not necessarily as a complete one".

3.2 Listeners

Four normal hearing experienced listeners took part in these experiments. Their ages ranged from 24 to 27 years.

3.3 Stimuli

3.3.1 Music

A fast-varying and a slowly-varying in time melodies were created on a PC with the help of the soundcard's software synthesizer (Figure 2). The two melodies were composed in the same octave and the instrument that was chosen to play them was a trumpet.

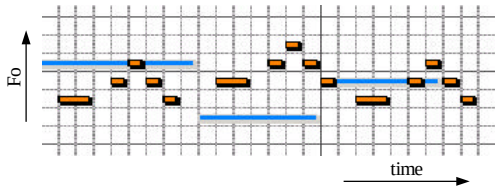

Figure 2: music stimuli - fast and slow melodies

3.3.2 Noise

The noise stimuli were a low-frequency band-pass-filtered noise (LF) 200 to 770 Hz and a high-frequency band-pass-filtered noise 1.7 to 3.7 kHz. Their onset and offset time were 10ms and their duration was 500ms or 1000 ms. The ETs were measured for the 500ms versions of LF for the cases depicted in figure 3.a & 3.c and of HF for the cases depicted in figure 3.b & 3.d.

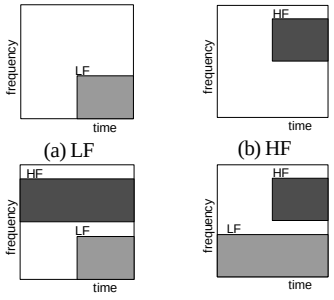

Figure 3: noise stimuli - (a) LF, (b) HF, (c) LFM: LF in Mixture, (d) HFM: HF in Mixture

3.4 Results

3.4.1 Results for Music

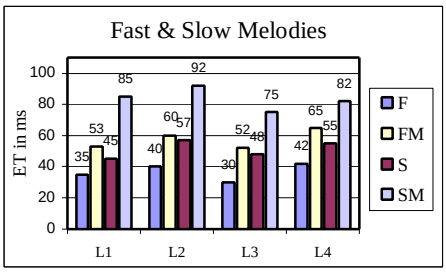

Figure 4: ETs of the music streams for 4 listeners (F: Fast, FM: Fast in Mixture, S: Slow, SM: Slow in Mixture)

Observation of the second and the fourth bar, for each listener, of the graph in figure 4 shows that the fast and the slow streams, when presented in the mixture, have different ETs. Additionally, observation of the first and second bar and also of the third and the fourth imply that the ET of each stream is different when presented in the mixture compared to the one when presented separately.

3.4.2 Results for Noise

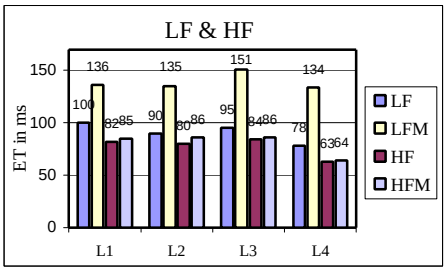

Figure 5: ETs of the noise streams for 4 listeners

The results presented in figure 5 imply that there is a difference of the ET of the LF when presented in the mixture to its ET when presented separately. For the HF on the other hand no particular change of the ET in the both cases is observed.

4 Experiments II: JNDs measurement for two simultaneous auditory streams

During the design phase of the ET experiments reported earlier for noise stimuli, it was observed that for relatively small delays, below 20ms, the perceived location and extension for each one of the two noises was different when presented simultaneously, and for the HF different to the ones when presented separately. This observation was in contradiction to the results of the previous experiment, where the presence of LF did practically not affect the ET of the HF. The goal of these experiments was to confirm qualitatively the above observation. For that reason an indirect way was used; the measurement of the JNDs for the delay of the lag loudspeaker. The rationale of this measurement was that for increasing delays the main changes of the perceived sound are in its location and its extension.

4.1 Method

A 2I-2AFC paradigm was used. In the first interval the delay of the lag loudspeaker was d1. The initial value of d1 was set to 1ms. In the second interval the delay of the lag loudspeaker was d2, greater or equal to delay d1. The interstimulus interval was 1 sec. A one-down, one-up adaptive tracking rule was used to estimate the 50% correct point on the psychometric function (Levitt, 1971). When a JND was found, the d1 was set to d2 and the experiment was continued until the next JND was found. The experiment was finished when d2 was higher than 15ms.

4.2 Stimuli

The stimuli for this experiment were the ones described in 3.3.2 and depicted in figure 3. The JNDs of LF, LFM, HF and HFM were measured.

4.3 Listeners

Four normal hearing experienced listeners took part in these experiments. Their ages ranged from 24 to 27 years.

4.4 Results

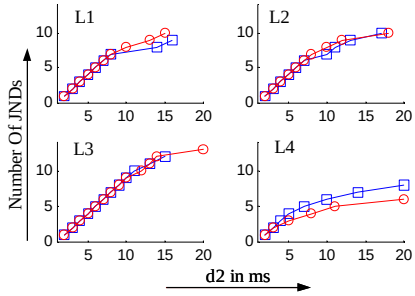

Figure 6: JNDs for LF (squares) & LFM (circles)

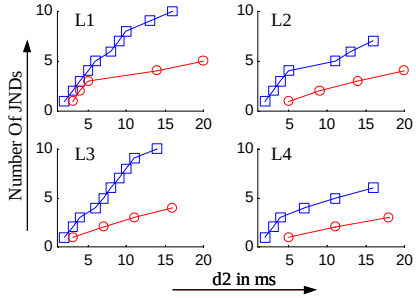

Figure 7: JNDs for HF (squares) & HFM (circles)

The obtained results indicate that for the LF there is no change in the JNDs whether it is presented separately or in the mixture. This does not apply to the HF where it is obvious that the presence of LF affects significantly the JNDs.

5 Discussion for all of the experiments, Synopsis and Conclusions

We have shown with various types of stimuli, that the PE can be stream dependant. Additionally we have located an "interaction" occurring between two auditory streams since the simultaneous existence of one stream can affect the perception of the other. Further investigations are a necessity in order to understand the underlying mechanisms of this type of "interaction".

Acknowledgements

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