Simulating the Franssen Illusion

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The Franssen illusion is created with sine tones, presented by loudspeakers in a reverberant room. In this illusion, a listener localizes a tone at the position of its onset, even though the onset may have faded away and a continuous steady-state tone is arriving from a different location. The illusion has been attributed to a reweighting of localization cues, caused by the plausibility of direct onset cues in contrast to steady-state cues that are made implausible by standing waves in the room. This explanation was tested by comparing the Franssen illusion in a room to a headphone simulation with reduced complexity. In both configurations, slow-onset tones were used to determine the uncertainty associated with standing waves (room) and conflicting interaural time and intensity cues (headphones). The effect of adding the abrupt onset was compared for conditions of comparable uncertainty for the room and headphone configurations. The comparison showed that headphone listening can lead to a clear analog to the Franssen illusion, but with somewhat reduced strength. The difference might be attributed to the temporal fluctuations that occur in the room but are absent in the headphone simulation.

INTRODUCTION

The Franssen illusion is one of the most dramatic effects in psychoacoustics [1, 2]. It is created with two loudspeakers in a standard stereophonic configuration in a room that must not be too dry. The signal is a sine tone.

To create the illusion, the tone is turned on with an abrupt onset at one of the two speakers (leading). Immediately, the tone begins to fade away while a tone in the other speaker (lagging) grows in such a way as to keep the total power approximately constant. The duration of the transition is not important; transitions from 30 to 2000 ms can work. After the transition, the leading speaker is off and the lagging speaker is on. The illusion is that the listener continues to localize the tone at the position of the leading speaker, even though it is completely silent.

The illusion fails if the room is too dry. It also fails if the stimulus is noise instead of a tone. An explanation for the illusion that is consistent with the facts [3] is that signals are localized on the basis of weighted binaural cues. The weighting is a central operation so that cues can be evaluated for self-consistency. In the case of a sine tone in a room, the standing waves lead to steady-state differences in interaural level (ILD) and interaural time (ITD) that are invariably inconsistent. By contrast, a transient event, such as an abrupt onset, can be evaluated by the binaural system from its direct transmission path without interference from room reflections. The result, with respect to the Franssen illusion, is that the steady-state tone from the lagging speaker is discounted in the weighting process because of its implausible binaural cues. The onset receives high weight because its ILD and ITD cues are mutually consistent, and they are also consistent with visual cues. If this explanation is correct then it ought to be possible to create an analog to the Franssen effect using headphones by putting an implausible steady-state (or lagging) sound in competition with an onset (or leading) transient having plausible binaural cues.

EXPERIMENTS

The goal of the experiments was to compare a headphone analogy to the Franssen effect with a real Franssen effect as it occurs in a room. Experiments were done with sine tones, with frequencies of 250, 500, and 4000 Hz. There were two types of trial: abrupt onset (instantaneous) and slow onset (1-s ramp). The abrupt-onset trials were intended to create the Franssen effect. The slow-onset trials served to establish a baseline lateralization/localization for the steady-state tone, the natural competition for the onset. Immediately after the onset, the transition to the steady-state occurred, a 30-ms linear sweep. Steady-state tones were 4 s in duration to give listeners a good opportunity to evaluate the position. Tones were turned off together with a noise burst from the forward direction to mask the offset. After the noise burst the listener was required to indicate the location of the steady-state tone, left or right. The above conditions apply to both the room experiment and the headphone experiment.

Room Experiment

The room experiment was done in a large room 8.5 by 7.3 by 4.6 meters high, with concrete walls and ceiling and a vinyl floor. In this room left (L) and right (R) loudspeaker positions and the listener's square formed an equilateral triangle 5 meters on a side. The listener changed locations within the 1-meter square after each trial to randomize the standing wave pattern. Leading-lagging tones were L-L, L-R, R-L, and R-R, equally in a balanced design. Trials of type L-R and R-L tested the Franssen effect.

Headphone Experiment

The headphone experiment was the simplest possible analog to the Franssen effect. The onset was lateralized by a finite ITD but zero ILD. The transition (30 ms) retained the ITD but introduced an ILD for the steady state, either agreeing (L-L or R-R) or disagreeing (L-R or R-L) with the onset.

RESULTS AND CONCLUSIONS

Because the headphone conditions were manufactured whereas the room conditions were uncontrolled, it is necessary to compare the two experiments on an equivalent basis. Headphone and room conditions were called equivalent for comparable responses to slow-onset tones.

Ambiguity-conditional analysis

Many headphone conditions failed to produce ambiguous lateralization - listeners responded consistently. In the ambiguity conditional analysis, data from abrupt-onset trials of the form L-R or R-L were accepted only if the corresponding conditions for slow-onset trials produced between 20 and 80 percent correct responses. The percentage of responses following the steady-state ILD for headphones or the percentage of correct responses in the room is shown in Fig. 1. The smaller the percentage, the larger the Franssen effect. The comparison in Fig. 1 indicates similar effects in the room and with headphones. Both tend to disappear at higher frequency.

Unambiguity-conditional analysis

The unambiguity-conditional analysis in Fig. 2 is for headphones only. It shows that as the steady-state ILD cue becomes more effective (70 to 100 percent following ILD for slow onsets) the abrupt onset results vary from 20 to 65%. This variation, only 45%, is rather small compared to the strength of the Franssen effect. We expected that for 100% correct given slow onsets listeners would score much better than 65% given abrupt. In the end, the two analyses suggest that an analog to the Franssen effect can be produced with headphones but that it is weak compared to the Franssen effect in a room.

REFERENCES

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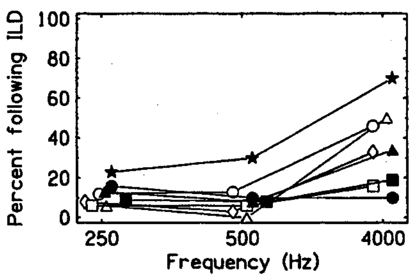

FIGURE 1. Ambiguity-conditional analysis, percent vs sine tone frequency. Filled symbols are for headphones open symbols are for the room. Triangles for listener S; squares for T; circles for W; star for N, and diamond for X.

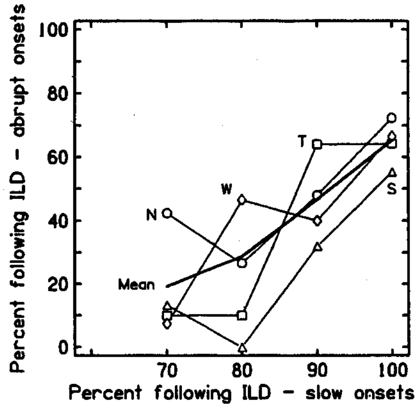

FIGURE 2. Unambiguity-conditional analysis. For four listeners in the headphone experiment the plot shows the percentage of lateralization judgements that followed the ILD for abrupt onsets given that the percentage for slow onsets (with the same ILD and ITD) was 70-100 percent, as given on the horizontal axis. The heavy curve called MEAN is the average of all data points.