Published in final edited form as:

Ear Hear. 2008 December ; 29(6): 973–979. doi:10.1097/AUD.0b013e31818bc150.

Gap detection and ear of presentation: examination of disparate findings: re: Sininger Y.S., & de Bode, S. (2008). Asymmetry of temporal processing in listeners with normal hearing and unilaterally deaf subjects. *Ear Hear* 29, 228-238

John H. Grose, Ph.D.

Dept. Otolaryngology – Head & Neck Surgery, University of North Carolina at Chapel Hill

Abstract

Objectives—The purpose of this Letter is to address incongruent findings reported in two current papers concerning an ear advantage for gap detection. The methodology of one of the studies was closely replicated in order to determine whether those data were confounded by a floor effect. A novel methodology not prone to a floor effect was also implemented to test for an ear advantage.

Design—In the replication of one of the studies, gap detection was measured for three stimuli: a 400-Hz tone, a 4000-Hz tone, and a broad band noise. Temporal gaps were positioned at the midpoints of 500-ms waveforms and imposed with linear 5-ms ramps. An adaptive procedure incorporating an arithmetic step size was used to estimate threshold. In the novel methodology, gap detection in 500-ms segments of broad band noise was measured using an adaptive procedure with interleaved tracks and a geometric step size. Gap boundaries were not shaped. The observers were 7 right-handed, normal-hearing adults.

Results—The replication of the published study suggested that the procedure was likely to be confounded by a floor effect. No evidence of an ear advantage was observed in this replication. The novel methodology yielded threshold estimates for broad band noise that were not contaminated with a floor effect and, again, no evidence of an ear advantage was observed.

Conclusions—No evidence was found for an ear advantage for gap detection. The demonstration that the procedure used by one published study was likely prone to a floor effect does not account for the finding of an ear advantage in that study. The issue remains unresolved.

Keywords

gap detection; ear advantage

I. Introduction

Two studies published in early 2008 addressed the same question, yet came to diametrically opposed conclusions (Baker et al., 2008; Sininger and de Bode, 2008). Both studies examined whether an ear advantage exists for gap detection. Because an ear advantage is presumed to reflect a contralateral cortical hemisphere advantage, implicit in this question is the issue of whether there exists a hemispheric specialization for temporal processing. Specifically, if the ubiquitous left hemisphere advantage for speech and language is a manifestation of a more

basic left hemisphere advantage for temporal processing, a right ear advantage for temporal processing might be expected.

Sininger and de Bode (2008), on the one hand, found a significant right ear advantage for gap detection using broadband noise markers. On the other hand, Baker et al. (2008) found no evidence of an ear advantage for detecting gaps in broadband noise. Given that the gap detection task is relatively straightforward, what accounts for these disparate findings? As a first step, it is important to compare in some detail the methodologies of the two studies for the conditions where they overlapped the most.

The Baker et al. study consisted of a series of 3 experiments, all of which measured gap detection in broadband noise (50 – 10,000 Hz) presented at an overall level of 75 dB SPL. Noise segments were either 300 ms or 500 ms in duration and gaps were placed at the midpoint of the segments. The transitions into and out of the gaps consisted of 0.5-ms raised-cosine ramps, and gap duration was defined as the interval between the half-amplitude points on the ramps. The minimum possible gap was therefore 0.5 ms. The experiments used either a 2- or 3-interval forced choice adaptive procedure, or a single interval Yes/No procedure. In the adaptive procedures, gap duration was varied by a factor (final value of 1.1), and the 2-down, 1-up stepping rule converged on the 71% correct point. The starting gap duration was always 10 ms. The Yes/No procedure yielded a complete psychometric function for gap detection. Observers were right-handed, normal-hearing adults, and 25 – 33 observers participated per experiment. It appears that some modest practice was included, at least to familiarize the observers with the task. For each observer, four estimates of threshold were obtained for each condition, and all four were averaged to yield the final threshold value.

The Sininger and de Bode study included measurements of gap detection in broadband noise (20 – 14,000 Hz) presented at an overall level of 50 dB SPL. The gaps were placed at the midpoint of noise segments that were 500 ms in duration. The transitions into and out of the gaps consisted of 5-ms linear ramps, and gap duration was defined as the interval between the 0-voltage points at the termination and start of these gap ramps. The minimum possible gap was therefore 0 ms. The experiment used a 3-interval forced choice adaptive procedure, and the 2-down, 1-up stepping rule converged on the 71% correct point. The gap duration was varied arithmetically, with an initial step size of 10 ms reduced to 1 ms after two reversals. The starting gap duration was always 100 ms. Observers were 30 right-handed, normal-hearing adults. There is no indication whether practice runs were administered, and it appears that only one threshold estimate was collected per condition from each observer.

Although the two studies differed in other respects – most notably the inclusion of tonal gap markers and unilaterally deaf observers in the Sininger and de Bode study – there was considerable commonality in the measurement of gap detection in broadband noise for normal-hearing adults. However, there were at least three key methodological differences in this area of overlap: (1) the characteristics of the ramps bounding the gap; (2) the parameters of the adaptive procedure to measure gap detection threshold; and (3) the inclusion, or not, of practice and replication.

The gap detection results for the broadband noise differed across the two studies. Baker et al. measured monaural gap thresholds of between 2.4 and 3.6 ms across the three experiments; there was no difference between ears. Sininger and de Bode measured gap thresholds of 1.5 ms for the right ear and 3.7 ms for the left ear – a difference that was highly significant. The average thresholds found by Baker et al. are therefore between the right and left ear thresholds of Sininger and de Bode. Does this mean that the difference between the two studies is just due to sampling variability? The answer is clearly not since, had Sininger and de Bode defined gap

duration as the interval between the half-amplitudes of the ramps – as Baker et al. did—their thresholds would have been 6.5 ms and 8.7 ms for the right and left ears respectively.

One troubling aspect of the Sininger and de Bode study is that over half of their subjects must have hit the 0-ms floor of the adaptive gap procedure at least once for right ear presentation (see their Fig. 2). With a final step size of 1 ms, any threshold less than 1.5 ms must have included a reversal at floor (0 ms). Recall that a 0-ms gap consists of a 5-ms linear down ramp followed immediately by a 5-ms linear up ramp; the standard stimulus contained no gap at all. A 0-ms gap so defined should be quite salient to a normal-hearing adult and the surprising aspect, perhaps, is that all observers did not track the gap to the floor level for both left and right ears.

II. Replication of Sininger and de Bode

To examine the possible role of a floor effect in the Sininger and de Bode study, their method was implemented almost exactly as described for their three stimuli: (1) a 400-Hz tone; (2) a 4000-Hz tone; and (3) broadband noise (here, 0 – 12,000 Hz shaped only by the Sennheiser HD580 phones). The two exceptions to the replicated method were: (1) a 3-down, 1-up stepping rule (estimating 79% correct) was used here rather than the 2-down, 1-up stepping rule (estimating 71% correct) used in their study; (2) a stopping criterion of 12 consecutive trials at floor (0 ms) was implemented here. The method was implemented using a digital signal processing platform (Tucker-Davis Technologies [TDT], Alachua, FL) operating at a 25-kHz sampling rate, interfaced in software with Matlab (Mathworks, Natick, MA) control code. Seven normal-hearing adults were tested (thresholds ≤ 20 dB HL from 250–8000 Hz; age range 20 – 53 yrs, mean 36 yrs). All were right-handed, as gauged by a standard handedness questionnaire. Although some observers had participated in other psychophysical tests, none were given practice on this test. The order of ear of presentation and stimulus type was randomized across listeners.

The pattern of results was dissimilar to that of Sininger and de Bode. Of the 42 threshold estimates (3 stimuli $\times$ 2 ears $\times$ 7 observers), there were only 2 instances where the stopping criterion of 12 successive trials at floor was not met –i.e., where a non-zero threshold estimate was obtained. Both of these instances occurred for the 400-Hz stimulus – in the left ear for one observer and in the right ear for the other observer. In both cases, immediate replication of the condition resulted in a track that met the stopping criterion of 12 successive trials at floor. It is likely that the two instances of non-zero thresholds were due to listener fatigue or inattention because of the rather long threshold tracks. Fig. 1 (Panel A) plots the track for one of the non-zero threshold estimates. It shows that the ‘floor criterion’ was almost met (9 consecutive trials at floor rather than 12), and that the overall duration of the track was about 8 minutes. To illustrate the effect on track duration of a spurious error early in the track compounded by a 1-ms step size, Fig. 1 (Panel B) shows the very first track of a completely novice observer participating in the study. This observer made a spurious error after 22 trials, at a gap duration of 30 ms, resulting in a reduction in step size from 10 ms to 1 ms. The observer then took 126 trials to converge on the floor, requiring a period of prolonged attention. In general, these results suggest that a ‘0-ms gap,’ as defined by Sininger and de Bode, should be salient even to an unpracticed listener who is attending to the task. Without the benefit of practice or condition replication, their study did not allow for any spuriously elevated threshold estimate to be offset prior to inclusion in the data set. Two caveats should be noted: (1) the 3-down, 1-up stepping rule used here results in longer tracks than the 2-down, 1-up stepping rule used by Sininger and de Bode; (2) the speculation that some threshold estimates may be spuriously elevated due to inattention, fatigue, etc., does not account for the ear asymmetry found in their study since they randomized ear of presentation.

III. Additional test of ear asymmetry for gap detection

To contribute additional data to the question of whether there is an ear effect for gap detection in broadband noise, thresholds were also measured on the same 7 observers using an interleaved tracking procedure. In this method stimulus parameters were employed that made a floor effect extremely unlikely. The stimulus was again a 500-ms segment of noise presented at an overall level of 50 dB SPL. The noise was digitally generated on a trial-by-trial basis at a sampling rate of 25 kHz, and the gap was imposed at the midpoint of the segment by setting the waveform points associated with the gap duration to zero voltage. The gap boundaries were therefore abrupt and unshaped, and gap duration was simply the duration of the 0-voltage points. A 3-alternative forced choice procedure incorporating a 3-down, 1-up stepping rule was used to converge upon the 79% correct point. The target interval, at random, contained the gapped noise segment and the other two observation intervals contained noise segments without gaps. Each threshold estimation run consisted of two interleaved tracks. Three conditions were implemented where the stimuli were presented to one ear at a time: (1) monaural left; (2) monaural right; (3) monaural left/right. In the first two monaural conditions, the interleaved tracks yielded two estimates of threshold for that ear for each run. In the left/right condition, one interleaved track was for monaural left presentation, and the other was for monaural right presentation. A single run therefore yielded one threshold estimate for the left ear and one estimate for the right ear. Because the tracks were randomly interleaved, the ear of presentation for any trial was unpredictable; however, once a trial began in a certain ear it was predictable that the remaining observation intervals of that trial would continue in that ear. A second set of three conditions was therefore also run where an independent noise was presented synchronously to the non-test ear. Thus, uncorrelated 500-ms noise bursts were presented concurrently to both ears in all intervals, but in the target interval the gapped stimulus was presented to only the test ear. This meant that for the left/right condition, where the test ear was randomly selected based on which track was in the foreground for that trial, the observer did not know which ear would contain the gapped target stimulus on any given trial. Four threshold estimates were collected for each observer/condition and averaged.

The group mean results are shown in Fig. 2. Gap thresholds were slightly poorer in the presence of contralateral noise ($F_{1,6} = 28.08$; $p = 0.002$) but did not differ between ears for any of the conditions ($F_{1,6} = 1.06$; $p = 0.343$). These results therefore do not support an ear effect for gap detection in broadband noise.

IV. Summary

The results of Baker et al. (2008) and Sininger and de Bode (2008) remain incongruent. A replication of the Sininger and de Bode method suggests that their procedure appears to be associated with a floor effect – an effect that is evident in some of their data. However, the present results, using tonal and broadband noise gap markers, showed no ear asymmetry for this effect, as performance was at floor for both left-ear and right-ear gap presentation. A different method for measuring gap detection for similar noise stimuli, which is free of a floor effect, also yielded results that gave no indication of a right-ear advantage for gap detection in broad band noise.

Acknowledgments

Work supported by NIDCD R01-DC01507

VI. References

Baker RJ, Jayewardene D, Sayle C, et al. Failure to find asymmetry in auditory gap detection. *Laterality* 2008;13:1–21. [PubMed: 17852705]

Sininger Y, de Bode S. Asymmetry of Temporal Processing in Listeners With Normal Hearing and Unilaterally Deaf Subjects. *Ear & Hearing* 2008;29:228–238. [PubMed: 18595187]

Fig. 1.

Panel A: Track for a non-zero threshold estimate plotting gap duration against trial number. Notice that the 9 consecutive trials at floor failed to meet the criterion for terminating a run. The overall duration of the track was about 8 minutes. Panel B: Track for a novice listener showing the effect on track duration of the occurrence of a spurious error early in the track.

Fig. 2.

Gap detection as a function of condition. The gapped stimuli were presented monaurally either to the left ear only (Mon L), right ear only (Mon R), or randomly alternating between left only (Dic L) and right only (Dic R). The non-test ear either received no stimulation (– Contralateral noise) or received uncorrelated noise (+ Contralateral noise). Error bars are ± 1 standard deviation.