The results of Experiment 1 have another interesting implication for the filled-time illusion: it seems to reach a temporal limit for intervals that are longer than 2.4 s. In this case, instead of leading to overestimations, segmenting intervals helps to stay closer to the target. Without segmentation, there seems to be a tendency to overestimate when reproducing longer target durations. The segmentation strategy, in this case, seems to be beneficial in that it appears to prevent this tendency. Actually, the benefits from segmentation are not only apparent with regard to mean target production, but also in terms of variability. In both experiments, there was a step in the function linking variability and time when targets increased from 1.2 to 1.4 s. In addition, while there was no variability difference between the segmented and nonsegmented conditions for durations inferior to 1.2 s, a significant difference occurred at 1.4 s.

With regard to these observations, one might suggest that the extra mental time required to process each subinterval might depend on their length rather than on their number. Indeed, it would seem to take extra time to process very short subintervals, while it would be cost-free to process longer durations. This explanation could conciliate the fact that there is some overestimation when multiple dividers are inserted, but no additional overestimation with only one divider. The shorter productions (CE closer to 0) in the segmented condition for long intervals are interpreted as a result of the beneficial effects of segmenting time. In terms of variability, there seems to be a beneficial impact if intervals are longer than 1.2 s.

References

Adams, R. D. (1977). Intervening stimulus effects on category judgments of duration. *Perception and Psychophysics, 21,* 527–534.

Buffardi, L. (1971). Factors affecting the filled-duration illusion in the auditory, tactual, and visual modalities. *Perception & Psychophysics, 10,* 292–294.

Getty, D. (1976). Counting processes in human timing. *Perception & Psychophysics*, *20*, 191-197.

Grondin, S. (1992). Production of time intervals from segmented and nonsegmented inputs. *Perception & Psychophysics, 52*, 345-350.

Grondin, S., Ouellet, B., Roussel, M.-E. (2004). Benefits and Limits of Explicit Counting for Discriminating Temporal Intervals. *Canadian Journal of Experimental Psychology, 58,* 1-12.

Grondin, S., Meilleur-Wells, G., & Lachance, R. (1999). When to start explicit counting in a time-intervals discrimination task: A critical point in the timing process by humans. *Journal of Experimental Psychology: Human Perception and Performance*, *25*, 993-1004.

Hall, G.S. & Jastrow, J. (1886). Studies of rhythm. *Mind, 11*, 55-62.

Nakajima Y, (1987). A model of empty duration perception. *Perception, 16*(4) 485-520.

ten Hoopen, G., Miyauchi, R., & Nakajima, Y. (in press). Time-based illusions in the auditory mode. In S. Grondin (Ed.). *Psychology of time*. Emerald Publisher.

Thomas, E. A. C., & Brown, I. (1974). Time perception and the filled duration illusion. *Perception & Psychophysics, 16,* 449–458.

Wearden, J. H., Denovan, L., Fakhri, M., & Haworth, R. (1997). Scalar timing in temporal generalization in humans with longer stimulus durations. *Journal of Experimental Psychology: Animal Behavior Processes, 23,* 502–511.

Wearden, J. H., Norton, R., Martin, S., & Montford-Bebb, O. (2007). Internal Clock Processes and the Filled-Duration Illusion. *Journal of Experimental Psychology: Human Perception and Performance, 33* (3), 716–729.

Acknowledgements

This research was made possible by a Graduate Scholarship awarded to PLG and to MER by the Natural Sciences and Engineering Council of Canada (NSERC), an NSERC Summer Scholarship awarded to NB, a CLLRNet Scholarship awarded to LH and a research grant awarded to SG by NSERC: pierre-luc.gamache.1@ulaval.ca ; simon.grondin@psy.ulaval.ca

EAR ASYMMETRIES IN GAP DETECTION

David Epter, Ikaro Silva, LaTasha Fermin, and Mary Florentine

Institute for Hearing, Speech and Language and Communications Research Laboratory, Department of Speech-Language Pathology and Audiology, and Department of Computer and Electrical Engineering, Northeastern University, Boston, MA

Abstract

Some research suggests a right-ear advantage for the ability of normal listeners to detect brief gaps (pauses) in noise, whereas other research does not. This experiment uses a narrowband gap detection procedure to assess a possible right-ear advantage in two frequency regions (500 Hz and 4 kHz) using a cued yes-no method of maximum likelihood (MML). The gaps were carried by 786-ms noises set at 85 dB SPL and started at 250-ms after the onset of the noise. Thirty right-handed normal listeners were presented stimuli in mixed order in the presence of a band-stop masker to prevent audible cues from spectral splatter. There were no significant differences between the data from left and right ears at either frequency region as indicated by analysis of variance for repeated measures. Present results and data from the literature suggest that the type of stimulus plays a role in ear asymmetries in gap-detection tasks.

Because central auditory processing disorders can be identified with temporal tasks and adequate temporal processing is highly likely to be related to the ability to understand speech in noise, there has been a quest to find a simple and reliable measure of temporal processing that can be used with individual listeners in clinical settings. One such measure that has offered promise is the ability to detect a pause, or gap, in a noise. Florentine, Buus, and Geng (2000) examined a possible clinical procedure for a narrowband gap-detection test that is simple, frequency specific, and reliable. Results were encouraging. A subsequent study showed a significant correlation between this task and the ability of normal-hearing listeners to understand speech in narrowband noise (Costa, Silva, and Florentine, in revision).

One aspect that needs to be considered in any clinical gap-detection task is the possibility of a right-ear advantage in temporal tasks. Whereas a right-ear advantage has been found in some gap-detection tasks (Varoon, Timmers, and Tempelaars, 1977; Brown and Nicholls, 1997; Nicolls, Schier, Stough, and Box, 1998), it is not universally observed (Efron, Yund, and Nichols, 1985; Oxenham, 2000; Sulakhe, Elias, and Lejbak, 2003; Sininger and de Bode, 2008). The purpose of the present study was to measure gap-detection thresholds in the left and right ears of a group of normal listeners to determine the presence or absence of a right-ear advantage in the clinical gap-detection task proposed by Florentine *et al*. (2000).

Method

Listeners. Thirty normal-hearing listeners (15 males and 15 females) participated in the experiment. They ranged in age from 19 to 32 years. Only two listeners had prior experience with gap-detection tasks. All listeners were right handed and were paid for their participation.

Stimuli and Procedures. The stimuli and procedures were the same as those used by Florentine *et al*. (2000). The stimuli were gaps in bandpass narrowband noises presented at 85 dB SPL at two center frequencies (500 Hz and 4 kHz). Each bandpass noise that carried the gap was 786 ms and had a 20-ms rise and fall time. The gap occurred 250-ms after the onset of the noise. The initial gap duration was clearly audible for all listeners.

Each listener was tested separately in a sound-attenuating room on four conditions: 2 ears (left and right) x 2 center frequencies (500 Hz and 4 kHz). Six measurements were made for each of the four conditions in counterbalanced order. A cued yes-no method of maximum likelihood (MML) procedure was used. This method has been showed to yield reliable data (Florentine, Buus, and Geng, 1999). During each trial, listeners were presented two narrowband noises separated by 500-ms. They were instructed that the first noise would never contain a gap and to use it as a reference for a “no gap” sound. They listened for a “gap” or “no gap” in the second noise and indicated their responses by selecting the appropriate button on the display box. Three warm-up trials were given and no feedback was given. For details of the procedure, see Florentine *et al*. (2000).

Apparatus. A PC-compatible computer with a signal processor (TDT AP2) generated the stimuli, sampled the listeners’ responses, and executed the psychophysical procedure. The gap noise and the notched-noise masker were reproduced by a D/A converter (TDT DD1; sample rate=41.67 kHz), whose output was attenuated (TDT PA4) and anti-alias filtered (TDT FT 5 fC=20 kHz, 135 dB/octave. The output of the filter was led through a summation amplifier (TDT SM3) to the headphone amplifier (TDT HB6), which fed one earpiece of a Sony MDR-V6 headphone.

Results

Data from two of the 30 listeners (one male and one female) were omitted from the analysis because their data were highly inconsistent. Figure 1 shows the average minimal detectable gap (MDGs) for both ears of 28 listeners at the two center frequencies (500 Hz and 4 kHz). Results show larger MDGs at 500 Hz than at 4 kHz. The average of right and left ear MDGs is 24.7 ms at 500 Hz and 7.7 ms at 4 kHz. These average values are in agreement with data in the literature using the same procedure (Florentine *et al*., 1999; Florentine *et al*., 2000). At 500 Hz the average MDG is 25.3 ms for the right ear and 24.2 ms for the left ear. At 4 kHz the MDG is 7.5 ms for the right ear and 7.8 ms for the left ear. Therefore, there is no indication of an ear advantage for the MDG task used in the present experiment. These observations are supported by an ANOVA with three repeated-measures factors (ear, frequency, and repetition) and one between-subject factor (gender). Ear is not significant (P=0.988), but frequency and repetition are significant (P<0.001). Although order effects are evident, the stimuli are run in counterbalanced order to reduce the effects of practice. All cross factors of repetition, frequency, ear, and gender are not significant.

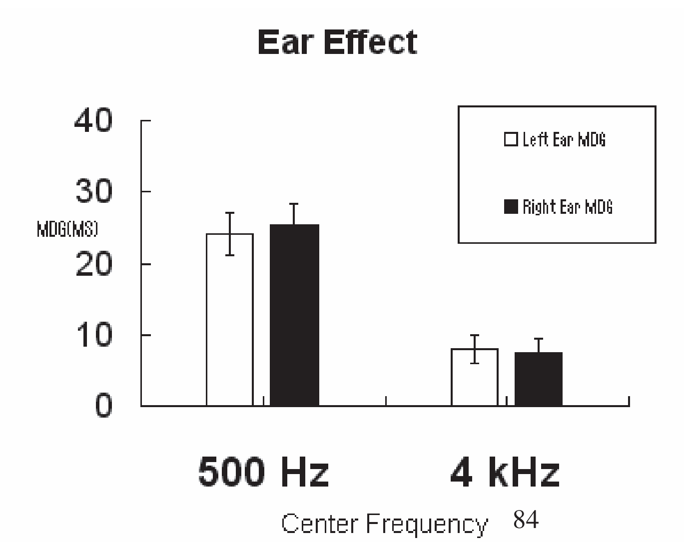

Fig. 1. The average minimal detectable gap (MDG) is shown for left and right ears at the two center frequencies. The error bars show plus and minus one standard error of the mean.

Discussion

The results of the present study show no ear advantage in the clinical gap-detection task proposed by Florentine *et al*. (2000). If an ear advantage exists, it is too small to influence the outcome measures of the task. Accordingly, separate normative data for left and right ears are not required.

The fact that the data from two of the 30 listeners were so inconsistent that they warranted elimination from the data analysis is of concern, especially because this test has been proposed as a potential clinical test. Both listeners were paid students, who may have not attended to the task. Variability was large over the course of the experiment. Because these listeners did not return for more testing, this remains an open question.

Why is the right-ear advantage observed in some gap-detection tasks and not in others? One obvious difference between the two groups of studies is the type of stimuli used. Sulakhe *et al*. (2003) investigated experimental discrepencies in the right-ear advantage by presenting two different noise types: broadband and narrowband noise. They found that when gaps were presented in broadband stimuli, a right-ear advantage was observed, but when gaps were presented in narrowband noise, no ear advantage was observed. Sininger *et al*. (2008) also measured gap detection using two different stimulus types: broadband noise and tones. They found that when gaps were presented in broadband noise, a right-ear advantage was observed, but when gaps were presented in 400-Hz and 4-kHz tones, a left-ear advantage (only significant at 4 kHz) was observed. When gap detection data are categorized by stimulus type, we find the following:

Broadband noise. A right-ear advantage is observed with broadband noise (Vroon *et al*., 1977; Brown and Nicolls, 1997; Nicolls *et al*., 1998; Sulakhe *et al*., 1999; Sininger and de Bode, 2008). An exception to this is the study by Oxenham (2000), who reported no apparent ear effect. However, only six female listeners were used and the study was not controlled for handedness. Evidence exists that male brains may be more asymmetrically organized than female brains (Brown, Fitch, and Tallal, 1999).

Tones. A left-ear advantage is observed with tones (Sininger and de Bode, 2008).

Narrowband noise. No ear advantage is observed with narrowband noise (Efron *et al*., 1985; Sulakhe *et al*., 1999; the present study).

The categorization of the results based on stimulus type for broadband noise and tones makes sense in terms of the well-documented functional specialization of the left and right auditory cortex. In this context, the fact that no advantage was observed when using the narrowband stimuli is not too surprising. Sininger and de Bode (2008) point out that the “exact distinctions between tonal and temporal complexity that distinguish left lateralized from right lateralized functions have not yet been established and certainly a narrowband noise may be too much of both to demonstrate lateralized function.” In fact, one could argue that the narrowband gap detection task may be the ideal stimulus for assessing the temporal processing in both hemispheres. In any case, the stimulus that carries the gap (*aka* gap marker) is likely to be important in this lateralization of function.

Acknowledgment

Professor Michael Epstein provided help with statistical analysis and gave helpful comments on an earlier version of the manuscript. Candice Costa, CCC-A, AuD tested listeners for normal hearing. Whitney Danse assisted in manuscript preparation. This work supported by NIH-NIDCD grant DC001087 and the Undergraduate Research Program of the Provost's Office of Northeastern University.

References

Brown, C.P., Fitch, R.H., & Tallal, P. (1999). Sex and hemispheric differences for rapid auditory processing in normal adults. *Laterality, 4(1),* 39-50.

Brown, S. & Nicholls, M.E.R. (1997). Hemispherical asymmetries for temporal resolution of brief auditory stimuli. *Perception and Psychophysics, 59 (3)*, 442-447.

Costa, C.J., Silva, I., & Florentine, M. (in revision). Frequency-specific correlations between temporal resolution and speech perception in noise. *Ear & Hearing*.

Efron, R., Yund, E.W., & Nichols, D. (1985). An Ear asymmetry for gap detection following anterior temporal lobectomy. *Neurophysiology*, 23: 43.

Florentine, M., Buus, S., & Geng, W. (1999). Psychometric functions for gap detection in a yes-no procedure. *Journal of Acoustical Society of America, 106*, 3512-3520.

Florentine, M., Buus, S., & Geng, W. (2000). Toward a clinical procedure for narrowband gap Detection 1: A psychophsysical procedure. *Audiology, 39*, 161-167.

Nicholls, M.E.R., Schier, M., Stough, C.K.K., & Box, A. (1998). Psychophysical and Electrophysiological Support for a Left Hemisphere Temporal Processing Advantage. *Neuropsychiatry, Neuropsychology, and Behavioral Neurology, 12*, 11-16.

Oxenham, A.J. (2000). Influence of spatial and temporal coding on auditory gap detection. *Journal of the Acoustical Society of America, 107,* 2215-2223.

Sininger, Y.S. & de Bode, S. (2008). Asymmetry of temporal processing in normally hearing and unilaterally deaf subjects. *Ear & Hearing, 29*(2)*,* 228-238.

Sulakhe, N., Elias, L.J., & Lejbak, L. (2003). Hemispheric asymmetries for gap detection depend on noise type. *Brain and Cognition, 53*, 372-375.

Vroon, P.A., Timmers, H., & Tempelaars, S. (1977). Attention and performance VI: Procedings of the sixth international symposium on attention and performance, 231-235.

FILLED INTERVALS ARE PERCEIVED AS LONGER THAN EMPTY ONES: THE EFFECT OCCURS EVEN WITH A BETWEEN-SESSION DESIGN

Marilyn Plourde, Pierre-Luc Gamache, and Simon Grondin
École de psychologie, Université Laval, Québec, Canada

Abstract

The timing literature usually reveals that, for a same physical duration, filled intervals are perceived as being longer than empty ones. This effect is known to occur when filled and empty intervals are randomized within a same block of trials. In the present experiment, the magnitude of the effect was tested with three experimental designs: filled and empty intervals grouped by sessions, by blocks, or randomized within blocks. The results tended to show that filled durations are perceived as longer than empty intervals, and this potential effect does not seem to be reduced by the use of a between-session design. Finally, higher sensitivity was observed with empty intervals, which is inconsistent with a portion of the literature.

The structure of a time interval, i.e., whether it is marked by two distinct sensory signals (empty) or by a continuous signal (filled) influences time judgements. However, demonstrations of its influence have been very heterogeneous, since researchers have used various duration ranges and "filling" methods for investigating the phenomenon (Wearden, Norton, Martin, & Montford-Bebb, 2007; for a review see Grondin, 2003).

A relatively consistent finding though is that filled intervals are perceived as being longer than empty ones (Wearden et al., 2007). In the context of temporal discrimination tasks, this effect is generally observed when filled and empty intervals are compared directly, that is, when both types of signals are presented within an experimental block. In order to understand the cause of the difference between filled and empty intervals for perceived duration, we used three different contexts, i.e., three different experimental designs in which both types of signals were randomized within blocks, grouped by blocks, or grouped by sessions. In other words, we wanted to know to what extent the temporal proximity of these interval types influences their relative estimates.

We expected that the filled-empty difference would be governed basically by the same mechanisms as those observed, for instance, for the auditory-visual difference reported in the memory-mixing model proposed by Penney, Allan, Meck and Gibbon (1998; see Gamache & Grondin, 2008). This model implies the creation of a common memory reference generated from the temporal information issued from both temporal types. If only one interval type is presented within a session, there should be no influence of interval type on the other, and the perceived duration should be the same in both structure conditions. Therefore, we anticipated that the filled-empty difference would be greater with a within-block design; minimal, if any, with a between-session design; and intermediate with a between-block design.

Method

Participants

Seven 20- to 26-year-old volunteer students at Université Laval, 3 females and 4 males, participated in this experiment. They were paid CAN$25 for their participation.