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Functional Specialization in Tone Perception: Evidence from Dichotic Listening in Yalálag Zapotec¹

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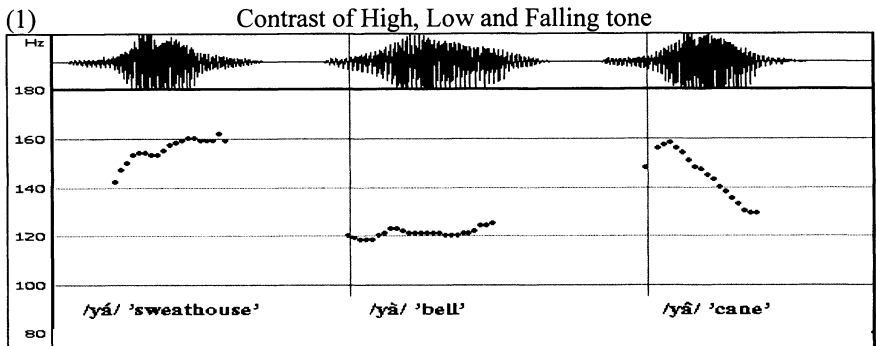
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1 Introduction. An important tradition of clinical and experimental studies suggests that there is a left hemisphere specialization substrate for linguistic functions, while the right hemisphere is less involved in linguistic tasks (e.g. Fitch *et al.* 1997, Kimura 1961, Moffat and Hampson 2000, among others). This model of asymmetrical functions in the human brain, particularly the linguistic prepotence of the left hemisphere, has been grounded mainly on clinical evidence. Findings of many studies point out that the likelihood of aphasia following damage of the left hemisphere of the brain is far higher than in cases where the lesion has affected the right hemisphere (e.g. Corina 1998, Penfield and Roberts 1959). More recent evidence from non-aphasic populations suggests a similar conclusion. In particular, dichotic listening studies in normal subjects and commissurotomy patients have demonstrated a consistent right ear advantage (REA) in linguistic stimuli, an observation that has been interpreted as an indication of left hemisphere superiority in processing such stimuli (Hugdahl 1988, Kimura 1961, 1967, Zaidel 1976, among others). Some studies have indicated that the right hemisphere is particularly involved in processing stimuli based on fundamental frequency, such as pure tones and intonation (Blumstein *et al.* 1974, Goodglass and Calderon 1977, Perkins *et al.* 1996). However, other studies of pitch perception in languages which use phonemic contrasts of tone (Gandour *et al.* 1988, Hugdahl *et al.* 1999) suggest that there is a left hemisphere dominance in the perception of phonemic tone. Experiments that have used a dichotic listening technique to examine the processing of linguistic vs. non-linguistic use of pitch are particularly relevant for the study described in this paper (Moen 1993, Van Lancker 1980, Van Lancker and Fromkin 1973, 1978, Wang *et al.* 2001) have reported a right ear advantage for discriminating tone. In agreement with the generally accepted model of hemispheric specialization for language, these results have been interpreted indicating that the perception of

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lexical tone is lateralized to the left hemisphere. Because the acoustic parameter fundamental frequency (f_0) underlies a range of linguistic and non-linguistic functions, the study of functional specialization for the perception of f_0 in languages with contrastive use of pitch presents crucial evidence to understand how tonal stimuli is processed in the brain. In this context, the present study would like to contribute towards the major research agenda on understanding of the neural correlates of language. This paper reports an investigation of the patterns of hemispheric specialization for tone perception in native listeners of Yalálag Zapotec (a tone language). Using a dichotic listening technique, three issues were investigated: the pattern of lateralization of pitch perception of phonemic tone in Yalálag Zapotec, in contrast to pitch perception of non-linguistic stimuli; the role of selective attention in the perception of tone; and the correlation between the contrastive tones of Yalálag Zapotec and their pattern of lateralization.

2 Phonological preliminaries. Yalálag Zapotec (henceforth YZ) is an Otomanguean language spoken in the district of Villa Hidalgo, municipality of Villa Alta, Oaxaca, by 5,000 speakers. An undetermined number of YZ speakers have also settled in Los Angeles. Yalálag Zapotec has three lexical tones: high (H), low (L) and falling (F). In what follows, I will describe the basics of YZ tone patterns. Figure 1 illustrates the f_0 contours of a representative triple contrast between High, Low and Falling tones. The High and Low tones illustrated by /yá/ 'sweathouse' and /yâ/ 'bell', respectively, are fairly steady, in contrast with the significant falling trajectory observable in /yâ/ 'cane'.



3 Method. Two experiments were designed to test pitch perception and laterality in linguistic and non-linguistic stimuli. The first experiment consisted exclusively of words whereas the second included the hummed versions of words. Selective attention was investigated by three experimental conditions: non-forced (NF), forced to the left (FL) and forced to right (FR). Six right-handed native speakers of YZ (ages 30-50; 3 females, 3 males) without antecedents of hearing problems were binaurally presented with a set of minimal pairs of words differing in tone and a set of pairs of hums differing in their f_0 values. Each subject was

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tested individually in the presence of the experimenter in the Phonetics Laboratory at UCLA or in his or her home. Trials consisted of 32 words and an equal number of hums. The experimental stimuli thus consisted of 16 dichotic pairs of words and 16 dichotic pairs of hums. Each stimuli token was presented to each ear counterbalanced, so that the total number of tokens was 32 per condition ($32 \times 3 = 96$ total). Other things being equal, variation in f_0 was the only difference between the members of a pair. In order to control for possible differences related to lexical accessibility, the words were of the same grammatical category and presumably of equal frequency. The same native speaker whose voice was used to produce the word stimuli also produced the hummed versions of the same words. The subjects listened to the same words (in isolation) that would be tested in a binaural condition before commencing the experimental trials. There was a practice session before the experimental trials. The words in the practice session were different from those used in the experiment. The subjects repeated the practice trials as many times as they wanted until they felt confident with the task. The subjects were asked to repeat, as soon as possible, the word or hum that they had heard. The responses were tape-recorded. The method of using oral responses was intended to reveal perceptual accuracy, since the subjects had to match one of the words of the dichotic pair. In standard procedures of dichotic listening tasks, the subject is asked to press a button which selects one of a pair of words or images from a computer screen. However, there is evidence showing that handedness has some effect biasing such responses (see Mazzucchi *et al.* 1981 for discussion on the relevance of this factor). The present design, using oral responses, aimed to avoid a handedness bias, especially because the interference of reading with the perception of dichotic stimuli is not yet fully understood. Moreover, since YZ is a language without a written tradition, the protocol in which a written word is selected from a screen would have been clearly inappropriate. The experiment lasted between 90 and 120 minutes. There was a recess of five to ten minutes between each section of the experiment. Data were collected, recorded and processed with Psyscope and independent recordings of the sessions were made on analogue tapes. Statistical analysis were obtained with SPSS software. The dichotic stimuli were normalized in duration and amplitude (70 dB) so that, other things being equal, the only difference between the members of each dichotic pair was its fundamental frequency. Stimuli normalization was done with the resynthesis function of the Praat program (Boersma and Weenick 2002). In order to ascertain the accuracy of the responses after the experimental session was over, each subject listened to his/her responses and gave the corresponding glosses in Spanish or English to the experimenter. In the case of hums, the f_0 traces of the oral responses recorded were inspected to confirm a match with one of the components of the members of the dichotic stimulus.

4 Hypotheses. Hypothesis 1. Based on the robust evidence accumulated over the last decades, the basic hypothesis to test in this study is that if lexical tone entails the processing of linguistic stimuli, then a right ear advantage (REA) is predicted, whereas a left ear advantage (LEA) would be expected for the processing of non-linguistic stimuli such as hums. Hypothesis 2. If selective

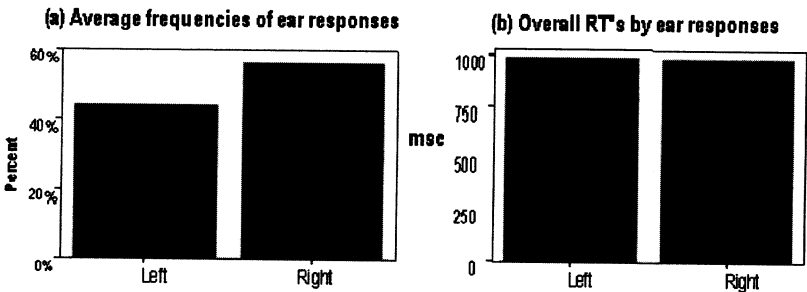
attention is conceived as a condition that enhances responses from the attended ear, it is expected that the responses of the attended ear (left or right) will increase according to the forced condition, in comparison with the non-forced condition. Thus, specifically, a greater REA is predicted for the lexical tone stimuli when the condition is forced to the right ear than in the non-forced condition. On the other hand, a reduction in responses from the right ear is expected when the condition is forced to the left. The opposite tendency is expected for the non-linguistic stimuli; that is, a greater LEA is predicted when the condition is forced to the left in comparison to the non-forced condition. If the results show the reverse tendency, this would suggest that selective attention is not a process of enhancement of the attended ear but rather a process that inhibits the intrusions from the non-attended ear. Hypothesis 3. A REA is expected for the processing of lexical tone. However, it is not immediately obvious what would be the pattern of lateralization among the three different tones. Nevertheless, it is possible to advance two potential hypotheses with respect to the saliency of the tones in a dichotic situation based on the psychoacoustic properties of the stimulus: the complexity hypothesis and the excitatory hypothesis. In the complexity hypothesis, the degree of complexity of the signal will resolve the decision of subjects regarding the perception of the dichotic stimuli. Thus, because the falling tone is a more complex signal, it could be considered inherently more distinguishable than a simple level tone, low or high and therefore it is expected a REA for falling tones. In the excitatory hypothesis, the characteristic frequencies of excitation of each tone will be computed to decide the perception of the tone in a dichotic condition. There is evidence that the excitatory patterns of high frequencies over the auditory nerve fibers are 'stronger' than those of low frequencies. Thus, the excitatory hypothesis predicts that in the dichotic pair high-low, the high tone will have perceptual saliency over a low tone. The two hypotheses can be empirically tested in the present study since in the duplet high-falling tones, both hypotheses can be valid. Thus, if the results indicate a greater advantage of H tone over F tone, we can propose that excitatory 'saliency' overrides complexity of the signal. However, if Falling has a greater advantage over H, that would indicate that complexity overrides saliency.

5 Results. Linguistic stimuli. Overall, the combined results across the three conditions (NF, FR and FL) showed a tendency towards responses from the right ear in processing lexical tone (see Figure 2a): Right ear 56% (316) versus left ear 44% (248). The same tendency was observed across all speakers, except one, EC, who showed the opposite tendency. The results showed an essentially identical reaction time for responses coming from the left ear and those from the right ear (mean 990 ms versus 985 ms ($F .762$, $df 2$, $sig. 467$)). Overall, the results hold across speaker. Examination of the results for selective attention (presented in Figure (3a) below) revealed an overall REA, yet this advantage showed a higher score when the attention was non-forced or when the attention was forced to the right than when attention was forced to the left. The same tendency was observed across speakers (except for EC, who showed the opposite trend). When attention was forced to the right, an increased REA was observed, compared to non-forced and forced to the left conditions. The findings regarding the interaction of tone

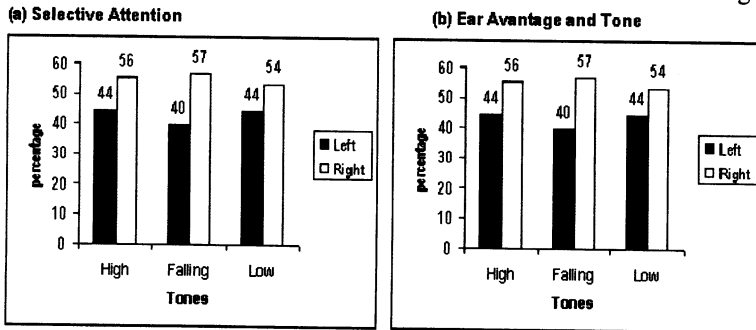
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and ear advantage are summarized in Figure (3b). The results showed a robust trend for a REA for all the tones. Nevertheless, a closer inspection of the data revealed intra-listener variation. The results for each subject are presented in Figure (4) below. First, there was a robust REA for falling tone across four speakers (except EC). Second, there was a robust REA for low tone across speakers (moderate in EV and LEA for EC). Third, there was a robust REA for high tone in three speakers (SA, EX, RR); no ear advantage in two (JB and EV); and LEA for one (EC).

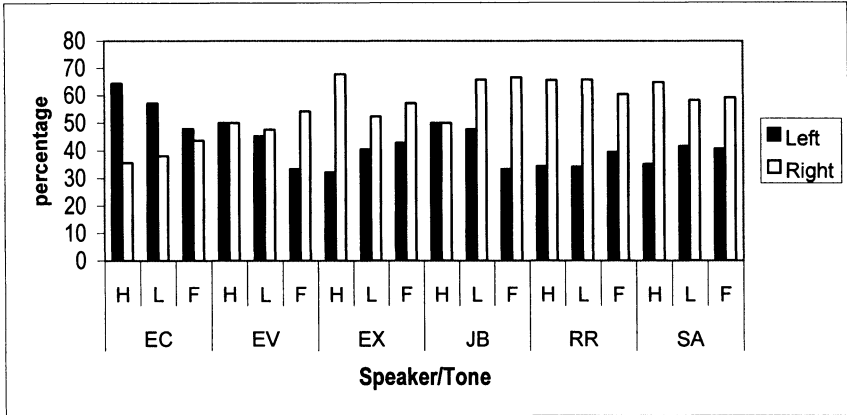
(2) Average frequencies and reaction time results



(3) Results of Selective Attention and Interaction of Ear advantage and Tone

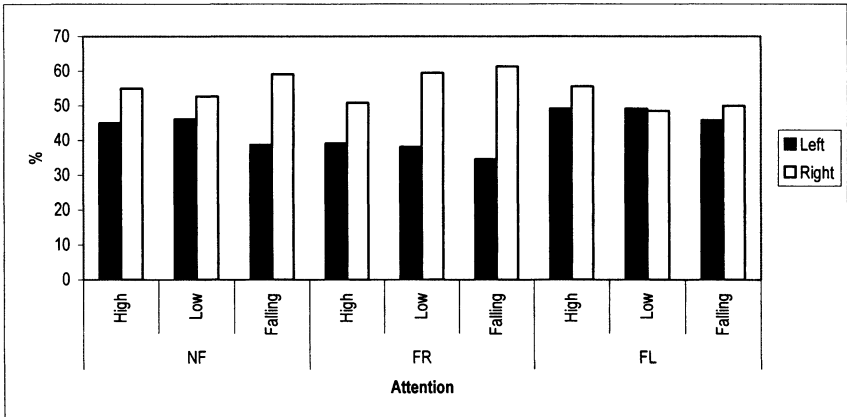


(4) Intralistener variation by tone and ear advantage



With respect to the interaction of tone and selective attention, the results showed the following patterns. First, there was a REA for all the tones except low in the forced to the left condition (FL). Second, high and falling tones showed a REA regardless of the attention condition. Third, with attention forced to the left, falling and low tones showed a greater incidence of intrusions from the left ear than did high tone. The results regarding the interaction of dichotic pairs of tone and selective attention are summarized in Table 6. In general, high and falling tones showed a consistent REA. Selective attention to the right enhanced the overall REA, although the highest differences were found in NF. Low tone showed the 'weakest' score when matched with H or F, as indicated by the absence of a clear EA in the pair F-L, and the LEA in the dichotic pair H-L.

(5) Selective attention and tone



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(6) Dichotic pairs of tone and selective attention interaction

Tone Left- Tone Right	Overall	FL	NF	FR
H-F	REA (65-35%)	REA (64-34%)	REA (64-36%)	REA (67-33%)
F-H	REA (64-36%)	no EA (50-50%)	REA (75-25%)	REA (66-34)
H-L	LEA (51-49%)	no EA (50-50%)	LEA (63-37%)	REA (61-39%)
L-H	REA (58-42%)	LEA (49-51%)	REA (66-34%)	REA (59-41%)
L-F	REA (60-35%)	REA (50-44%)	REA (68-26%)	REA (61-35%)
F-L	no EA (48-47%)	LEA (50-44%)	REA (50-47%)	REA (50-44%)

Non-linguistic stimuli. Overall, the results showed a greater incidence of responses from the left ear in processing hums: 52% (151) > 48% (137). Only one speaker (SA) deviated from this tendency, showing a slight preference for the right ear (52% > 48%). With respect to the interaction of selective attention and the ear response the results showed a greater score for the left ear in both forced conditions than in the non-forced condition. Although the scores for the forced conditions are similar, the individual scores differ with respect to the distribution of responses. Table 7 summarizes these findings. The results regarding the interaction of tone type and response showed that listeners were more likely to identify the tones when they were delivered to the left ear than when they were delivered to the right ear: High= 50.5% > 49.4%, Falling= 53% > 47% and Low = 53.5% > 46.5 %.

(7) Ear responses and forced conditions for hums

	Forced to the left	Forced to the right	Non-forced
Left ear	55%	55%	49%
Right ear	45%	45%	51%

The results for the specific interactions of tones in the dichotic task are summarized in Table (8). Conspicuously, there is no homogeneous distribution of tone identification. However, a few generalizations emerge. First, low tone was less often identified than high or falling tone in the dichotic stimulus. This tendency was observed regardless of the condition directing the attention. This is absolute in the dichotic pairs involving high and low tone. As for the pairs involving falling and low tone, the tendency is similar with the exception of the pair L-F under the condition forcing attention to the right ear and the non-forced condition, where there was no ear advantage at all. Second, the identification of pairs formed by high and falling tone performed below chance when the high tone was delivered to the right ear. The results showed a non-significant interaction

between reaction time and ear response (one factor ANOVA $F(1, 289) = 0.218$, $p > .05$). No other significant interactions between any of the conditions tested were observed.

(8) Ear advantage of dichotic pairs and attention conditions for hums

	Overall	FL	NF	FR
H-F	REA 39%-61%	REA 33%-67%	REA 33%-67%	no EA 50%-50%
F-H	no EA 50%-50%	no EA 50%-50%	no EA 50%-50%	no EA 50%-50%
H-L	LEA 57%-43%	LEA 58%-42%	LEA 54%-46%	LEA 58%-42%
L-H	REA 47%-53%	REA 46%-54%	REA 46%-54%	REA 42%-58%
L-F	REA 46%-54%	REA 33%-67%	no EA 50%-50%	LEA 55.5%-44.5%
F-L	LEA 65%-35%	LEA 77%-23%	no EA 50%-50%	LEA 66%-34%

6 Summary and Discussion. The results of the present study have shown that there is a consistent REA in the processing of lexical tone, suggesting a left hemisphere advantage for the processing of tone by listeners of Yalálag Zapotec. In contrast, there was a tendency for a LEA for hums, which could be interpreted as a right lateralization for non-linguistic stimuli. On this interpretation the findings of the present study are consistent with the theory that proposes that the left hemisphere is highly specialized for linguistic functions, whereas the right hemisphere is less involved in linguistic tasks (Fitch *et al.* 1997, Moffat and Hampson 2000, among others). Particularly, the results of this study show a consistent REA for phonemic tones; this suggests that there is a left hemisphere dominance in the processing of f_0 when it is part of the linguistic system. The results obtained in the present study are consistent with similar findings by Van Lancker and Fromkin (1973, 1978), Wang *et al.* (2001), Moen (1993), Gandour *et al.* (1988) and Hugdahl *et al.* (1999), all of which report a REA in the processing of phonemic tone. Likewise, the findings of the present study indicating a right hemisphere dominance for processing f_0 in a non-linguistic context also confirm previous research (Blumstein and Cooper, 1974, Goodglass and Calderon 1977, Perkins *et al.* 1996, Ross *et al.* 1988). Two general accounts have been proposed regarding the hemispheric specialization of pitch: a theory of so-called “functional hierarchy” of pitch processing, put forward by Van Lancker (1980) and a theory of pure pitch processing, represented mainly by Ivry and Robertson (1998). In Van Lancker’s account the association of pitch processing with the left or right hemisphere depends on its function. Hence, more specialized linguistic functions of pitch, as in the use of phonemic tone, would be lateralized to the left hemisphere, whereas less or non-linguistic uses, such as pure tones, singing or even intonation, would be processed primarily in the right hemisphere. According

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to Ivry and Robertson, the asymmetries observed in linguistic tasks (as well as a broader range of perceptual phenomena) are explained as a dissimilar "power" of each hemisphere, which is further conditioned by attentional mechanisms. Overall, the findings obtained in this study are consistent with the view that proposes a functional processing of pitch. Thus, since phonemic tone is a highly specialized linguistic function in the sound pattern of YZ, it is processed primarily in the left hemisphere. In contrast, because of the non-linguistic nature of hummed words, these tended to be processed by the right hemisphere. It is not clear how Ivry and Robertson's proposal could account for these facts and the asymmetrical results based on the type of stimuli under different attention conditions. The results in the present study indicate a consistent tendency for a REA in processing lexical tone; however, the amount of responses from the left ear suggests that the right hemisphere is also active in the processing of tone. In fact, recent studies suggest that this is the case. Andy and Bhatnagar (1984) presented electroencephalographic evidence of direct brain stimulation showing that the right hemisphere is active in performing linguistic tasks. Other studies on split-brain subjects have also indicated that the right hemisphere is active in the processing of some linguistic functions (Gazzaniga 2000, Zaidel 1976). Thus, the results of the present study are consistent with the view suggesting that although the left hemisphere is prepotent for linguistic functions, the right hemisphere makes a significant contribution to the entire linguistic processing in ways yet undefined. The specific nature and extent of its contribution should be further investigated. This study also investigated attentional effects in dichotic listening to pitch pairs. Traditional models of dichotic listening would have predicted a null effect of attention on ear advantage (e.g. Kimura 1967). Instead, the findings obtained in the present study partially confirmed the initial hypothesis anticipating a positive interaction between ear advantage and directed attention of the subjects. The results are thus consistent with several recent studies addressing the issue of selective attention in dichotic listening (Hugdahl and Anderson 1986, Asbjørnsen and Hugdahl 1995). However, against the predictions about the lateralization for the non-linguistic stimuli, the results showed a LEA in the forced conditions and a minor REA in the non-forced condition. This pattern can be interpreted as an effect of attention enhancing the right-hemisphere processing of non-linguistic stimuli. Thus, the findings on the effects of directed attention in dichotic listening to pitch stimuli support the hypothesis that forcing attention to one of the ears enhances the performance of the attended ear rather than suppressing intrusions from the non-attended ear. One of the novel issues addressed in this study was the relationship between the individual pitches in a dichotic listening condition. The results showed that, unlike the linguistic stimuli, the interaction of non-linguistic pitch stimuli did not show a pattern at all. Such a result may suggest that the non-linguistic nature of hums is either irrelevant or more demanding for processing. The predictions concerning the interaction among individual lexical tones were supported in part. First, it was hypothesized that the low tone would be the least salient tone in the dichotic task. The overall results for both types of stimuli confirmed this expectation, since when low tone was delivered to the right ear, showed more intrusions from the left ear. The vulnerability of low tone was also observed when selective attention was considered. Even though, in the linguistic

stimuli, there was a REA for low tone delivered to the right ear under forced to the right condition, the magnitude of the enhancement was smaller than those obtained for high and falling tones. Second, I suggested two possibilities for the interaction between H and F tones. In one of them it was predicted that the inherent complexity of F would be more salient than the characteristics defining H. In the other, the high frequencies of H would exceed the perceptual properties of F. If the non-forced condition is taken as a diagnostic of the natural trend of lateralization, the higher score for high tone in the dichotic pair F-H (where high is delivered to the right ear) may indicate a perceptual preference for high frequencies over the complex signal of F. Nevertheless, if the condition forcing the attention to the left is considered as an index to measure intrusions to the prepotent left hemisphere, then the crucial results showing a REA in the pair H-F and lack of ear advantage in the pair F-H may indicate that the perceptibility of F is greater than that of H. Thus far, the conclusion seems to be that there is no single factor determining the perception of dichotic stimuli; rather both factors, the complexity of the signal and the patterns of excitation appear to be involved.

7 Concluding remarks. Based on the index of ear advantage, the evidence suggests that the processing of lexical tone by Yalálag Zapotec listeners occurs in the left hemisphere, in contrast with non-linguistic stimuli, which are processed in the right hemisphere. The results are consistent with other similar studies of tone languages (Moen 1993, Van Lancker and Fromkin 1973, 1978, Wang *et al.* 2001). Furthermore, the results of the present study should be evaluated in the light of two recent PET studies (Gandour *et al.* 2000, Klein *et al.* 2001) investigating the perception of f0 in tone languages using a similar behavioral paradigm to the present study have found a significant activation in frontal, parietal and parieto-occipital regions of the left hemisphere only in native listeners of tone languages when presented to linguistic stimuli, in contrast with listeners of non-tone languages who showed a right inferior frontal cortex activation. Since this study has presented initial evidence to suggest a pattern of brain lateralization for pitch processing in Yalálag Zapotec, it would be desirable to examine the current findings in the light of modern neuroimaging techniques to fully understand the hemispheric specialization of pitch in a tone language in future research.

References

- Andy, Orlando J. and Subashi C. Bhatnagar. 1984. Right-Hemispheric language evidence from cortical stimulation. *Brain and Language* 23, 159-166.
- Asbjørnsen, A. and K. Hugdahl, 1995. Attentional effects in dichotic listening, *Brain and Language* 49, pp. 189-201.
- Blumstein, S., and W. Cooper. 1974. Hemispheric processing of intonation contours. *Cortex*, 10, 146-158.
- Boersma, Paul and David Weenick. 2002. *Praat. Doing phonetics by computer.* Version 4.0.11 Institute of Phonetic Sciences of the University Amsterdam.

Functional Specialization in Tone Perception

- Corina, David. 1998. Aphasia in signed languages. *Aphasia in atypical populations*. Patrick Coppens, Yvan Lebrun and Anna Basso (eds.) Lawrence Erlbaum Associates, Publishers. 261-309.
- Fitch R. H., S. Miller, and P. Tallal. 1997. Neurobiology of speech perception. *Annual Review of Neuroscience*, 20, 331–353.
- Gazzaniga, M. S. 2000. Cerebral specialization and interhemispheric communication. Does the corpus callosum enable the human condition? *Brain*, 123, 1293-1326.
- Gandour, J., S. H. Petty and R. Dardarananda. 1988. Perception and Production of Tone in Aphasia. *Brain and Language*, 35, 201-240.
- Gandour, J., D. Wong, L. Hsieh, B. Weinzapfel, D. Van Lancker and G. Hutchins. 2000. A crosslinguistic PET study of tone perception. *Journal of Cognitive Neuroscience*, 12.207-22.
- Goodglass, Harold and M. Calderon. 1977. Parallel processing of verbal and musical stimuli in right and left hemispheres. *Neuropsychologia*, 15, 397-407.
- Hugdahl, Kenneth (ed.) 1988. Handbook of dichotic listening : theory, methods, and research. Chichester: New York.
- Hugdahl, Kenneth; Kolbjorn Bronnick; Soren Kyllingsbae; Ian Law; Anders Gade and Olaf B. Paulson. 1999. Brain Activation during Dichotic Presentations of Consonant-Vowel and Musical Instrument Stimuli: A 15O-PET Study. *Neuropsychologia*, 37, 4, Apr, 431-440.
- Hugdahl, Kenneth and L. Anderson 1986. The ‘forced attention paradigm’ in dichotic listening to CV-syllables: A comparison between adults and children. *Cortex*, 22, 417-432.
- Ivry, Richard and Lynn Robertson. 1998. *The two sides of perception*. MIT Press.
- Kimura, D. 1961. Cerebral Dominance and the Perception of Verbal Stimuli. *Canadian Journal of Psychology*, 15: 166-171.
- Kimura, D. 1967. Functional Asymmetry of the Brain in Dichotic Listening. *Cortex*, 3:163-178.
- Klein, D., R. J. Zatorre, B. Milner, V Zhao. 2001. A Cross-Linguistic PET Study of Tone Perception in Mandarin Chinese and English Speakers. *NeuroImage*, 13.646-53.
- Mazzucchi, A., M. Parma and R. Cattelani. 1981. Hemispheric dominance in the perception of tonal sequences in relation to sex, musical competence and handedness. *Cortex*, 17, 291–302.
- Moen, Inger. 1993. Functional Lateralization of the Perception of Norwegian Word Tones – Evidence from a Dichotic Listening Experiment. *Brain and Language*, 44, 4, May, 400-413.
- Moffat, Scott D and Elizabeth Hampson. 2000. Language Lateralization?. *Neuropsychology*, 14, 1, Jan, 71-81.
- Penfield, Wilder and Lamar Roberts. 1959. *Speech and brain-mechanisms*. Princeton, N.J., Princeton University Press.
- Perkins, J. M. Baran, and J. A. Gandour. 1996. Hemispheric specialization on processing intonation contours. *Aphasiology*, 10, 343-362.
- Ross, Elliott D., Jerold A. Edmonson, G. Burton Seibert and Richard W. Homan. 1988. Acoustic analysis of affective prosody during Right-Sided Wada Test:

A within-subjects verification of the right hemisphere's role in language. *Brain and Language*, 33, 128-145.

Van Lancker, Diana. 1980. Cerebral lateralization of pitch cues in the linguistic signal. *Papers in Linguistics: International Journal of Human Communication*, 13, 201-277.

Van Lancker, Diana and Victoria Fromkin. 1973. Hemispheric specialization for pitch and "tone": Evidence from Thai. *Journal of Phonetics*, 1, 101-109.

Van Lancker, Diana and Victoria Fromkin. 1978. Cerebral dominance for pitch contrasts in tone language speakers and in musically untrained and trained English speakers *Journal of Phonetics*, 6, 19-23.

Wang, Yue, Allard Jongman and Joan A. Sereno. Dichotic Perception of Mandarin Tones by Chinese and American Listeners. 2001. *Brain and Language*.

Zaidel, Eran. 1976. Language, dichotic listening, and the disconnected hemispheres. (ms)

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