A Left-Ear Advantage for Forced-Choice Judgements of Melodic Contour

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Abstract Listeners heard a sequence of five tones presented monaurally, and then made a forced-choice judgment about the sequence's contour (i.e., its pattern of upward and downward shifts in pitch between successive tones). The forced-choice method ensured that contour judgements were independent of absolute-pitch or interval cues. Performance was better for sequences presented to the left ear (right hemisphere) than it was for sequences presented to the right ear (left hemisphere). This finding provides support for claims of a right-hemisphere bias for the processing of melodic contour.

Résumé Les sujets ont écouté une séquence de cinq tonalités lors d'une présentation uniaurale et ont ensuite fait un jugement à choix forcé sur la courbe de la séquence (le modèle des déplacements vers le haut et vers le bas dans les tons des tonalités successives, par exemple). La méthode à choix forcé permettait d'avoir des jugements sur la courbe indépendamment de l'oreille absolue ou des indices d'intervalle. La performance était meilleure dans les séquences présentées à l'oreille gauche (l'hémisphère droit) que dans les séquences présentées à l'oreille droite (l'hémisphère gauche). Ce résultat confirme l'hypothèse qui veut que l'hémisphère droit biaise le processus de la courbe mélodique.

Hemispheric asymmetries have been identified for many cognitive processes, including vision, learning, attention, and language (Hellige, 1993). Because such asymmetries exist across modalities as well as species, hemispheric specialization appears to be a fundamental feature of brain organization. In the present study, we sought to determine whether short tone sequences presented *monaurally* (to one ear at a time) are processed differentially by the two hemispheres. Studies of auditory processing often indicate that linguistic and musical stimuli are processed preferentially by the left and right hemispheres, respectively (for reviews see Hellige, 1993; Zatorre, 1984). Nonetheless, although a wide body of research makes it clear that linguistic skills rely mainly upon the functional integrity of the left hemisphere (Hellige, 1993), the association between music processing and right-hemisphere functioning is not as clear (Peretz, 1993). Music is comprised of numerous components (e.g., rhythm, melody) that could be lateralized differently or even localized in distinct modules (Peretz & Morais, 1989).

Our listeners were required to make forced-choice judgements of the *contour* of short melodies (tone sequences). Contour refers to the pattern of upward and downward shifts in pitch between successive tones. For example, the first seven tones of *Mary Had a Little Lamb* have a down-down-up-up-same-same contour (i.e., *Ma-ry* goes down, *ry-had* goes down, *had-a* goes up, and so on). We chose to present stimuli monaurally because other researchers (e.g., Peretz & Babaï, 1992; Peretz & Morais, 1987) have reported reliable effects with this method. Monaural presentation assumes that whereas stimuli presented to the left ear are processed preferentially by the right hemisphere, stimuli presented to the right hemisphere are processed preferentially by the left hemisphere (Springer & Deutsch, 1993).

Results from previous studies (Mazzucchi, Parma, & Cattelani, 1981; Peretz, 1990; Peretz & Babaï, 1992; Peretz & Morais, 1988; Zatorre, 1985) suggest that contour processing is the most likely component of music to be lateralized to the right hemisphere, presumably because of its global nature. Hence, we expected listeners to exhibit better performance for tone sequences presented to the left ear over those presented to the right ear. In an earlier study, Mazzuchi et al. (1981) identified a left-ear advantage for forced-choice judgements of the contour of tone sequences presented *dichotically* (different sequences presented simultaneously to the left and right ears). Dichotic listening tasks often have poor reliability (Blumstein, Goodglass, & Tatter, 1975), however, and attentional strategies can affect performance (Springer & Deutsch, 1993). Indeed, other investigators (Gordon, 1970; Bartholomeus, Doehring, & Freygood, 1973; Schulhoff & Goodglass, 1969; Spellacy, 1970) used this method with

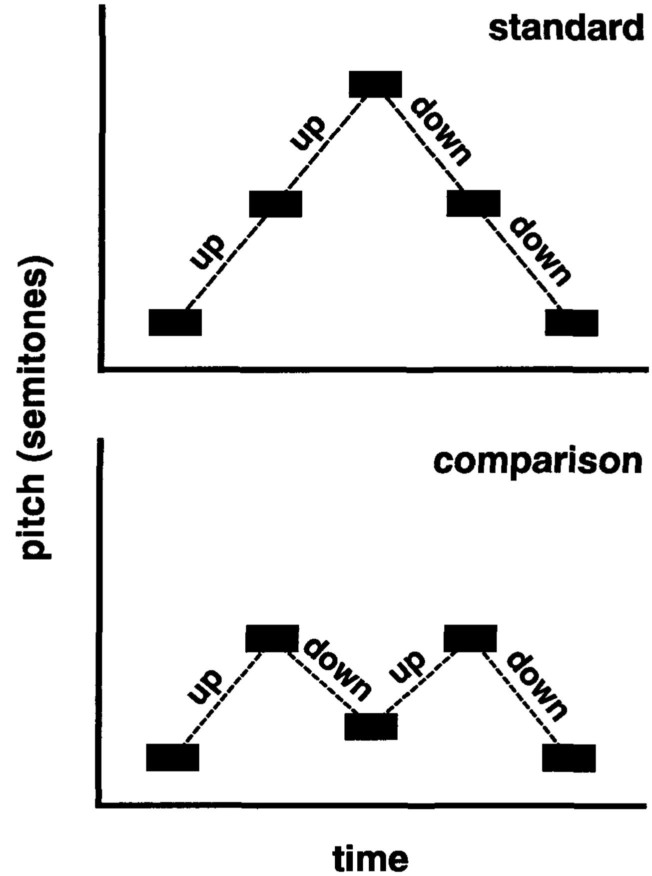

Figure 1. Schematic drawing of *standard* and *comparison* tone sequences. The third tone of the comparison is displaced downward relative to the standard. The displacement changes the contour (from up-up-down-down to up-down-up-down), the intervals (between the second and third tones and between the third and fourth tones), and the absolute pitch of the displaced tone.

tone sequences and *failed* to find significant differences between ears.

In a related study (Peretz & Babaï, 1992), musically trained listeners (*M* = 11 years of lessons) heard a sequence of tones followed by a shorter "probe" sequence and judged whether the probe was part of the initial sequence. Some of the probes had small intervals (i.e., small differences in pitch between successive tones) and a constant contour (e.g., up-up); others had larger intervals and a contour change (e.g., up-down). Listeners were better able to recognize a contour-changed probe when stimuli were presented to the left ear, a finding consistent with the proposal that contour is processed preferentially by the right hemisphere. Unfortunately, it is impossible to attribute this finding to the contour manipulation rather than to differences in interval size. It is also unclear if the effect would generalize to listeners with little or no musical training.

Other studies of hemispheric asymmetries for contour processing have required listeners to discriminate between standard and comparison tone sequences (Peretz, 1990; Peretz & Morais, 1988; Zatorre, 1985). Although these studies reported a left-ear superiority in performance, the use of a discrimination task makes interpretation of the findings equivocal. As illustrated in Figure 1, any change to a tone sequence that alters its contour will also alter its intervals and the absolute pitch of its component tones. Hence, one cannot conclude that differential responding actually stems from a right-hemisphere processing bias for detecting contour changes instead of a bias for detecting changes in absolute pitch or interval size. The forced-choice task of the present study rectified this problem by eliminating the requirement of *comparing* sequences.

Additional demonstrations of lateralization for melodic contour come from studies of brain-damaged patients (Peretz, 1990) and from studies using brain imaging techniques (positron emission tomography and magnetic resonance imaging; e.g., Zatorre, Evans, & Meyers, 1994) or invasive procedures (e.g., sodium amytal testing; see Zatorre, 1984). Although these methods provide information about the neural correlates of auditory processing, they are invasive, expensive, or require special populations. In sum, the objective of the present study was to examine hemispheric asymmetries for melodic contour using a method that was simple to administer and capable of providing easily interpretable results.

METHOD

Participants

The listeners were 29 undergraduates (17 female, 12 male) who were recruited without regard to musical training (*M* = 3.86 years of lessons, *SD* = 4.51 years). All were right-handed as assessed by self-report. Listeners received token remuneration or academic credit for participating, which took approximately 30 minutes.

Apparatus

The stimuli were musical instrument digital interface (MIDI) files constructed with a music sequencing program (*Cubase*) installed on a Power Macintosh computer (7100/66AV). Stimulus presentation and response recording were controlled by a customized software program and a mouse connected to the computer. MIDI files were output through a MIDI interface (Mark of the Unicorn MIDI Express) to a Roland JV-90 synthesizer. The stimuli were presented with lightweight personal stereo headphones (Sony CD550) in a sound-attenuating booth manufactured by Eckel Industries.

Stimuli

Tone sequences consisted of five contiguous piano tones (JV-90 factory preset: Acoustic Piano II) of equal intensity. Each tone had a duration of 200 ms; the silent interval

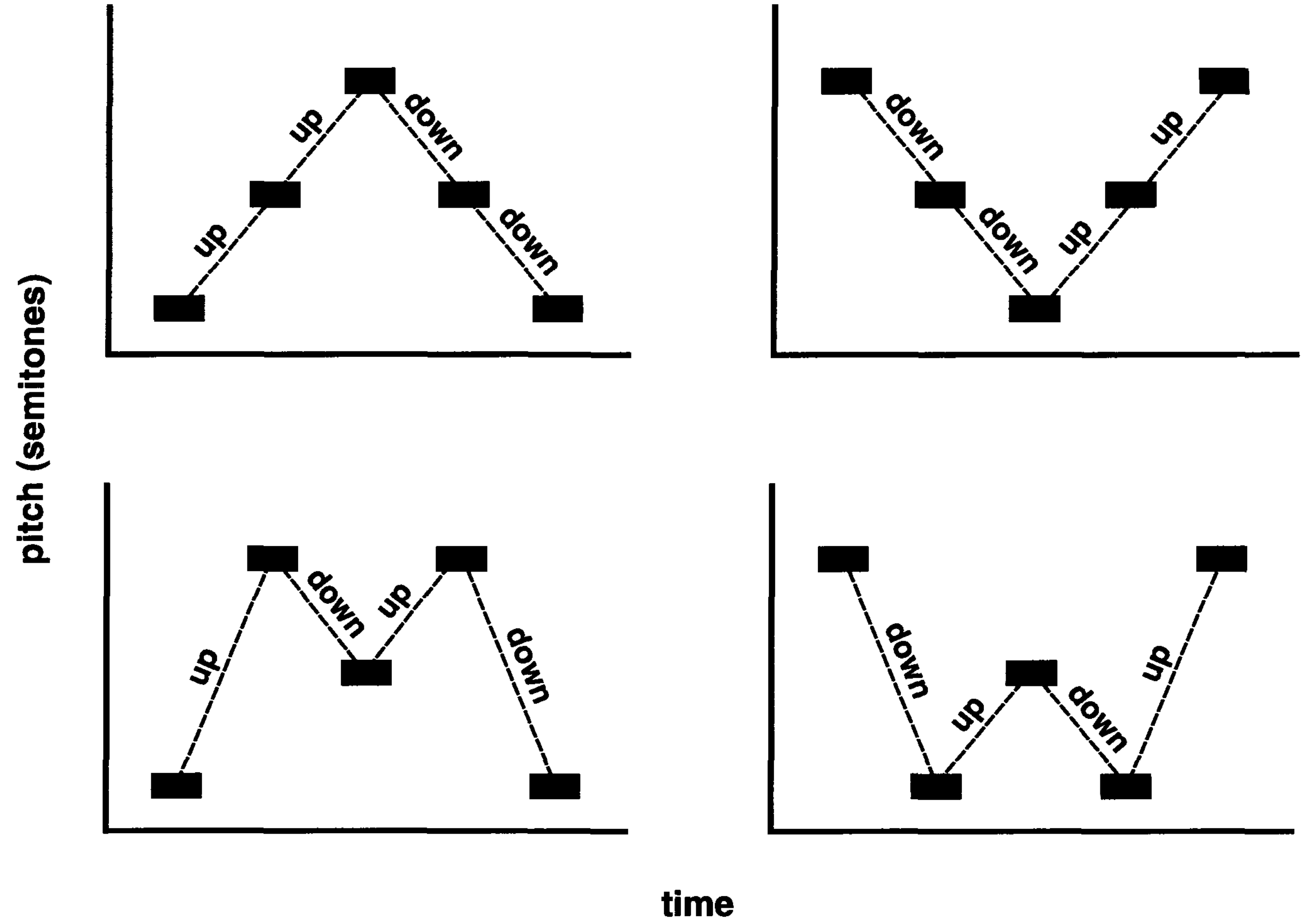

Figure 2. Schematic drawing of the four stimulus sequences.

between successive tones was also 200 ms. As illustrated in Figure 2, four sequences were used, each with a different contour: up-up-down-down (e.g., C_4 - $D^{\#}_4$ - $F^{\#}_4$ - $D^{\#}_4$ - C_4)[1], down-down-up-up (e.g., $F^{\#}_4$ - $D^{\#}_4$ - C_4 - $D^{\#}_4$ - $F^{\#}_4$), up-down-up-down (e.g., C_4 - $F^{\#}_4$ - $D^{\#}_4$ - $F^{\#}_4$ - C_4), and down-up-down-up (e.g., $F^{\#}_4$ - C_4 - $D^{\#}_4$ - C_4 - $F^{\#}_4$). For two of the sequences (up-up-down-down and down-down-up-up), the interval between consecutive tones was always 3 semitones. Intervals between tones of the other two sequences (up-down-up-down and down-up-down-up) were 6, 3, 3, and 6 semitones. Hence, each sequence had a counterpart with identical intervals but an inverted contour.

Tones in each sequence belonged to a single diminished triad. Diminished triads are relatively uncommon in Western music and are considered to be perceptually unstable (Aldwell & Schachter, 1989). They were chosen to ensure that any observed asymmetries would not depend on the use of conventional musical structures. Each of the four sequences was presented at 12 different pitch levels (total of 48 sequences). The initial tone of the lowest level was C_4; the initial tone of other levels was 1 to 11 semitones higher (i.e., from $C^{\#}_4$ to B_4). Demonstration and practice trials were randomly selected from the set of test trials but were presented at half speed (i.e., tones and intertone silent intervals were 400 ms).

Procedure

Listeners were tested individually and received instructions both orally and on the computer screen. They were told to attend to pitch differences between successive tones (i.e., whether each tone was higher or lower than the preceding tone) and to respond as accurately and as quickly as possible. Listeners used the mouse (presumably with their right hand) to signal that they were ready for a trial and to make their responses. On each trial, they heard one of the stimulus sequences presented monaurally and judged which of four options corresponded to its

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[1] The subscript indicates the pitch height of the tones. C_4 is middle C. Other tones with the same subscript ($D^{\#}_4$, $F^{\#}_4$) fall within the octave above middle C.

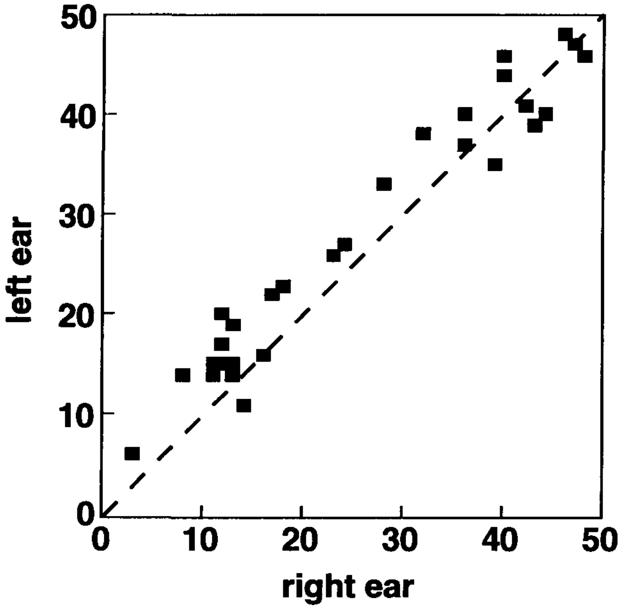

Figure 3. Number of correct responses for each listener. Points above the diagonal indicate superior performance for the left ear.

contour by clicking the mouse on one of four boxes displayed visually on the computer screen. Each box contained a statement describing one of the four possible contours (e.g., "up-up-down-down"). Hence, the mode of responding made the task a conservative one because it required verbally-mediated responses that should promote left- rather than right-hemisphere processing. After each trial, listeners received feedback presented visually (*correct* or *incorrect*) on the computer screen. The test session consisted of 96 trials (2 ears X 4 contours X 12 pitch levels), which were presented in a completely randomized order that differed for each listener. Prior to the test session, listeners heard two demonstration trials followed by seven practice trials to familiarize them with the procedure.

RESULTS

For each participant, the number of correct responses was calculated separately for each ear. The results are illustrated in Figure 3. Overall levels of performance were well above chance levels (25% correct), regardless of whether sequences were presented to the left ear, $t(28) = 6.48$, $p < .001$ ($M = 58\%$), or to the right ear, $t(28) = 5.08$, $p < .001$ ($M = 53\%$). Although seven participants performed at or below chance levels when sequences were presented to the right ear, only two performed this poorly when sequences were presented to the left ear.

A paired t-test comparing performance between the left and right ears revealed a significant laterality effect, $t\ (28) = 3.69, p < .001$. As illustrated in Figure 3, performance was superior for left-ear presentations. A nonparametric sign test confirmed that the effect was consistent across listeners ($p = .007$), with 21 of 29 exhibiting better performance for the left ear. A final set of correlational analyses revealed that musical training (i.e., years of formal music lessons) was not associated with performance accuracy for either the left or the right ear, nor with the advantage for the left ear over the right ear (rs $< .35$, ps $> .05$).

DISCUSSION

The present investigation provides new evidence of a right-hemisphere bias for the processing of melodic contour. Listeners were better able to identify the contour of tone sequences that were presented to the left ear instead of to the right ear, and this effect was independent of listeners' musical training. Our finding confirms that right-hemisphere lateralization of contour processing can be identified readily and reliably without the use of invasive experimental procedures, expensive imaging techniques, or brain-damaged populations.

Even young infants are sensitive to the contour of tone sequences, reliably detecting changes that alter the contour of a sequence but failing to identify changes that leave the contour intact (Trehub, Bull, & Thorpe, 1984). Thus, performance levels of our adult listeners (56% correct when chance is 25%) may seem surprisingly low. Although listeners could have responded accurately by attending to only the first two or three tones of a sequence, it appears that most listeners did not adopt this strategy or others that would substantially improve baseline levels of performance for both ears. In the forced-choice task with dichotic presentations used by Mazzucchi et al. (1981), performance levels were similar to those reported here (47% correct when chance was 20%). Hence, knowledge of melodic contour may be implicit rather than explicit, such that listeners with little musical training find it difficult to associate contours with explicit verbal descriptions. Our use of tones from the diminished triad likely increased the difficulty of the task. Because diminished triads are unstable structures for Western listeners (Aldwell & Schachter, 1989), they would be harder to process and represent than sequences formed from stable structures (e.g., the major triad).

Dowling (1978) proposes that listeners organize the information contained in melodies along two dimensions: contour and interval size. The contour of a melody operates independently of its precise pitch values, simply specifying the pitch direction between successive tones (see Figures 1 and 2). Because encoding a melody in terms of its contour ignores more detailed information, such as the absolute pitch of the tones and the intervals between tones, contour processing is considered to be the most basic or global form of melodic processing (Peretz &

Morais, 1987). Hence, our finding of a right-hemisphere advantage for judgements of contour is consistent with the notion of a general right-hemisphere superiority for tasks requiring global rather than local processing (Hellige, 1993).

Future research could determine whether the observed response patterns reflect a right-hemisphere advantage for music processing in general or a specific advantage for contour processing. For example, there is some evidence that temporal factors in music (e.g., rhythm) may be preferentially processed by the left rather than the right hemisphere (Borchgrevink, 1982; Halperin, Nachshon, & Carmon, 1973; Peretz, 1990). Regardless, our findings reveal that a simple and noninvasive method can be used to identify lateral asymmetries in auditory processing. Indeed, the forced-choice procedure of the present study is appropriate for normal and brain-damaged populations and can be modified easily to test for lateralization of other aspects of auditory processing.

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References

Aldwell, E., & Schachter, C. (1989). *Harmony and voice leading* (2nd ed.). San Diego: Harcourt Brace Jovanovich.

Bartholomeus, B.N., Doehring, D.G., & Freygood, S.D. (1973). Absence of stimulus effects in dichotic listening. *Bulletin of the Psychonomic Society, 1*, 171-172.

Blumstein, S., Goodglass, H., & Tatter, V. (1975). The reliability of ear advantage in dichotic listening. *Brain and Language*, *2*, 226-236.

Borchgrevink, H. (1982). Prosody and musical rhythm are controlled by the speech hemisphere. In M. Clynes (Ed.), *Music, mind, and brain* (pp. 151-157). New York: Plenum.

Dowling, W. J. (1978). Scale and contour: Two components of a theory of memory for melodies. *Psychological Review, 85*, 341-354.

Gordon, H.W. (1970). Hemispheric asymmetries in the perception of musical chords. *Cortex, 6*, 387-396.

Halperin, Y., Nachshon, I., & Carmon, A. (1973). Shift of ear superiority in dichotic listening to temporally patterned nonverbal stimuli. *Journal of the Acoustical Society of America, 53*, 46-50.

Hellige, J. B. (1993). *Hemispheric asymmetry: What's right and what's left.* Cambridge, MA: Harvard University Press.

Mazzucchi, A., Parma, M., & Cattelani, R. (1981). Hemispheric dominance in the perception of tonal sequences in relation to sex, musical competence and handedness. *Cortex, 17*, 291-302.

Peretz, I. (1990). Processing of local and global musical information by unilateral brain-damaged patients. *Brain, 113*, 1185-1209.

Peretz, I. (1993). Auditory agnosia: A functional analysis. In S. McAdams & E. Bigand (Eds.)., *Thinking in sound: The cognitive psychology of human audition* (pp.199-230). New York: Academic Press.

Peretz, I., & Babaï, M. (1992). The role of contours and intervals in the recognition of melody parts: Evidence from cerebral asymmetries in musicians. *Neuropsychologia, 30*, 277-292.

Peretz, I., & Morais, J. (1987). Analytic processing in the classification of melodies as same or different. *Neuropsychologia, 25*, 645-652.

Peretz, I., & Morais, J. (1988). Determinants of laterality for music: Towards an information processing account. In K. Hugdahl (Ed.), *Handbook of dichotic listening: Theory, methods and research* (pp. 323-358). New York: Wiley.

Peretz, I., & Morais, J. (1989). Music and modularity. *Contemporary Music Review, 4*, 277-291.

Schulhoff, C., & Goodglass, H. (1969). Dichotic listening, side of brain injury and cerebral dominance. *Neuropsychologia, 7*, 149-160.

Spellacy, F. (1970). Lateral preferences in the identification of pattern stimuli. *Journal of the Acoustical Society of America, 55*, 574-578.

Springer, S.P., & Deutsch, G. (1993). *Left brain, right brain.* New York: Freeman.

Trehub, S.E., Bull, D., & Thorpe, L.A. (1984). Infants' perception of melodies: The role of melodic contour. *Child Development, 55*, 821-830.

Zatorre, R. (1984). Musical perception and cerebral function: A critical review. *Music Perception, 2*, 196-221.

Zatorre, R. (1985). Discrimination and recognition of tonal melodies after unilateral cerebral incisions. *Neuropsychologia, 23*, 31-41.

Zatorre, R., Evans, A.C., & Meyers, E. (1994). Neural mechanisms underlying melodic perception and memory for pitch. *Journal of Neuroscience, 14*, 1908-1919.

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