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Electrical Brain Activity Associated with Automatic and Controlled Processing of Melodic Contour and Interval

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INTRODUCTION

Melodic information is thought to be encoded in the brain in two different forms, a contour code, consisting of the up/down pattern of pitch changes, and an interval code, consisting of the exact pitch distances.[1] In both cases, the important melodic information lies more in the relative relation between tones than in the absolute pitch of the tones. Because the organization of auditory cortex appears to be tonotopic, it is interesting to ask at what stage of processing relational pitch information is extracted. A related question concerns the extent to which relational melodic contour and interval are automatically processed in the absence of focused attention. These two questions were investigated using event-related brain potentials (ERPs).

MATERIAL AND METHODS

Eleven musically untrained adults listened to sequences of five-note melodies. On 80% of the trials, a melody from a standard set was played; on the remaining 20% of the trials, a melody from a deviant set was played. In the contour condition, the standard melodies all had a rising pitch contour (intervals varied across melodies); on deviant melodies, the final interval descended. In the interval condition, standard melodies consisted of the first five notes of a major scale (starting note varied); deviant melodies were the same as standards except that the final interval (but not contour) was changed. Thus, detection of the deviant melodies in both contour and interval conditions relied on the abstraction of relational pitch information, because the absolute pitch information changed from trial to trial. Melody note onset-to-

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onsets were 300 ms; trials were separated by 2,000 milliseconds. Each individual listened to each of the contour and interval conditions twice, once while reading a book (passive listening) and once while indicating by button pressing whether a standard or oddball trial was heard (active listening).

The EEG was digitized continuously (250-Hz sampling rate per channel; bandpass 0.05–50 Hz) from 47 electrodes. ERP epochs were extracted off-line, re-referenced to an averaged reference, and included 200-ms prestimulus activity and 1,200-ms poststimulus activity, starting from the onset of the final melody note in each trial. Eye movements and blinks were corrected for each individual average, using an ocular source components approach.

RESULTS AND DISCUSSION

During the passive listening condition, both interval and contour deviant trials elicited a significant mismatch negativity (MMN) wave (FIG. 1, *left*). MMN is thought to reflect the updating of traces in auditory sensory memory, as it is elicited for infrequent deviant sounds in a set of standard frequent sounds, even in the absence of attention.[2] Thus, relative contour and interval information are both extracted automatically and encoded in sensory memory. The MMN peak was earlier in the contour (150 ms) condition than in the interval (180) condition, but the amplitude was similar in both cases.

When individuals were required to listen actively to the sequence, the deviant trials generated an additional frontal positive wave that was maximum over the frontocentral region (FIG. 1, *right*). This frontal positivity peaked earlier for the contour (317 ms) than for the interval (379 ms) condition, but was significantly greater for the interval than for the contour condition. Frontal positivities, named P3as, were reported previously for salient nontarget stimuli in either attended or unattended channels[3,4] and were linked to the inadvertent capture and/or orienting of attention. Our frontal positivity for contour and interval deviants was found for target stimuli only in the attended channel, so it is not a typical P3a. It is possible that the frontal positivity reflects the ongoing processing of a patterned sequence of sounds. Whether this frontal positivity is specfic to musical processing remains a question for future research.

In the active condition, the frontal positivity was followed by a P3b wave maximum over the parietal regions. The P3b is associated with analysis of information in conscious working memory.[5] The P3b did not differ significantly between the contour and interval conditions in either latency (580 ms) or amplitude at Pz (FIG. 1, *right*).

FIGURE 1. *Left*: Difference waves (oddball–standard) for the contour and interval passive conditions showing mismatch negativity (MMN). *Right*: Difference waves (oddball–standard) for the contour and interval active conditions showing frontal positivity (FP) and P3b components.

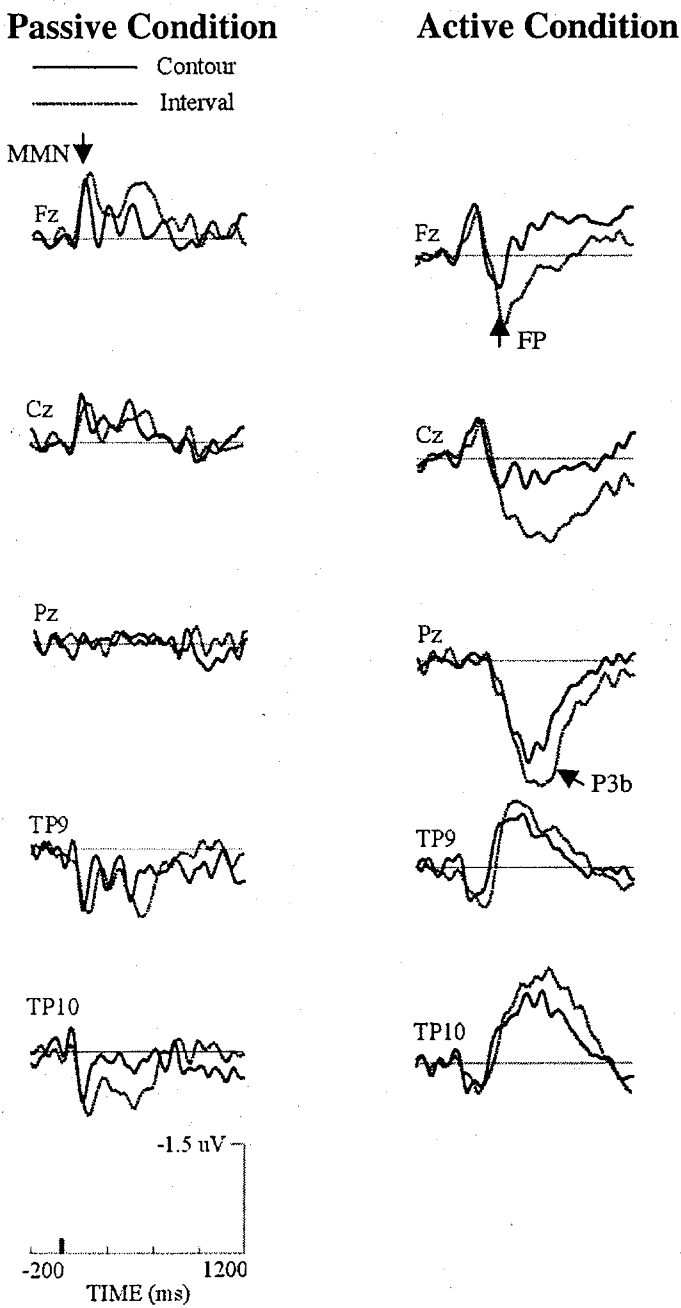

FIGURE 1. *See previous page for caption.*

CONCLUSIONS

These findings indicate that both relational contour and relational interval information are extracted automatically in relatively early stages of processing in auditory cortex. They further indicate that processing melodic contour and interval information involves a widely distributed neural network that can be dissociated into automatic and controlled processes.

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