Evidence of Spatially-Tuned Auditory Analysers

Russell L. Martin and Ester Klimek

Abstract: The primary-plus-probe uncertainty technique was used to explore the possibility that analysers tuned to different spatial locations exist within the human auditory system. Eight subject's psychometric functions for detection of a 500 Hz tone when presented from each of two locations referred to as the primary and probe were measured in each of two conditions. In the first, the intermixed condition, subjects knew that 80% of signals would be presented from one location (the primary) and 20% would be presented from the other (the probe). In the second, subjects knew that all signals would be presented from either the primary or probe location. For each subject the primary location was 0 degrees azimuth for half the sessions and 90 degrees for the others. Each function was measured using a two-interval forced-choice task and five signal levels ranging from 7.5 dB above to 4.5 dB below the subject's previously estimated threshold. For primary location signals, average functions for the two conditions were indistinguishable. For probe location signals, however, functions differed, reflecting significantly poorer detection performance in the intermixed condition \(F(1,7)=22.38, p<0.01\). This uncertainty effect provides support for the notion that the human auditory system contains analysers tuned to different spatial locations.

INTRODUCTION

It is well established that our ability to comprehend target speech in the presence of masking speech and other noise is greatly enhanced when the target and masker sources are spatially separated (eg., 1-4). This enhancement is likely to result from the operation of neural mechanisms that allow us to attend selectively to auditory signals that emanate from particular locations in space. A necessary component of any such mechanism is a set of analysers, or filters, tuned to different spatial locations. In the study described here, the primary-plus-probe uncertainty technique (5) was used to seek evidence of the existence of these analysers within the human auditory system.

METHOD

Five males and three females ranging in age from 21 to 33 years participated in this study. All had normal hearing as revealed by standard audiometric testing.

For each subject, four psychometric functions were measured describing their ability to detect a 500 Hz tone of 200 ms duration incorporating 10 ms rise and decay times. One when the signal was presented from a location referred to as the primary and one when it was presented from a location referred to as the probe in each of two conditions. In the first, the intermixed condition, subjects knew that 80% of signals would be presented from one location (the primary) and 20% would be presented from the other (the probe). In the second, the alone condition, subjects knew that all signals would be presented from the primary or probe location only. All functions were derived from pooled data collected across eight experimental sessions. For each subject the primary location was 0 degrees azimuth for four sessions and 90 degrees for the others. During each session, two blocks of intermixed and two of alone trials were presented. Each intermixed block was divided into two half-blocks, each of which contained 60 trials where signals were presented from the primary location and 15 where they were presented from the probe location. These 75 trials comprised of twelve primary and three probe location trials at each of five signal levels ranging from 7.5 dB above to 4.5 dB below the subject's previously estimated threshold in steps of 3 dB. The signal level on any given trial was randomised except for this constraint. Each alone block was also divided into two half-blocks. One contained 75 primary location trials (15 at each of the five signal levels) and the other contained 75 probe location trials. For each subject, therefore, both the primary and probe location psychometric functions in the alone condition were based on data from 1200 trials, while in the intermixed condition the primary location function was based on 960 trials and the probe on 240. Order with respect to 0 and
90 degree azimuth primary location sessions, intermixed and alone blocks within sessions, and primary and probe location half-blocks within blocks was counterbalanced across subjects.

On each trial the subject's task was to determine during which of two time intervals the signal was presented. The relevant intervals were separated by 500 ms and were signified by two 220 ms duration light pulses emitted from a light emitting diode located immediately in front of the subject. All tests were carried out in a sound-attenuated, anechoic chamber.

RESULTS AND DISCUSSION

Psychometric functions for the primary and probe locations in the alone and intermixed conditions averaged across all eight subjects are presented in Tables 1 and 2.

**TABLE 1.** Average psychometric functions for the primary location in intermixed and alone conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>+7.5 dB</th>
<th>+4.5 dB</th>
<th>+1.5 dB</th>
<th>-1.5 dB</th>
<th>-3 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermixed</td>
<td>94.4</td>
<td>90.0</td>
<td>78.4</td>
<td>63.5</td>
<td>56.7</td>
</tr>
<tr>
<td>Alone</td>
<td>95.3</td>
<td>90.0</td>
<td>79.7</td>
<td>65.3</td>
<td>57.0</td>
</tr>
</tbody>
</table>

**TABLE 2.** Average psychometric functions for the probe location in intermixed and alone conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>+7.5 dB</th>
<th>+4.5 dB</th>
<th>+1.5 dB</th>
<th>-1.5 dB</th>
<th>-3 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermixed</td>
<td>93.7</td>
<td>87.0</td>
<td>72.4</td>
<td>62.1</td>
<td>52.2</td>
</tr>
<tr>
<td>Alone</td>
<td>93.8</td>
<td>88.5</td>
<td>78.1</td>
<td>64.1</td>
<td>57.6</td>
</tr>
</tbody>
</table>

For primary location signals (Table 1), average functions for the two conditions were statistically indistinguishable. This suggests that subjects directed their attention in the intermixed condition to the primary location, as was appropriate given that the majority of signals were presented from there. For probe location signals (Table 2), however, functions for the two conditions differed, with percent correct detections being lower at each signal level in the intermixed condition. An analysis of variance revealed that this difference was statistically significant \( F(1,7)=22.38, p<.01 \). Poorer detection performance for probe location signals in the intermixed condition also is consistent with subjects directing their attention in this condition to the primary location. Furthermore, it can be taken as evidence of the existence of auditory analysers tuned to this location.

REFERENCES