Introduction and Background

The ability to utilize interaural difference cues to determine the location of a sound source is a benefit of binaural hearing. Monaural listeners must rely on the overall level and spectral shape to determine if a sound is in the left or right. Unfortunately, these spectral cues are unreliable because many sounds (like speech) have levels and spectral shapes that vary. Here, we tested the ability of subjects to monaurally discriminate between virtual sources, located to the left and right of the midline, that were producing stimuli with random overall levels and spectral shapes.

Traditional linear decision models provide predictions about the effects of spectral variability on discrimination performance. These models assume that each frequency component of the stimulus is given a certain weight. These models allow the weights to vary across individuals, but assumes that for each individual the weights are fixed and applied without any noise. Here, we extend these models of spectral shape discrimination to allow for noise in the weighting of each component.

Methods

- **Task**: To discriminate between sources located ±30° from midline when listening monaurally.
- **Stimuli**: Headphones were used to present monaural stimuli.
- **Stimulus Levels**: The overall level of the stimuli for both the left and right headphones was fixed at 60 dB. The level of each frequency component was independently varied across trials by adding a fixed level deviation, 0, 1, 2, 4, or 8 dB.
- **Feedback**: Provided after every trial.

**Spectral Shape Perturbation**

- Weighting of each frequency component is perturbed across trials by independently varying the weights of each component. Five different standard deviations of 0, 1, 2, 4, or 8 dB were used.
- Spectral shape was perturbed across trials by independently varying the levels of each frequency component; five different standard deviations were used (0, 1, 2, 4, and 8 dB).

### Linear Decision Model Predictions

We extend the linear decision model to include a weighting noise $\eta_w$ in addition to the internal channel noise $\eta_i$. For this model the decision variable $Y$ and $d'$ are given by:

$$Y = \sum_i \left( X_i + \eta_i \right)$$

$$d' = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp\left( -\frac{Y^2}{2\sigma^2} \right) dY$$

- The weighting noise $\eta_w$ changes the variance of the decision variable $Y$, but does not change the mean of $Y$.
- Model was fitted to the data with:
  - Optimal weights with internal channel noise
  - Measured weights with internal channel noise
  - Measured weights with internal channel noise and weighting noise

<table>
<thead>
<tr>
<th>Stimulus (dB)</th>
<th>Difference (dB)</th>
<th>$d'$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0</td>
<td>0.84</td>
</tr>
<tr>
<td>30</td>
<td>0</td>
<td>0.75</td>
</tr>
<tr>
<td>35</td>
<td>0</td>
<td>0.68</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Table 1. Parameters ($\sigma_i$ and $\sigma_w$) used in fitting the model and the percent of the variability in the measured $d'$ accounted for by the model predictions.

**Relative Weights**

- To obtain the same $d'$, a linear decision model with non-optimal weights requires less internal noise (smaller $\sigma_i$) than a linear decision model with optimal weights.
- Reducing $\sigma_i$ results in the performance of a linear decision model falling off faster.
- For each subject, weights were measured with two different values of $\sigma_i$. These measurements are independent of the measurements of $\sigma_w$ shown in Fig. 2.

**Summary**

- With moderate amounts of external variability subjects can still reliably discriminate between virtual sources located ±30° from midline when listening monaurally.
- Potentially the information used for discrimination between source locations could provide a segregation cue allowing monaural listeners to obtain a spatial release from masking.
- The weights reveal inefficiencies in the decision strategies of the subjects.
- Discrimination performance can be predicted with a linear decision model which incorporates both weighting noise and internal noise.

**Acknowledgements**

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