

JSmasklab: An Interactive Experiment for Measuring Auditory Frequency Masking

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This project explores an online interactive experiment, JSmasklab, for the purpose of accessibly measuring personal frequency masking curves across masker frequencies of 500, 1000, and 2000 Hz. User response is measured using a two-interval, forced-choice (2IFC) staircase method in order to reduce answering bias. The first mode is the "baseline" mode, where one interval contains the probe tone, and the other contains silence. There is no masker frequency present in this mode. The second is the "with masker" mode, where one interval contains just a masker frequency, and the other contains a masker frequency with a probe tone. Users must choose the interval that they believe has the probe tone in both modes. The results from these two different measurements provide the overall "masking amount" curve plot. Results reveal that masking is greatest closest to the masker center frequency, and asymmetric masking occurs above and below each masking center.

Keywords: Psychoacoustics, Frequency masking, Auditory frequency selectivity, Critical bands, Detection thresholds, Adaptive staircase, Two-interval forced choice (2IFC)

1 INTRODUCTION

Auditory masking refers to when one sound's presence increases the detection threshold of another. More specifically, in frequency-dependent masking, the fluid wave that comes from one sound and travels along the basilar membrane becomes suppressed if there is another larger wave near the same characteristic place of the basilar membrane, representative of a louder masker sound. These masking instances can be measured and formed into what is known as a masking curve for a specified number of frequencies. Because ear anatomy varies from person-to-person, everyone experiences auditory masking differently, leading to individualized masking curves. JSmasklab works to provide users with an available and accessible resource to measure their own personal frequency masking curves.

2 BUILDING THE MODEL

JSmasklab was built as a standalone, web-based application through HTML, CSS, and JavaScript. While the HTML and CSS files handle user interface and site appearance, the JS files manage functionality including audio generation, measurement methods, and plots. The overall goal for the building portion of the experiment was to maximize accessibility, so running the platform locally in a browser avoids compatibility issues and the need for application installation.

The interface of JSmasklab is shown in Figure 1 and contains three views: Experiment, Results, and Method & Notes. Users can choose the masker frequency, masker level, probe frequency, and probe level. Trial playback options of the probe tone alone and the two interval choices are available to the user before beginning the session. To respond during the test, users make a choice between two intervals of which they believe the probe tone is present in.

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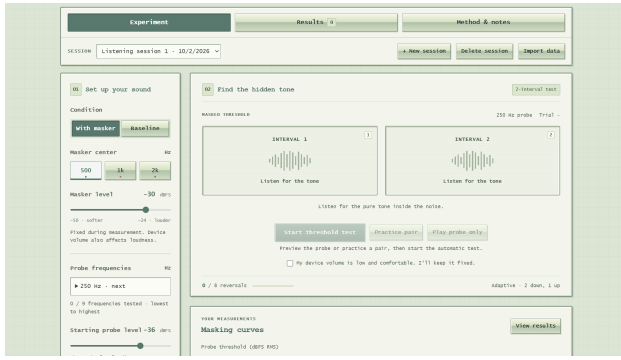


Fig. 1. Home page interface of JSmasklab, showing Experiment, Results, and Method & Notes page options, along with test interface.

Default masker frequencies of either 500, 1000, or 2000 Hz allow for measurement sample spacing of an octave, while maintaining consistent comparisons through ratios of probe frequencies per masker center. A total of nine probe frequencies are generated for each masker center, spanning from 0.5x to 2x the frequency value:

Listing 1. Probe frequency ratios.

```
const RATIOS = [.5, .7, .85, .95, 1, 1.05, 1.2, 1.5, 2];
```

```
function frequencies(center) {
  return RATIOS.map(r => Math.round(
    center * r));
}
```

The masker is comprised of 48 different sinusoidal elements with randomly assigned frequencies within 1/6 of an octave band from the center. Contrastingly, the probe is a pure sinusoidal tone. Since the playback system is not calibrated in dB SPL between users, levels are expressed as dBFS RMS.

After a test for a masker and probe frequency pair has been completed by the user, a point on the "Your masking curves" result plot, as shown in Figure 2, is placed in relation to the determined threshold value. This process continues until all probe values for each masker frequency have been tested and plotted. The baseline mode uses this same framework, but removes the masker frequency and only focuses on the probe tone. Frequency menus within the "Set up your sound" block act as checklists to keep track of which frequencies have been completed in the current session.

Masking curve measurements are automatically saved in browser storage, and users can alternatively export their data to CSV or JSON files.

3 METHOD OF MEASUREMENT

For this self-paced experiment, the measurements are obtained using a two-interval forced-choice (2IFC) staircase implementation. Each trial within a test consists of two 600 ms intervals separated by a 350 ms pause, where one of the

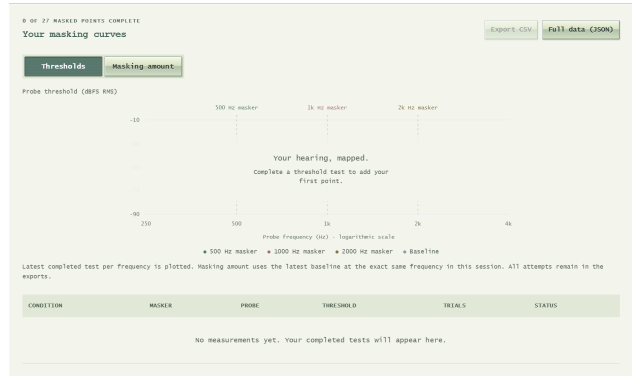


Fig. 2. Personalized masking curve results plot on "Results" view, pre-session.

intervals contains the masker and a 300 ms probe, while the other only contains the masker. The interval containing the probe is randomized, and the user has to pick which interval they believe contains the probe tone.

After the user gets two responses correct, the probe level decreases by 4 dB. An incorrect response increases the level of the probe. A reversal occurs when the direction of level adjustment changes, with step sizes decreasing from 4 dB to 2 dB after two reversals are recorded. A total of eight reversals results in continuing to the next probe frequency.

The adaptive staircase portion of the measurement procedure follows the framework discussed by Levitt (1971) in his paper *Transformed Up-Down Methods in Psychoacoustics* [1]. Levitt touches on using eight reversals to determine a threshold, which is calculated by disregarding the first two reversals and instead looking at the final six reversal levels.

Additionally and separate from Levitt's method, the program calculates the mean of the final six reversal levels and uses that as the threshold value to reduce any influences from individual responses. The equation for the threshold level is as follows:

$$L_{\text{threshold}} = \frac{1}{6} \sum_{i=3}^8 L_i \quad (1)$$

where L_i is the probe level in dBFS RMS at the i th reversal.

Masking amount was calculated as the masked threshold minus the baseline threshold at the same probe frequency.

4 DISCUSSION AND LIMITATIONS

4.1 Critical-Band Behavior

The results of this experiment remain consistent with critical-bandwidth behavior principles. More specifically, as seen in the masking amount plot in Figure 3, masking is strongest at the center of each masking frequency. As the probe frequency moves further away from the masker center frequency, the masking amount decreases.

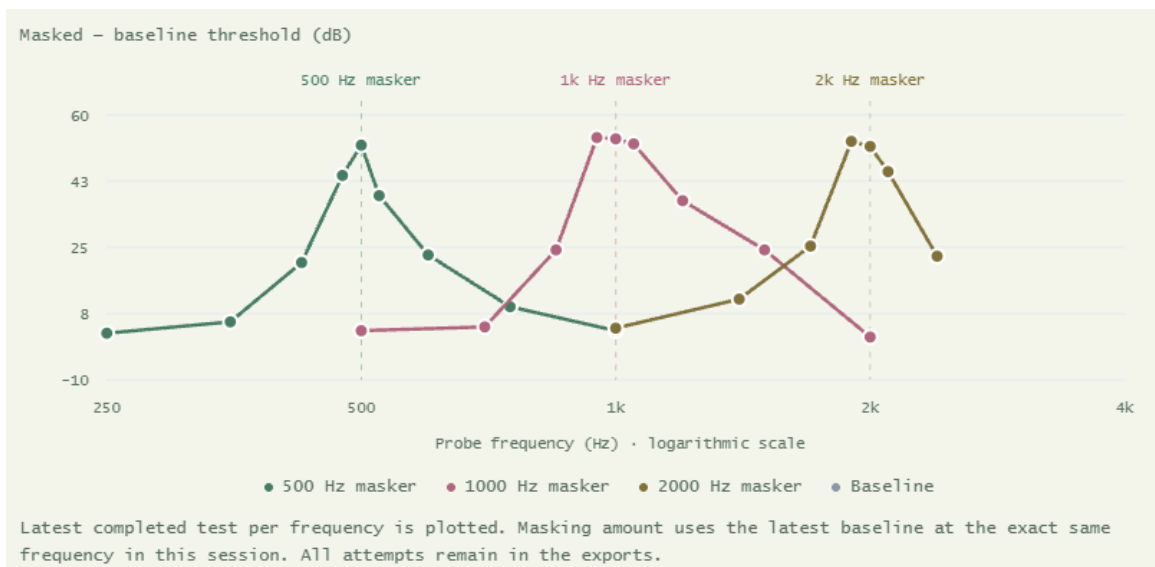


Fig. 3. Personally measured masking amounts for masker center frequencies of 500, 1000, and 2000 Hz.

This further demonstrates the process of auditory filtering in the cochlea because the human ear is sensitive to a range of frequencies in reference to a center frequency. The further away that the probe frequency is from that range, the easier it is for the cochlea to filter out the probe frequency from the masker frequency.

4.2 Masking Asymmetry

The 1000 Hz masker frequency line on the plot shown in Figure 3 demonstrates the asymmetry of masking levels above and below a masker frequency center. The general shape of the curve displays a sudden increase leading up to the masker center frequency, along with a more gradual decline in masking as the frequency increases away from the masker center.

Though this phenomenon is not as visually clear in the masker frequency centers of 500 Hz and 2000 Hz, the 1000 Hz center frequency line remains consistent with the non-linear response of the cochlea depending on level. This is better known as the upward spread of masking.

4.3 Masker Frequency Differences

It is important to note that the masking amount plot in Figure 3 contains a logarithmic frequency scale on its x-axis. This means that while general masking ranges surrounding each center frequency might look similar, the difference in hertz is realistically much greater.

For example, at the 2000 Hz masker frequency center, the masking range for above an 8 dB masking amount is approximately 1050 Hz. On the other hand, the masking range for the 1000 Hz masker frequency center for above an 8 dB masking amount, though it visually looks similar to the 2000 Hz center, is approximately 400 Hz. This portrays the idea that the ear's masking range, with reference to a center frequency, increases alongside the center frequency.

4.4 Experimental Limitations

One limitation of this online experiment is that levels are measured and reported in dBFS RMS as opposed to dB SPL. Because playback systems differ from user-to-user, they are unable to be acoustically calibrated to dB SPL. This may lead to limits when comparing frequencies and playback systems.

Another limitation of JSmasklab is its potential for variation in measurements. This may manifest as a result of either fatigue, due to the lengthy nature of the experiment, or guessing, since the measurement uses a forced choice method. Repeated experiments would be required per-user to avoid random deviations in the measurements.

A third limitation of the experiment is that the session uses a fixed masker level. The true width of a masking curve depends on differing masker levels, meaning that the generated results plots cannot be interpreted directly as measures of bandwidth.

5 CONCLUSION

JSmasklab provides an interactive experiment method for measuring personal frequency masking curves. In using a two-interval, forced-choice staircase measurement method, results from the experiment remain consistent with human ear anatomy phenomena. Masking was shown to be greatest near to the masker frequency centers. The masking curves also revealed that asymmetric masking occurs above and below a masker frequency center, with masking amount decreasing more gradually above a center than below. However, limitations such as lack of calibration, measurement variability, and the fixation of masker level can impact the masking curve results. JSmasklab could be improved through repeated experiments and measurements.

6 SUPPLEMENTAL MATERIAL

JSmasklab can be downloaded at <https://github.com/jacesch/JSmasklab>. Alternatively, the site can be accessed at <https://jacesch.github.io/JSmasklab/>.

7 ACKNOWLEDGMENT

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8 REFERENCES

[1] H. Levitt, "Transformed up-down methods in psychoacoustics," *The Journal of the Acoustical society of America*, vol. 49, no. 2B, pp. 467–477 (1971).

THE AUTHOR



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Jacey Schell is an audio engineer and DSP-focused developer pursuing a B.S. in Music Engineering Technology, a minor in Computer Engineering, and an M.S. in Music

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