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Investigation of the impact of pink and white noise in an auditory threshold of detection experiment

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ABSTRACT

Many listening experiments employ so-called "pink" and "white" noise, including those to find the threshold of detection (TOD). However, little research exists that compares the impacts of these two noises on a task. This study was an investigation of the TODs at whole and third octave bands using pink and white noise. A modified up-down method was utilized to determine the TOD in white and pink noise at eight frequency levels using a dB boosted bell filter convolved with the original signal. Six graduate students in audio engineering participated. Subjects were presented with an unfiltered reference signal followed by a filtered or unfiltered signal and then were instructed to respond "same" or "different". Correct answers decreased the filter boost while incorrect answers resulted in reversals that would increase the filter boost until the subject answered correctly. A trial would conclude when a total of ten reversals occurred. The filter boost levels of the last five reversals were collected to obtain an average threshold value. Results showed no significant differences between white and pink noise TOD levels at all frequency intervals. Additionally, the Just Noticeable Difference (JND) between the original and the boosted signal was observed to be ±3 dB, consistent with existing literature. Therefore, it can be suggested that white or pink noise can be equivalently employed in listening tests such as TOD measurements without impact on perceptual performance.

1 Introduction

A common practice in perceptual listening experiments is to find the threshold of detection (TOD). This is established when a minimum detected perceivable level is found. [1] The basis of detected thresholds is finding the central decision level by means of procedures following psychometric functions. Psychoacoustic research uses various methods, such as the staircase method, to determine an auditory threshold estimation. [2]

Pink and white noise are respectively defined as equal energy across octaves and equal energy across frequency bands. [3] [4] These noises are often utilized in perceptual listening tests. [2] However, there appears to be little research as to the reasoning for why one or the other may or should be employed. Pink noise was selected by Olive et al. due to subjects being more sensitive to the presence of resonances at given Q values. [5] Another study used pink noise due to similarities in frequency attenuation to the human auditory system. [6] A keyword search of "perceptual threshold white noise" returned only one relevant study by Miller that benchmarked perceptual

sensitivity to changes in white noise as compared to those observed with pure tones. [7] There are other instances in which bandpass filters are created using white noise. [8]

This study investigated the differences in the TODs at whole and third octave bands measured using so-called "pink" and "white" noise. The purpose of this research was to determine if there are measurable differences between perceptual performance obtained using pink and white noise conditions, and thus, to determine if one or the other may be more suitable for use in perceptual listening tests.

2 Methods

The stimuli were pink and white noise convolved with a bell-filter (a 12 dB per octave slope) with boost increments from 0.5 dB to 9.0 dB for eight octave bands. Octave bands were defined at central frequencies of 125, 250, 500, 1000, and 4000 Hz. Third-octave bands were specified at 2000, 2500, and 3150 Hz for their association with speech recognition in those bands. Figure 1 shows an example of a bell filter with various levels of boost at 250 Hz frequency band. Additional bands are shown with a 4 dB boost to display the whole and third octave bands used in trials.

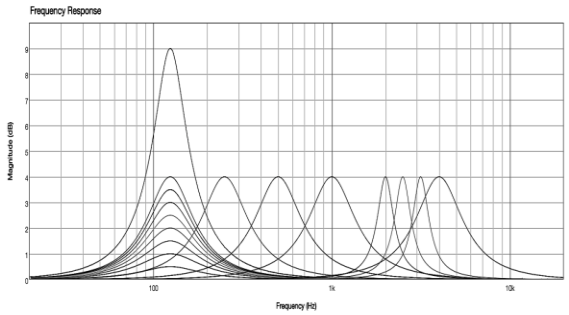


Figure 1. An example of a bell filter with various levels of boost at 250 Hz frequency band. Additional bands are shown with a 4 dB boost to display the whole and third octave bands used in trials.

Six graduate students (five males and one female) in their mid-20s with self-reported normal hearing participated. All but one had completed a graduate level critical listening course. Testing was conducted over a duration of four weeks in a semi-anechoic environment with Sennheiser HD 280 headphones and a specified frequency response of ±3 dB.

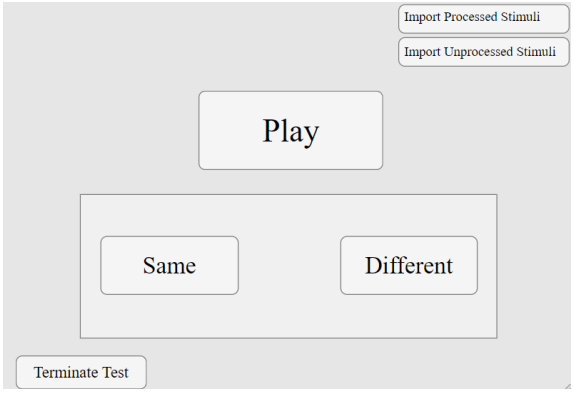


Figure 2. MATLAB interface used to conduct trials using the modified up-down method.

Each subject participated in the experiment using a MATLAB interface, shown above in Figure 2, based on an earlier study [9], listening at a self-determined comfortable listening level. A modified up down method [10] [11] was used, where the strongest boost increment was introduced and then decremented in 0.5 dB steps until ten consecutive reversals occurred, at which point the trial was completed. Subjects were required to respond "same" or "different" after listening to an unfiltered reference signal followed by either a filtered or unfiltered signal. If the subject correctly identified the stimuli as "same" or "different," the filter boost would decrease by 0.5 dB. Incorrect responses resulted in reversals with a 0.5 dB increase in filter boost in the following trial. The filter boost level at reversals was recorded. Once a trial was finished, the average of the five last reversals was calculated as an estimated threshold value to avoid pre-emptive threshold identification. In total, 16 trials were conducted for each of eight frequency bands and two noise types.

3 Results

A non-parametric analysis of variance (ANOVA) revealed a significant influence of subject response ($F(16,5) = 34.7$, $p < .001$). A Wilcoxon test indicated one subject's mean TOD (5.7 dB) was significantly higher than the rest ($Z = 2.55$, $p = .01$, $N = 16$), suggesting a different proficiency of perceptual resolution, as can be seen from Figure 3. Therefore, the data from this subject were excluded from further analyses.

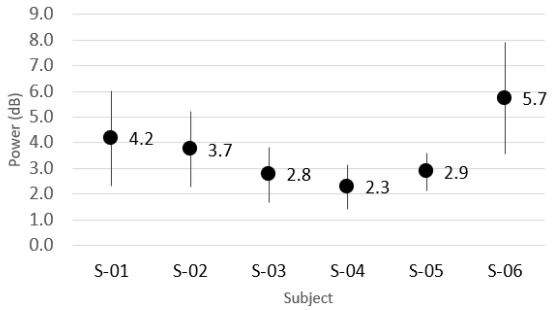


Figure 3. Average TOD values across all bands for each subject. Subject 6's data were removed from further analyses.

Table 1 shows TOD levels across all bands and all five subjects with a mean of 3.17 dB and standard deviation of 0.6 dB ("All" column). This is consistent with previous findings of a ±3 dB sensitivity difference in human auditory perception between two stimuli, or in this case boosted and original signal. [12] [13] The "Pink" and "White" columns report similar means and standard deviation values. Estimated thresholds were not normally distributed.

	All	Pink	White
M	3.17	3.04	3.30
SD	0.60	0.63	0.57
N	10	5	5

Table 1. TOD means and standard deviations of pink and white noise across all bands.

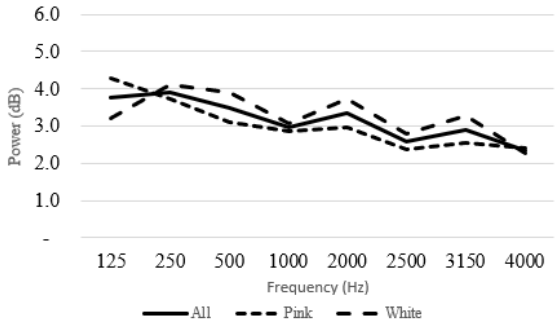


Figure 4. TODs measured for each frequency band using white and pink noise. Trials of pink and white noise were averaged at each frequency to find "All" averages at each band.

Figure 4 displays average TOD values obtained at each of whole and third octave band frequencies using white and pink noise (connected in short dashed and long dashed lines, respectively). The "All" TOD means connected in a solid line were averaged from the average TODs from "Pink" and "White" noises. The lines are for visual guidelines only; they do not carry any importance themselves.

Non-parametric ANOVAs for each frequency band found no influence of pink ($F(7,5) = 9.47$, $p = .22$) or white noise ($F(7,5) = 7.68$, $p = .36$). A *Wilcoxon* test found no significant difference between TOD levels measured using pink and white noise across all bands ($Z = 1.22$, $p = .22$, $N = 40$).

4 Discussion

In this study, TODs at whole and third octave bands using pink and white noise were measured to examine a possible impact of the type of noise used in the task. An analysis of the average TOD values revealed one subject having a higher detection threshold than the rest of the subjects. ANOVA and *Wilcoxon* tests were conducted and found that the subject's average TOD had a significant effect on the dataset. Therefore, the data from this specific subject had to be removed from further analyses. This step of data verification was important with the small number of subjects so that an excessive weighting of outlier values could be avoided.

The TODs measured with pink and white noise showed no significant differences based on the noise type, which suggests that either noise can be used equivalently for a TOD task. Also, the average of all TODs across frequencies and subjects was 3.17 dB, which agreed with the auditory JND reported in earlier studies. This validates our study since the task of TOD measurement using one type of noise is essentially the same as a JND measurement using the same noise.

5 Conclusion

In this investigation, pink and white noise TOD levels were found to have no significant differences across all whole and third octave bands that were examined. In the field of psychoacoustics, the results of this study would be beneficial to threshold experiments. Findings suggest that pink or white noise can be equivalently employed in TOD tests without an impact on performance.

Although both white and pink noise led to similar TOD values in this study, the results should be carefully interpreted. This lack of difference could come from the limited number of subjects. A follow-

up study is required with more subjects to develop a stronger conclusion. Also, adaptive step sizes for the up-down method may be beneficial in the future rather than the fixed step size of 0.5 dB to gather more accurate thresholds from subjects.

References

[1] A. Soranzo and M. Grassi, "PSYCHOACOUSTICS: A comprehensive MATLAB toolbox for testing," *Frontiers in Psychology*, vol. 5, 2014, doi: 10.3389/fpsyg.2014.00712.

[2] D. R. Luce, "A threshold theory for simple detection experiments," *Psychological Review*, vol. 70, no. 1, pp. 61-79, 1963.

[3] "pink noise," Merriam-webster.com, 2019. [Online]. Available: https://www.merriam-webster.com/dictionary/pink%20noise. [Accessed: Apr. 22, 2024].

[4] "white noise," Merriam-webster.com, 2019. [Online]. Available: https://www.merriam-webster.com/dictionary/white%20noise. [Accessed: Apr. 22, 2024].

[5] S. E. Olive, P. L. Schuck, J. G. Ryan, S. L. Sally, and M. E. Bonneville, "The Detection Thresholds of Resonances at Low Frequencies," Acoustics and Signal Processing, Institute for Microstructural Sciences, National Research Council, Ottawa; Ont., Canada, Canadian Audio Research Consortium, Audio Products International Ltd., Scarborough, Ont., Canada, 1997. [Online]. Available: https://aes2.org/publications/elibrary-page/?id=7868. [Accessed: Aug. 10, 2024].

[6] E. Burke, J. Hensel, T. Fedtke, S. Uppenkamp, and C. Koch, "Detection Thresholds for Combined Infrasound and Audio-Frequency Stimuli," *Acta Acustica United with Acustica*, vol. 105, pp. 1173-1182, 2019.

[7] G. A. Miller, "Sensitivity to changes in the intensity of white noise and its relation to masking and loudness," *Journal of the Acoustical Society of America*, pp. 609-619, 1947.

[8] C. Lorenzi, M. I. G. Simpson, R. E. Millman, T. D. Griffiths, W. P. Woods, A. Rees, and G. G. R. Green, "Second-order modulation detection thresholds for pure-tone and narrow-band noise carriers," *Journal of the Acoustical Society of America*, vol. 110, no. 5, pp. 2470-2478, Nov. 2001.

[9] C. Hickman and W. Bulla, "Just Noticeable Difference for Dynamic Range 'Limiting' of a Stereophonic Mix," *Audio Engineering Society Convention 147*, New York, 2019.

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

[11] T. Cornsweet, "The Staircase-Method in Psychophysics," *The American Journal of Psychology*, vol. 75, no. 3, pp. 485-491, 1962.

[12] D. McShefferty, W. M. Whitmer, and M. A. Akeroyd, "The Just-Noticeable Difference in Speech-to-Noise Ratio," Trends Ear, vol. 19, 2015.

[13] B. C. J. Moore, "Psychoacoustics," in *Springer Handbook of Acoustics*, T. D. Rossing, Ed. New York, NY, USA: Springer, 2007, pp. 461-481