Sensory Impact of Removing Pure Tones from Complex Vibrations

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I. Introduction

Compared to sinusoidal vibrations (one tone), little is known on the mechanisms underlying the ability to discriminate between complex signals (at least two tones), that are more representative of those occurring in natural tactile scene [1]. On one hand, studies have found that comparing two simple signals appears easier than comparing two complex signals, suggesting that complexity affect discrimination [2]. On the other hand, harmonic relationship between frequency seems to be also a potential cue [3]. However, most of the studies predominantly focused on signals composed of two frequencies which were usually chosen in the range of the Pacinian channel. Therefore, the present study aims to evaluate the effect of removal frequency on the perception of vibrotactile signals encompassing up to four pure tones with varying complexity and harmonicity targeting both Meissner and Pacinian channel.

II. Material and Methods

Thirty vibrotactile signals were created from two sets of four pure tones: 60, 120, 180, 240 Hz (Harmonic condition) and 75, 135, 195, 255 Hz (Non-harmonic condition) to create complex signals with the sum of two, three or four pure tones, which are equalized in peak acceleration amplitude (7 m/s^2). Signals from a computer are sent to a voice-coil actuator (Tactuator MM3C-HF, TactileLabs Inc.). Twelve participants performed a 3-AFC task in which participant's task was to differentiate two signals of which one had a pure tone removed. The two identical complex signals are called the REFERENCE signal while the remaining one was a signal with a REMOVED PURE TONE. After each trial, they indicated which one of three signals was different from the other two. Given the fifteen signals, 28 different comparisons were possible per condition: 4 tones vs. 3 tones ("Four-tones"), 3 tones vs. 2 tones ("Three-tones") and 2 tones vs. 1 tone ("Two-tones"). Each comparison was presented 8 times for a total of 448 signals per participant and condition. The actuator was placed on the top of the intermediate phalanx of their right hand's index finger, attached with a plaster. Pairs were analyzed separately according to their complexity using RStudio by designing a Generalized Linear Mixed Model (GLMM) including the following independent variables: REFERENCE, REMOVED PURE TONE, HARMONICITY (comparing the two conditions) which were tested by the analysis of deviance Wald chi-square tests. The ACCURACY (i.e., correct answer rate) was the dependent variable. Post hoc analyses were computed by using pairwise comparisons (Dunnett's method: <0.0001 '****', <0.001 '***', <0.01 '**', <0.05 '*').

III. Results

Main and interaction effects are depicted in Table. 1 while post-hoc tests are presented in Fig. 1. Overall, the results show strong discrimination when the lowest pure tone of the reference signal is removed. This effect is robust across the tested levels of signal complexity and was not impacted by harmonicity. Further investigations need to be performed on these points and the upcoming studies will focus on Pacinian channel exclusively and other inter-frequency interval.

TABLE I. EFFECTS OF WALD CHI-SQUARE TESTS (ALL PS <0.0001)

	Independent variables	χ2
Four-tones	REMOVED PURE TONE	82.9
Three-tones	REMOVED PURE TONE	77.5
	REFERENCE × REMOVED PURE TONE	189.7
Two-tones	REFERENCE	79.8
	REMOVED PURE TONE	107.1
	REFERENCE × REMOVED PURE TONE	118.5

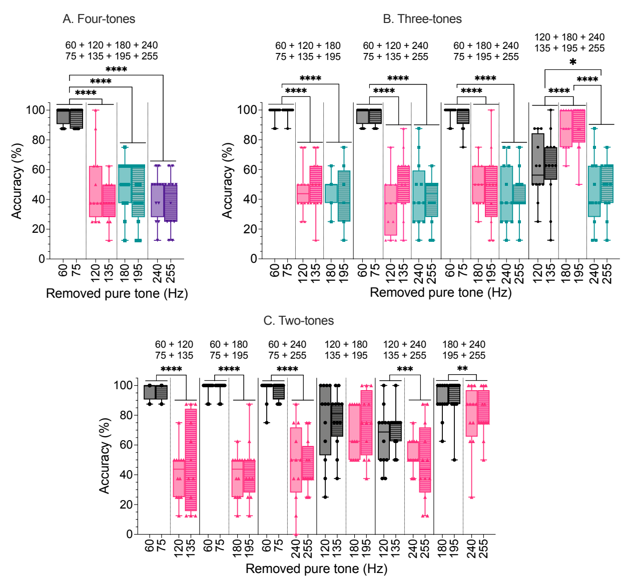

Figure 1. Accuracy (%) averaged across participants' individual data in Harmonic condition and Non-harmonic condition (hatched boxplots) as a function of (A) Four-tones, (B) Three-tones and (C) Two-tones.

References

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