ADAPTIVELY MATCHING PERCEPTUAL DURATION OF FLAT AND PERCUSSIVE TONES

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1 Introduction

Adaptive psychophysical procedures locate perceptual thresholds by dynamically altering stimuli based upon subject responses [1]. This offers greater efficiency as it maximizes trials about the thresholds of interest [2]. However, most approaches focus either on values that are (a) objectively equal or (b) thought to be equivalent based on priors. This approach is seldom used to find 'unknown' subjective thresholds.

Here we an adaptive approach to find the ratio at which sounds with different amplitudes are perceived equivalent in duration. Although prior research finds sounds with decaying amplitudes are perceived as shorter than sounds with constant or ramping amplitudes [3, 4, 5], the precise ratio of equivalence is not known. Here we use adaptive procedures to explore this value.

Accordingly, the present study measured the effectiveness of an adaptive procedure, specifically the adaptive staircase, in finding this unknown value. We designed a duration discrimination task measuring the point of equivalence between constant amplitude 'flat' and decaying amplitude 'percussive' tones.

2 Method

2.1 Subjects

We recruited 105 undergraduate students who completed the study online. We excluded those who spent more than ninety minutes on the task, and/or who failed to reach 'convergence' on all staircases (as defined below), resulting in 78 final subjects. Subjects took part in either a 'heterogenous' or 'homogenous' experiment, (N = 39 in each experiment).

2.2 Stimuli

Our stimuli consisted of 440Hz tones ranging in duration from 50 to 2025ms (in intervals of 25ms). The tones exhibited either a 'flat' or 'percussive' amplitude envelope, with flat tones ramping up over 2.5ms and maintaining a constant amplitude before decaying over 2.5ms. Percussive tones ramp up over 10ms before decaying exponentially for their remaining duration.

2.3 Procedure: Adaptive staircase

We used an interleaved, adaptive staircase design. Each trial presented a 'standard' tone and a 'comparator' tone in random order. Subjects indicated which tone (i.e., first or second) sounded longer. The comparator subsequently increased or decreased based upon participants' responses (the standard remained constant throughout the staircase).

The comparator began either 300ms above or below the standard tone's duration. We chose a 1-up 1-down design for this study, wherein every trial led to a change in the comparator. The comparator tone's duration initially changed by a step size of 200ms after each response, with this size halving after every two response reversals (i.e. changing from a response of "shorter" to "longer" than the comparison), to a minimum of 25ms. The staircase terminated after subjects either (a) reversed responses on four consecutive trials at the lowest step size (i.e. "converged") or (b) reached a maximum of 100 trials.

We blocked four interleaved staircases using percussive tones as the standard, and a second block of four interleaved staircases using flat tones as the standard (counterbalancing block order across participants). Trials then drew randomly from within a block's four staircases. In the heterogenous experiment the comparator and standard differed in envelope; in the homogenous experiment they exhibited the same envelope. Standard tones in each trial could be one of two potential durations: either 450/650ms for flat tones, or 675/975ms for percussive tones (we chose different values for flat and percussive in line with our prior intuition regarding the point of subjective equality).

3 Results

We excluded subjects whose final values differed by more than two standard deviations when approaching the same standard from above vs. below. This occurred similarly in the heterogenous (N = 6) and homogenous (N = 7) experiments.

3.1 Perceptual ratios

We used an ANOVA to assess if the ratios corresponding to the point of subjective equality between percussive and flat tones differed significantly from the grand mean (the overall ratio) (Fig 1). We found significant effects in the homogenous experiment for neither the standard duration ($F(1, 32) = 0.11$, $p = 0.75$), its envelope ($F(1, 32) = 1.02$, $p = 0.32$), nor the interaction ($F(1, 32) = 0.01$, $p = 0.92$). In the heterogenous experiment, neither standard duration ($F(1, 32) = 3.32$, $p = 0.08$) nor its envelope ($F(1, 32) = 0.08$, $p = 0.79$) produced significance. However we found a significant interaction between them, $F(1, 32) = 9.78$, $p < 0.01$. A post-hoc Sidak test found the two heterogenous percussive conditions differed significantly from one another, $t(32) = -3.19$, $p = 0.02$. We also conducted a Levene's test to check whether variance in

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ratios between the homogenous and heterogenous experiment differed. This was also found to be significant, $F(1, 258) = 90.87$, $p < 0.01$.

3.2 Slope coefficients

We conducted linear regressions for each experiment (Fig 2). One-way ANOVAs confirmed that subjects' slopes differ significantly from the overall slope in neither the homogenous ($F(1, 31) = 0.21$, $p = 0.64$) nor the heterogenous experiment ($F(1, 30) = 2.28$, $p = 0.14$). However, the variance of the slope coefficients differs substantially between experiments. A subsequent Levene's test found this difference in variation to be significant, $F(1, 63) = 30.10$, $p < 0.01$.

4 Discussion

Our homogenous results demonstrate the degree of accuracy for adaptive staircases as a tool for assessing duration. This is is important in interpreting results from our heterogenous experiment—which show considerably more variance—as it suggests that variance reflects either (a) difficulty in determining duration equivalence *across* envelopes, or (b) more individual variation in cross- vs. within-envelope duration assessment. Future research is needed to disambiguate.

Despite this variance, the heterogenous data show promise for the truth of its ratio and the paradigm's potential. Across averages of four staircases, subjects largely converged onto one ratio of flat to percussive duration. There were effects for neither standard duration nor envelope, suggesting consistent convergence to one ratio. Furthermore, though their slopes varied, most subjects presented a linear association between the durations of flat and percussive, thereby providing further assurance of their consistency, and consistent adherence to Weber's law. Although, the interaction effect wherein standard duration is significant for percussive standards casts some doubt on its adherence.

It is worth noting that some variance may be due to the online delivery of the experiment. Future iterations will be tested in lab to reduce online confounding variables. Furthermore, we only tested each subject in a small number of staircases, and not in both heterogenous and homogenous conditions. We will implement these in future studies to increase granularity and reduce potential false equivalency between the two conditions.

5 Conclusions

We tested the efficacy of an adaptive staircase procedure in finding an unknown perceptual threshold and found promising results for its potential, though with high variance. We will address this in future by testing in a controlled lab setting and extract more detail from each subject through a greater volume of testing.

Acknowledgments

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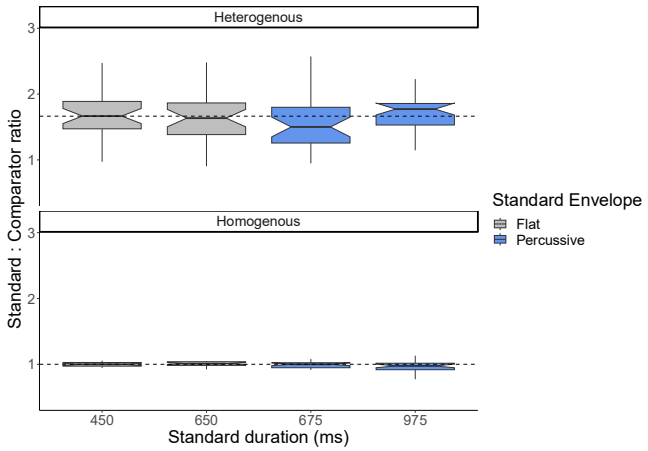

Figure 1: Boxplot presenting ratios of perceived duration between the standard and the comparator sounds for both the heterogenous and homogenous envelope experiments. Dotted lines represent the grand mean.

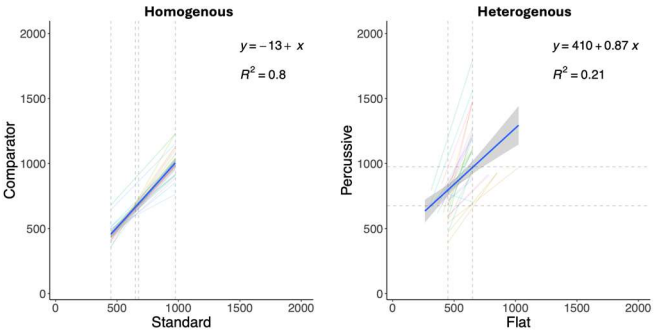

Figure 2: Linear regressions of flat against percussive duration (in ms) for heterogenous, and standard duration against comparator duration (in ms) for homogenous. Dotted lines represent standard durations and coloured lines represent individual subjects' lines.

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