Establishing Weber's Law for Time Perception using Auditory Interval Discrimination

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Abstract

18 subjects were tested to assess Weber's law for auditory interval discrimination with an adaptive staircase technique. Each subject performed judgments for three base intervals (500 ms, 1000 ms, 2000 ms), with just noticeable differences (JNDs) computed for each block. The resulting Weber fractions: 18.3%, 18.5% and 22.4% were shown to exhibit obvious consistency over durations (one-way ANOVA, $F = 0.91$, $p = 0.41$), and group-level regression provided $k = 21.4\%$ (95% CI: 16.4–26.5%, $R^2 = 0.979$), which supported Weber's law in this context. All participants responded well above chance and the data set was strong. As a secondary outcome, there were significant individual differences in threshold values, which were statistically verified ($F = 2.35$, $p = 0.017$). In addition, a negative correlation between accuracy and reaction time was established, and correct responses were made faster than incorrect ones. These results support Weber's law for auditory timing and demonstrate both significant individual differences and an association between the speed of decision and accuracy.

1 Experimental Methods

The experiment aimed to quantitatively evaluate Weber's law for auditory interval discrimination with a controlled adaptive staircase method.

Participants

18 participants (10 male, 8 female) were recruited. All reported normal hearing.

Stimuli

Three base durations were tested: 500 ms, 1000 ms, and 2000 ms. Auditory stimuli were pure tones (440 Hz, sine wave) produced by computer and presented via headphones. Two tones (one standard, one comparison) per trial, separated by 500 ms silence.

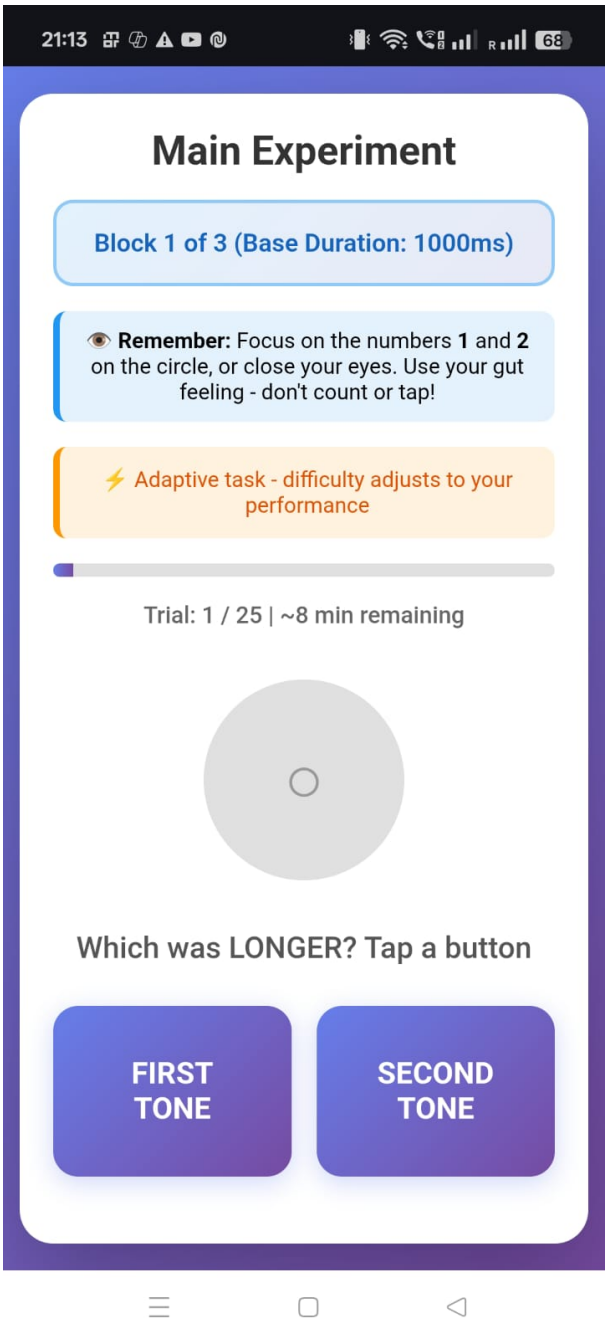


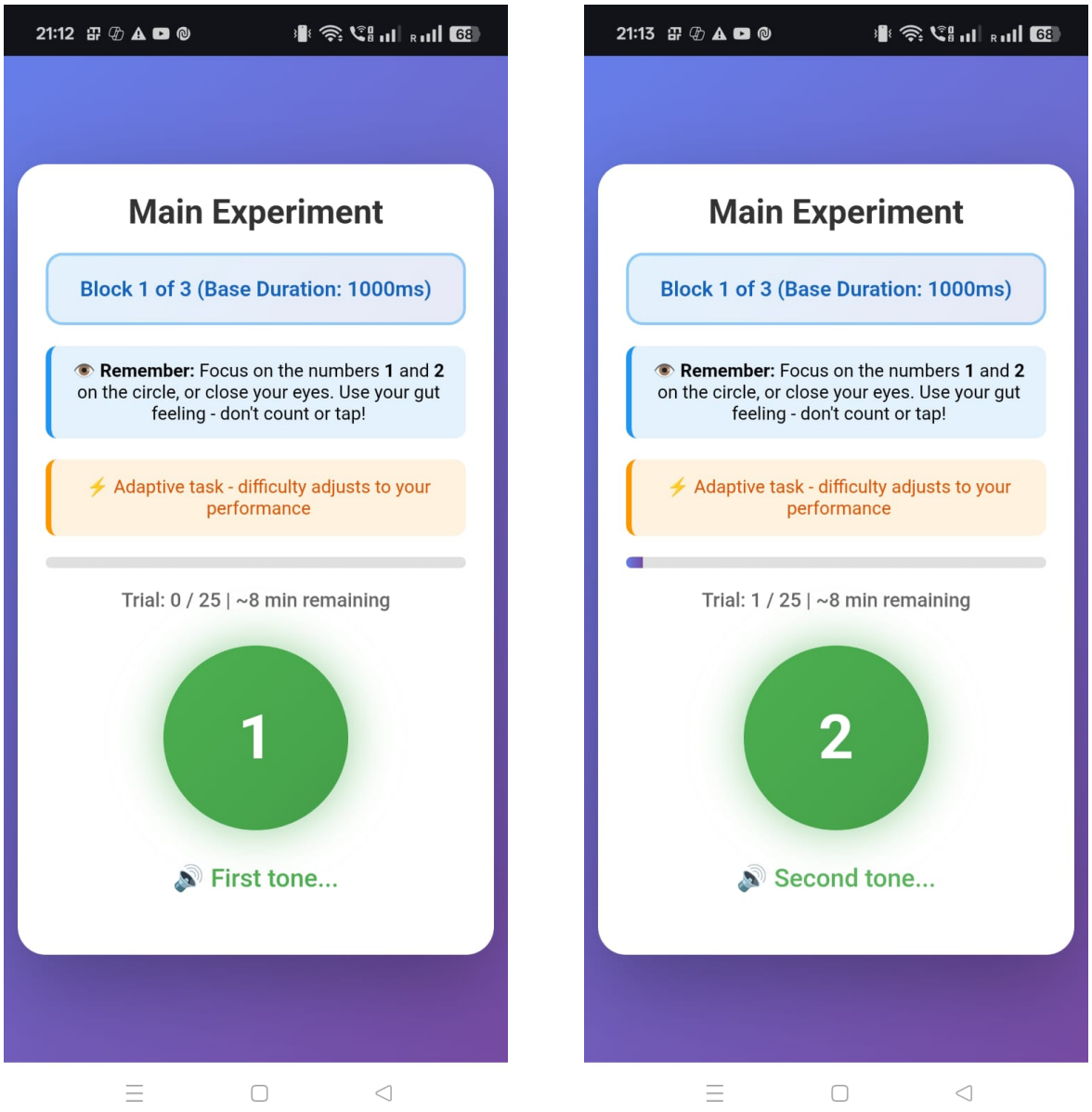
Figure 1: After stimulus presentation, the participant clicked either “First Tone” or “Second Tone”

Trial Design

Each base duration was tested in a separate block per subject. Block order was randomized. Within block, the standard interval was randomly "roved" per trial within ±10% of the base. The comparison duration started 50% longer than standard ($d_{\text{start}} = 0.5$):

$$d = \frac{\text{Comparison} - \text{Standard}}{\text{Standard}}$$

Participants indicated by button press which tone seemed longer (first or second). Each block contained 22-25 trials per participant. Across all subjects and blocks, a total of 1422 trials were run.



(a) First tone presentation (b) Second tone presentation

Figure 2: Screenshots of participant interface for each tone presentation

Adaptive Staircase Procedure

- If two successive correct responses: $d_{\text{new}} = \max(0.05, d - \Delta d)$
- If one incorrect response: $d_{\text{new}} = d + \Delta d$

Initial step size $\Delta d = 0.08$ (first 4 reversals), after which $\Delta d = 0.02$. A reversal was noted whenever the direction of d reversed. No feedback on correctness was given.

Controls

- Randomized block and trial order, standard/comparison position
- Quiet environment, headphones for all participants
- Standard instructions and practice prior to data collection
- No hypothesis disclosure to participants

Threshold Estimation

For each participant and block, JND was estimated as the mean value of d at reversal trials (at least 3 reversals required for inclusion).

Results

a) Does the data confirm Weber's Law? What is the Weber's Fraction?

Establishing Weber's Law: Methods Overview

- JND is calculated for each subjects and each block. (≥ 3 reversals)
- Mean JND is computed for each block for a subject by taking average of the *(comparison - standard)* at the reversal trials and then for each block we take mean over subjects to get final mean JND for each block.
- Then, mean JND vs base duration is plotted , error bars showing SD.
- A straight line passing through origin is fit, ensuring zero intercept: JND $= k \times$ Duration. Slope k is the canonical Weber fraction
- Then we test constancy of Weber fraction across blocks using one-way ANOVA.

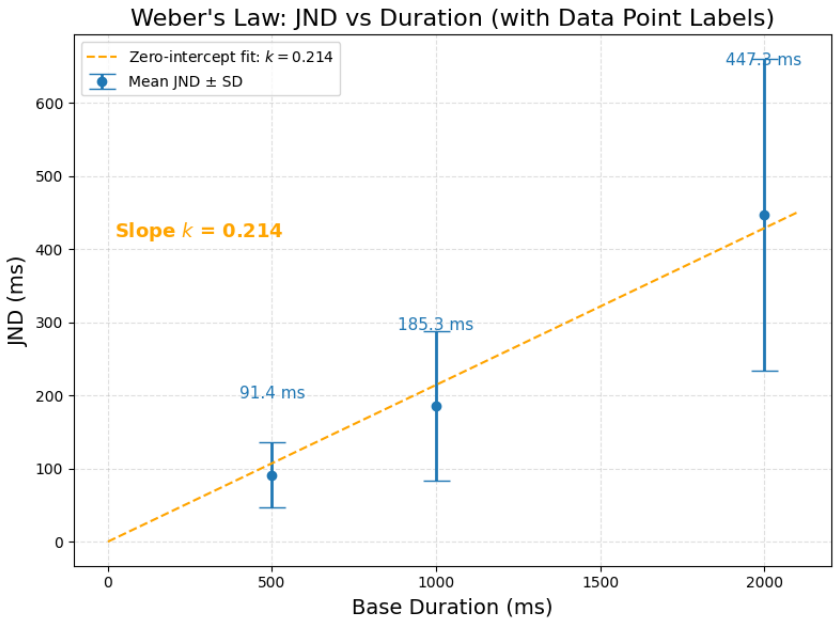


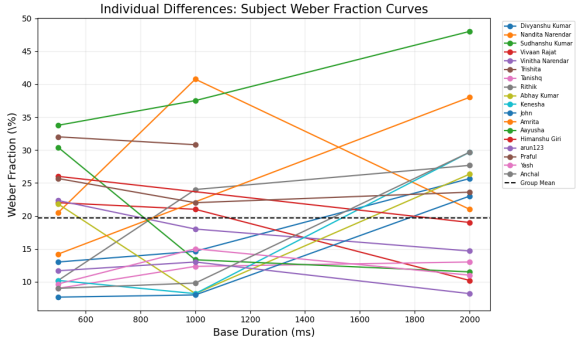
Figure 3: Mean JND (error bars = SD) vs base duration with Weber's Law regression line (passing through origin).

- The above plot shows that the mean JND rises almost linearly with stimulus duration.
- The line of regression, constrained to pass through the origin, fits tightly ($R^2 = 0.979$), with a slope $k = 0.214$, indicating classic proportionality as Weber's law predicts.
- Mean Weber fractions for each base duration are very similar: 18.3%, 18.5%, and 22.4%. (Mean Weber fraction is different than the slope of fitting line. For each block, it is the mean of all the subjects of the quantity:- Avg$(\frac{(comparison\ -\ standard)}{standard})$ where Avg is taken over reversal trials.
- A one-way ANOVA confirms no statistically significant difference between Weber fractions across durations ($F = 0.91$, $p = 0.41$) strongly supporting Weber's law in time perception.

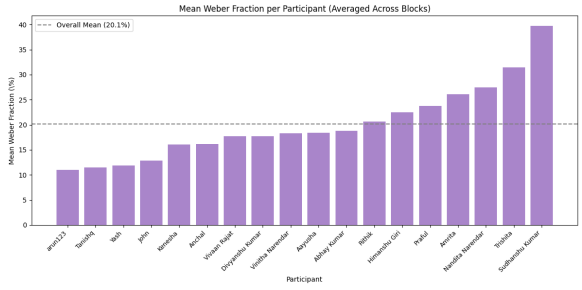
b) Does this fraction differ across subjects?

Assessing Individual Differences in Weber's Fraction

- JND fraction was calculated as the mean of their last 3–8 reversal trial differences for each subject and their base duration
- A trajectory of the Weber fraction was plotted across the three base intervals (see Fig. 4a) for each subject.
- Then the mean Weber fraction for each subject, averaged across all blocks was visualized for the sake of inter-individual comparison (see Fig. 4b).
- Then, A one-way ANOVA was performed on all subjects for testing for significant variation in the Weber fraction.



(a) Individual participant Weber fractions (trajectories across three base intervals). The group mean is shown as a dashed line.



(b) Mean Weber fraction of each participant, averaged over all blocks. The dashed line indicates the group mean.

Figure 4: Individual differences in Weber fraction: trajectories across blocks (left) and subject means (right).

- The first plot reveals strongly visible individual differences: There are participants who have consistently lower and others with higher Weber fractions for all intervals.
- The second plot (bar graph) emphasizes the range of subject means, pointing to inter-individual discrimination performance.
- The one-way ANOVA verifies that these differences are statistically significant ($F = 2.35$, $p = 0.017$).
- Remarkable inter-individual variability exists, even while group-level Weber's law is preserved

c) How do you know that your subjects were not guessing or cheating?

Assessing Data Authenticity and Anti-Guessing Evidence

- Accuracy is computed for each subject across all their trials.
- To rule out guessing we compare the subject accuracy rates to chance level (50%)

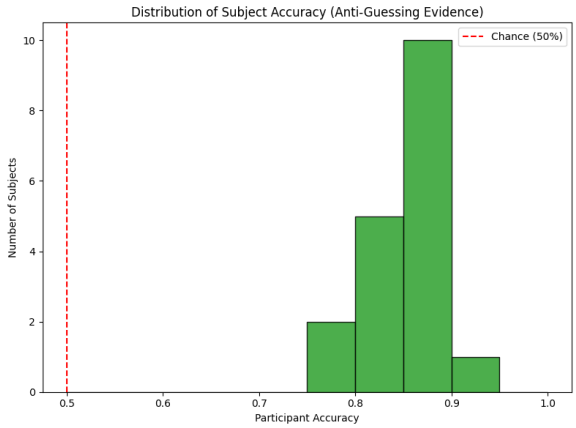


Figure 5: Histogram chart of the participants' accuracy rates, showing that all the subjects performed well above chance (50%).

- The histogram clearly shows that every participant performed well above the chance level, indicating they were not guessing.

d) Does your data contain other interesting patterns? Novel aspects and additional analyses

1) Clear Individual Differences

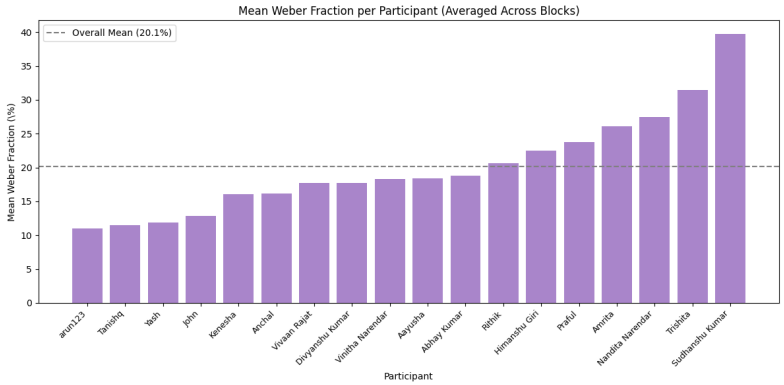


Figure 6: Mean Weber fraction per participant, averaged across all blocks (group mean as dashed line).

- The bar plot highlights the participant-to-participant variation in Weber fraction when averaged across all base durations.
- The spread clearly shows robust inter-subject differences in auditory discrimination ability, even when overall group-level Weber's law is well supported.

2) Reaction Time (RT) Patterns

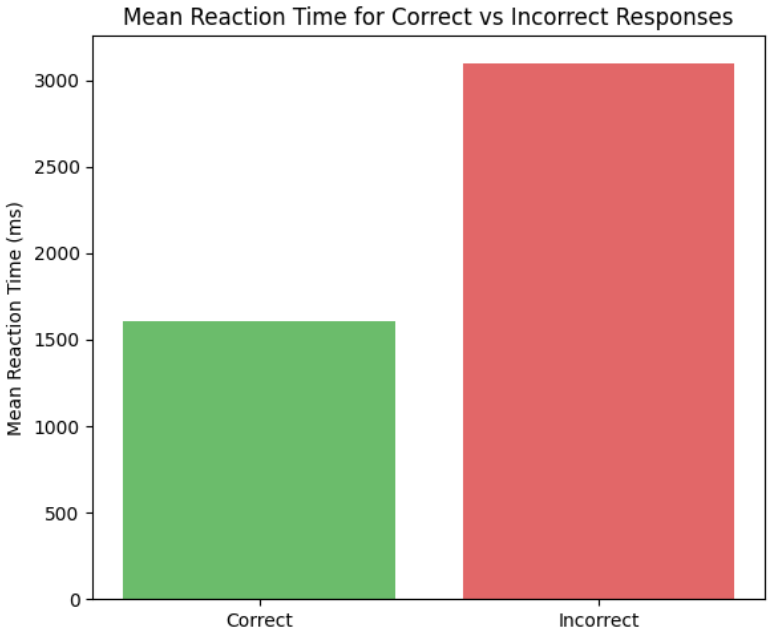


Figure 7: Mean reaction time (RT) for correct and incorrect responses across all trials.

- A noticable difference in reaction time is evident: correct responses are, on average, faster than incorrect responses.

- Statistical analysis shows a significant negative correlation between trial-by-trial performance and RT ($r = -0.129, p < 0.001$), supporting the argument that faster responses are more likely to be correct.
- This suggests that accuracy might be associated with more rapid and confident discriminative judgements, rather than deliberative guessing.

Discussion

1. **What would you conclude based on the data you collected?**
    - The findings give strong support to Weber's law in auditory interval discrimination: group-level JNDs scale almost linearly with base interval, and the Weber fraction is statistically invariant across most durations.
    - Analysis also showed significant individual differences in discrimination capacity, as well as correlation between faster responses and higher accuracy, indicating true perceptual decision processes.
2. **Why is there noise in your data? What are the possible sources?**
    - Behavioral data are noisy by nature because of trial-to-trial lapses of attention, transient distractions, and subjective uncertainty.
    - Inter-subject variance (fatigue, motivation, experience, or minor differences in hearing) contributes another level of statistical "error." Some variance is to be anticipated if a subject is repeated, particularly for threshold values near the discrimination limit.
3. **Would your result be different if you run the same subject twice? Why?**
    - Weber fraction might decrease by a little amount or stay as equal. It might decrease as the subject might be accustomed to the task and be more careful and thus could be more meticulous.
    - But the overall trend, with JND proportional to interval and same Weber fraction, should typically be replicable for any individual.
    - Minor differences can result from daily fluctuations in attention, strategy, or fatigue.
4. **Would your result be different if you changed some incidental details of your stimuli (e.g. if you are testing line length, does its brightness matter)? Why?**
    - Yes; perceptual thresholds are usually determined not only by the dimension tested (e.g., interval duration), but also by other stimulus properties, such as volume of sound in audition, or brightness/contrast in vision.
    - Modifying these "incidental" stimulus characteristics can influence task difficulty or introduce bias, that is a subject's sight be weaker then their hearing power, thus the weber fraction will come out to be more in case length discrimination task.
5. **Can you include yourself as a subject in this experiment? Why?**
    - Yes, I can include myself in the experiment, knowing about the task won't change my internal weber fraction, it will just be closer to my actual internal weber fraction, because I will be more careful.

Data and Code Accessibility

The codes for the UI design and the analysis of the data. And the link to the data collected are as follows:

- **Raw Experimental Data:** The complete dataset (trial-by-trial responses for all subjects) can be accessed at:
  `https://docs.google.com/spreadsheets/d/1llkrzHlXf2ex6RKVSfD0Bteo5CvndS9lzRVMnnp2Z`
  `edit?gid=0`
- **Online Experimental Task Design and UI:** The code for the design of UI for the task is available at:
  `https://midnight-koffee.github.io/weber-law-experiment/`
- **Analysis Code (Python/Jupyter):** All the data analysis code—including threshold calculation, line fitting, visualization, and statistics—is available at:
  `https://github.com/midnight-koffee/weber-law-experiment/blob/main/Result.ipynb`

These resources allow complete replication of all the reported findings above and are intended for verification and use in future.

References

1. https://en.wikipedia.org/wiki/Weber%E2%80%93Fechner_law
2. https://www.cns.nyu.edu/~msl/courses/0044/handouts/Weber.pdf
3. Arun, S.P. (2025). Sensation & Perception Assignment 1. (Course handout, Indian Institute of Science).
   Note: The questions in the Results and Discussion sections have been taken from, this assignment for better structure of the document.
4. The codes used in this project were refined by AI-assisted tools, mainly, perplexity.