# Differentiating perceptual, procedural, and task learning for an auditory temporal discrimination task

University of Pittsburgh | Department of Communication Science and Disorders, School of Health and Rehabilitation Sciences

Leslie Q. Zhen[1]; Sheila R. Pratt, PhD[1]

[1]Department of Communication Science and Disorders, University of Pittsburgh

## Background

- ❖Auditory temporal learning can be driven by:
  - ➢ *perceptual learning*, experience-driven improvements in the ability to detect changes in stimulus characteristics[1,2]
  - ➢ *procedural learning*, acquiring general skills and strategies[1,2]
  - ➢ *task learning*, learning the perceptual judgment specific to the task[1,2]
- ❖The time course for perceptual learning overlaps with that for procedural and task learning, making it difficult to isolate their individual effects[1,2,3].
- ❖Few studies in the time perception literature have formally evaluated the roles of each of the three types of learning for temporal-interval discrimination across multiple sessions.

## Research Question

- ❖To what extent does exposure to the stimulus, procedure, and/or task of an auditory temporal-interval discrimination task (target task) influences learning on the target task?

## Participants

- ❖ 83 untrained participants qualified and were assigned randomly to train on one of four exposure tasks prior to target task training:
  - ➢ *Interval*: temporal-interval discrimination; same as target task
  - ➢ *FDT*: frequency discrimination with timing information
  - ➢ *FD:* frequency discrimination without timing information
  - ➢ *Control:* no training

| | | Exposure | | | |
|---|---|---|---|---|---|
| Factor | | Interval | FDT | FD | Control |
| *N* | | 23 | 18 | 22 | 20 |
| Sex | Female | 12 | 15 | 16 | 15 |
| | Male | 11 | 3 | 6 | 5 |
| | | *M (SD)* | | | |
| Age | | 22.8 (2.7) | 23.9 (3.7) | 23.3 (2.7) | 23.6 (2.8) |
| 4-WTA[a] | Right Ear | 14.0 (6.6) | 13.7 (6.8) | 14.1 (8.1) | 13.2 (7.7) |
| | Left Ear | 13.9 (7.0) | 11.7 (6.6) | 14.3 (8.2) | 11.8 (8.3) |

**Table 1.** Demographics. [a] = Warble tone average, calculated as the mean of 0.5, 1.0, 2.0, and 4.0 kHz dB HL.

## Methods

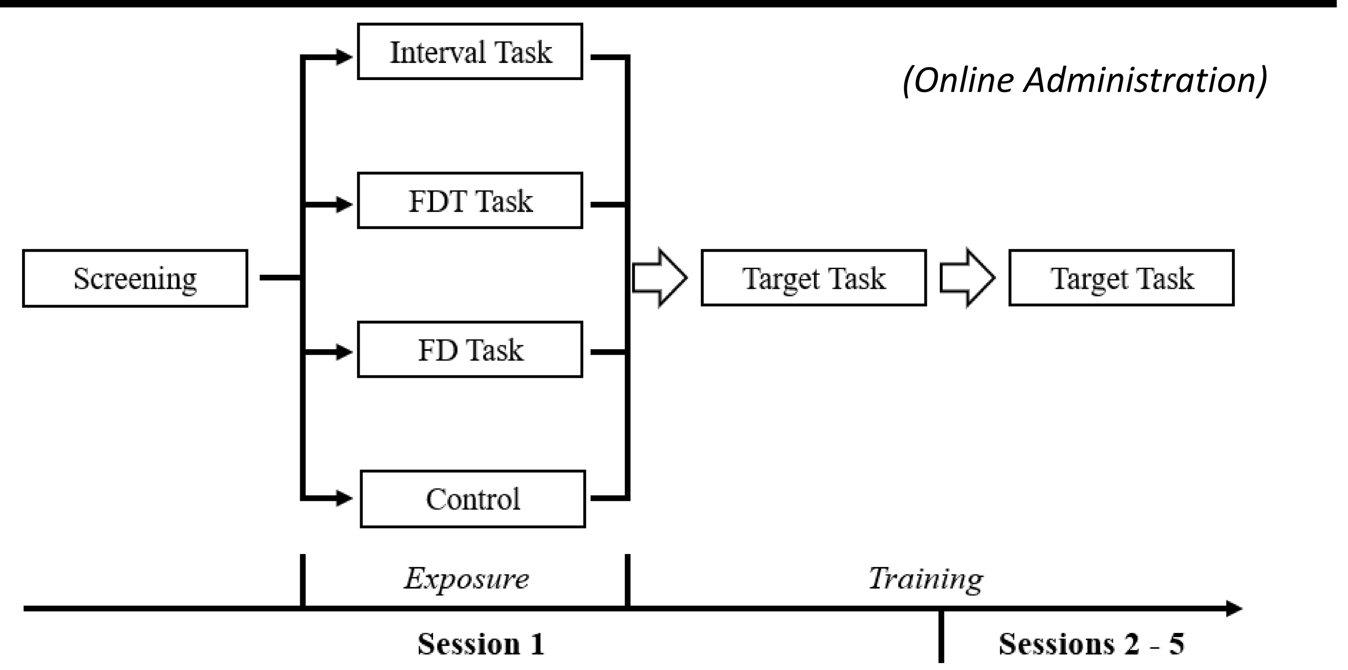


**Figure 1.** Study design.

| | Target Task Elements | | |
|---|---|---|---|
| Exposure | Stimulus | Procedure | Task |
| Interval | Y | Y | Y |
| FDT | Y | Y | N |
| FD | N | Y | N |
| Control | N | N | N |

**Figure 2.** Shared elements between the exposure and target tasks. N = No; Y = Yes.

## Results

### Psychometric functions & individual trajectories

Although learning was observed, difference limens were highly variable within and across listeners. Data were excluded for participants with deviant duration difference limen estimates, defined as > 1.5 times the interquartile range and > 25 ms.

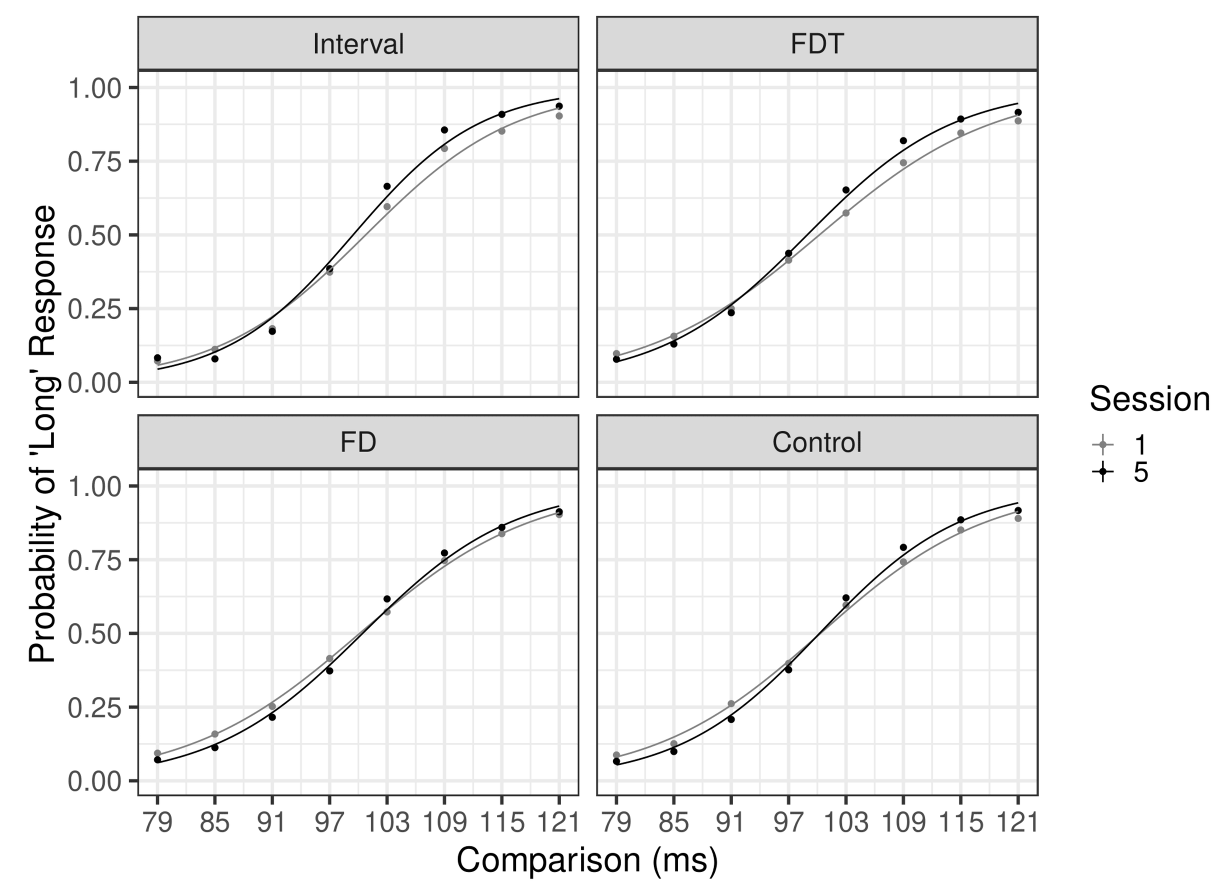


**Figure 3.** Psychometric functions from Initial to Final sessions of target temporal-interval discrimination training. $n_{sessions1,5}$: Interval, 18,17; FDT, 14,16; FD, 16,17; Control, 15,17.

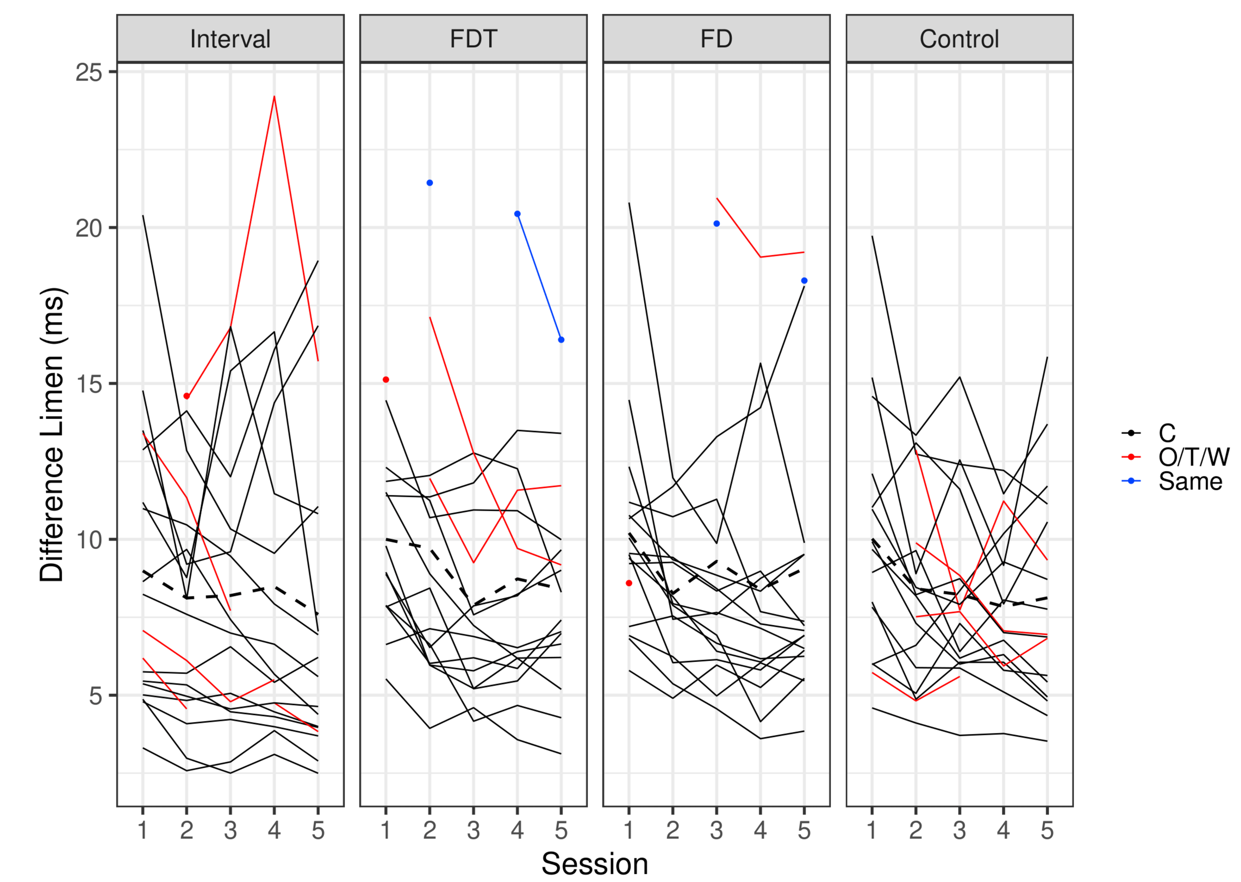


**Figure 4.** Subject level changes in difference limens for temporal-interval discrimination across sessions. C = complete data; O/T/W = missing ≥ 1 session due to deviant performance, technical error, or withdrawal; Same = same participant in group. Dashed lines represent group means. $n_{total}$: Interval, 20; FDT, 17; FD, 18; Control, 18.

### Slopes

Slopes tended to steepen with training to a greater extent for listeners exposed to elements of the target task than for naïve listeners without any prior experiences, but significant group differences were not observed. This pattern likely was masked by the large observed variances.

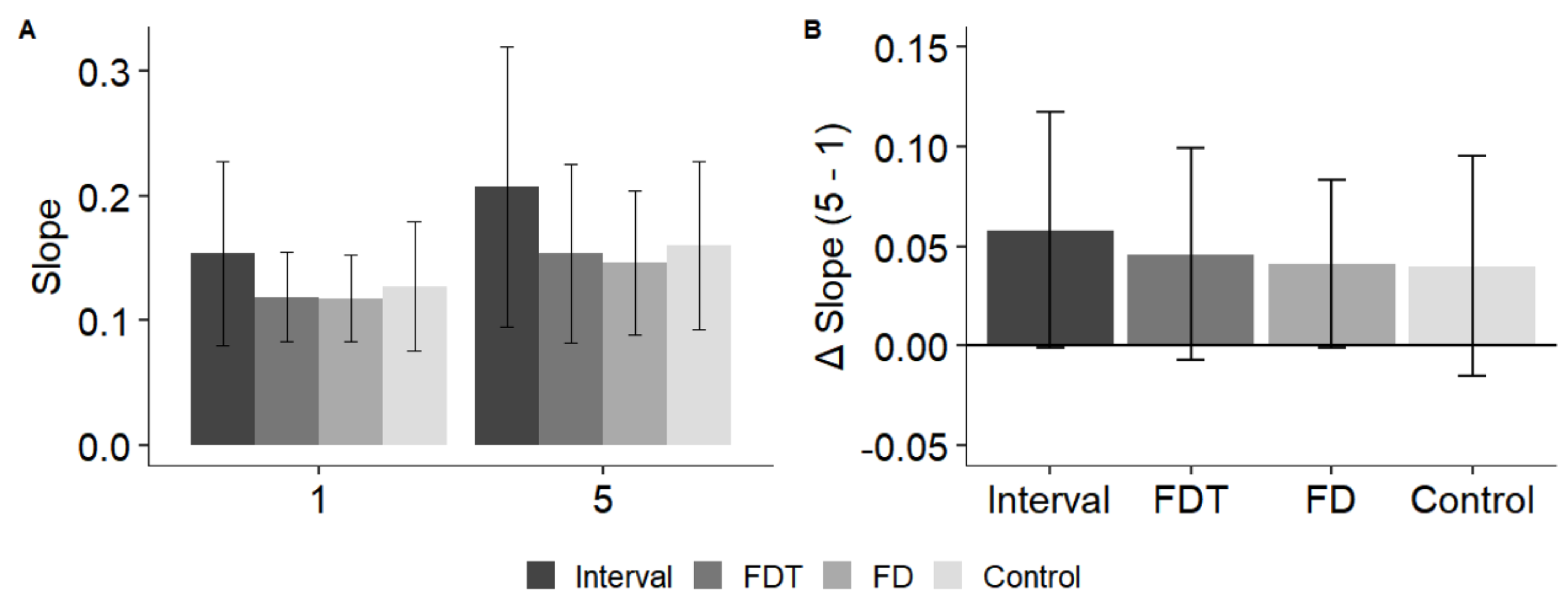


**Figure 5A.** Slopes by group and session. A mixed ANOVA revealed a significant effect of session, $F(1, 54) = 44.090$, $p = 1.58 \times 10^{-8}$, $\eta^2 = .109$, but not group, $F(3, 54) = 2.042$, $p = .119$, $\eta^2 = .088$. The interaction was not significant, $F(3, 54) = 0.354$, $p = .768$, $\eta^2 = .003$. n: Interval, 17; FDT, 14; FD, 16; Control, 15. Analyses with all five sessions returned identical conclusions (not shown).

**Figure 5B.** Slope change from the Initial to Final training sessions by group.

### Difference limens

Despite overall learning, some listeners performed best during early sessions. Boredom, inattention, and fatigue might explain their worsening.

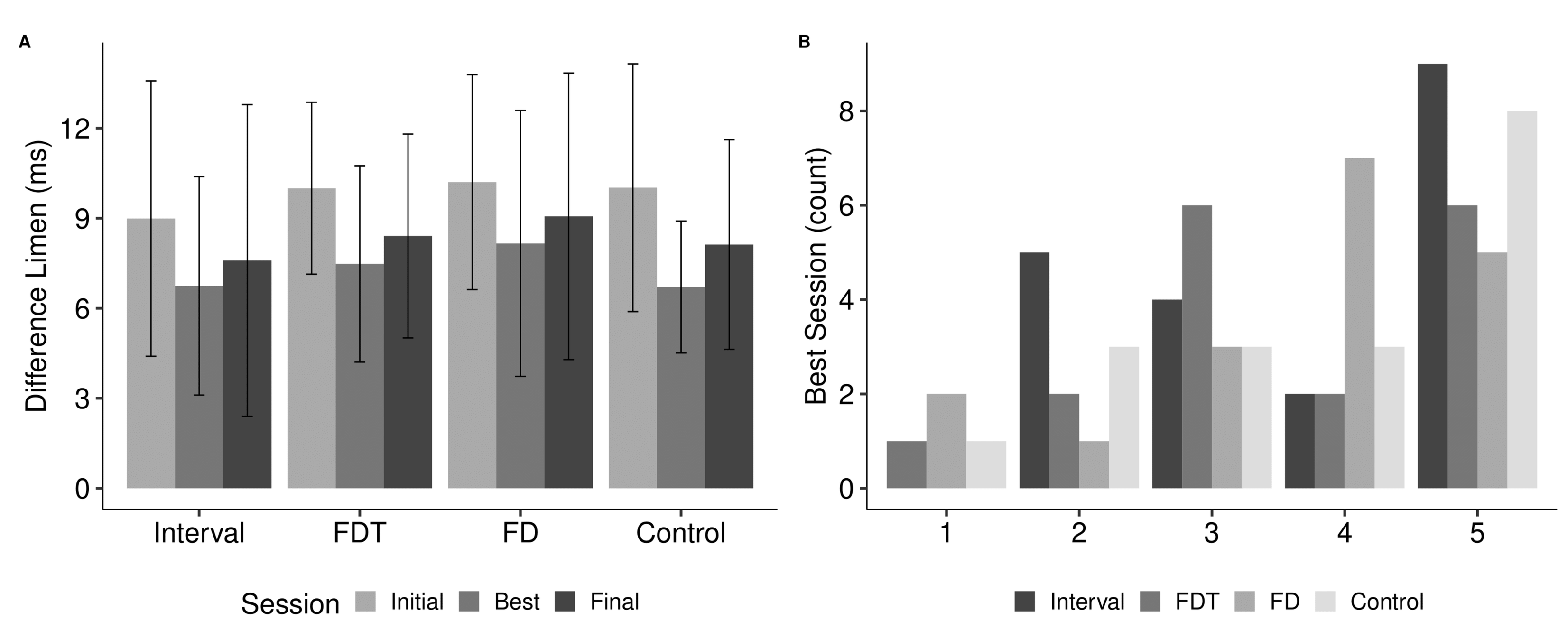


**Figure 6A.** Difference limens for the Initial, Best, and Final sessions. A mixed ANOVA comparing the Initial to Best sessions revealed a significant effect of session, $F(1, 57) = 102.530$, $p = 2.37 \times 10^{-14}$, $\eta^2 = .213$, but not group, $F(3, 57) = 0.438$, $p = .727$, $\eta^2 = .019$. The interaction was not significant, $F(3, 57) = 0.119$, $p = .949$, $\eta^2 = .001$. $n_{Initial,Best,Final}$: Interval, 18,20,17; FDT, 14,16,16; FD, 16,17,17; Control, 15,18,17. Analyses comparing the Initial to Final sessions and including all five sessions returned identical conclusions (not shown).

**Figure 6B.** Count of best difference limen at each session per group.

## Conclusions

- ❖Training improved slopes and difference limens for target temporal-interval discrimination for all groups.
- ❖An exposure effect was not observed when examined across sessions.
- ❖Despite this, changes in the slopes of the listeners' psychometric functions from initial to final sessions revealed that those exposed to elements of the target task tended to have greater increases in their slopes compared to naïve listeners without any prior experience.
  - ➢ The pattern of improvements suggested that stimulus and task learning were possible drivers of auditory temporal learning.
  - ➢ This pattern was not statistically significant, possibly due to substantive variability within and across listeners.
- ❖ That several listeners' best performance occurred either at or after Session 3 suggests that perceptual learning was the likely driver of temporal learning for those sessions.

## Discussion

- ❖ Overall, temporal-interval discrimination improved despite not observing a significant exposure effect.
- ❖ Several factors might explain the substantial variability that might have masked possible transfer of learning from the exposure phase to the training phase.
  - ➢ Online administration[4]
    - ➢ Reduced demand for procedural learning from familiar environment and hardware
    - ➢ Increased demand for procedural learning from fluctuating noise levels and presence of distractors within and between sessions
  - ➢ Boredom, inattention, fatigue
  - ➢ Learning decay

## Implications & Future Directions

- ❖ Multiple distinct processes might be engaged to varying extents during learning.[1,2]
- ❖ Caution should be exercised when designing studies of temporal perceptual learning to avoid biasing conclusions about changes to the perceptual system related to feature training alone.
- ❖ Given the negative results and large observed variances, this study does not discount contributions from factors beyond stimulus, procedure, and task on temporal learning.
- ❖ Future research is needed to identify these unobserved factors and the extent to which they contribute to temporal learning.

## References

1. Ortiz, J., & Wright, B. (2009). Contributions of procedure and stimulus learning to early, rapid perceptual improvements. J. Exp. Psychol. Hum. Percept. Perform., 35, 188-194.
2. Xu, R., Church, R.M., Sasaki, Y., & Watanabe, T. (2021). Effects of stimulus and task structure on temporal perceptual learning. Sci Rep, 11, 668.
3. Hussain, Z., McGraw, P., Sekuler, A., & Bennett, P. (2012). The rapid emergence of stimulus specific perceptual learning. Frontiers in Psychology, 3, 1-5.
4. Zhao, S., Brown, C., Holt, L., & Dick, F. (2021). Online tests yield robust thresholds with the right auditory hygiene. bioRxiv. Preprint.

## Acknowledgements

We are grateful to Dr. David McGovern for sharing the MATLAB scripts from his experiment, and to Waris Aiemworawutikul for providing feedback on programming with PsychoPy and for setting up alternative web hosting when https://pavlovia.org became unavailable because of a server fire. The project described was supported by the National Institutes of Health through Grant Number UL1 TR001857, KL2 TR001856, and/or TL1 TR001858.