



Investigating Processing Delay in Interaural Time Difference Discrimination by Normal-hearing Children

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INTRODUCTION

- Sensitivity to **interaural time difference (ITD)** as measured by a discrimination task is adult-like by 10 years of age among normal-hearing (NH) children (Ehlers et al., 2016)
- Little is known about the process to reach a decision during a conventional 2-alternative forced-choice discrimination task
- Looking behavior as measured by eye gaze position on screen in time-course gaze trajectories can provide inferences, such as **processing delay** and **uncertainty**, on participants' decision-making process prior to providing responses (Winn et al., 2013)

Study Aim: Investigate looking behaviors from eye gaze trajectories in processing ITD cues with varying magnitudes by NH children and adults during an ITD discrimination task

Hypotheses

- When the ITD becomes more salient, both children and adults are faster and more certain in responding to the cue
- Children's gaze trajectories show longer processing delay and patterns of higher degree of uncertainty than adults when reaching the final gaze position

METHODS

NH Participants

- 9 children, ages 8 to 14 years (M = 11.8 years)
- 10 adults, ages 18 to 24 years (M = 21.1 years)

ITD Discrimination Task

- Stimulus:** Transposed tone with 4 kHz center frequency, amplitude modulated at 128 Hz; ITD provided by whole waveform shift; masked by low level pink noise
- 3-interval, 2-alternative forced-choice (3I-2AFC)
- Method of constant stimuli

Timeline of A Single Trial

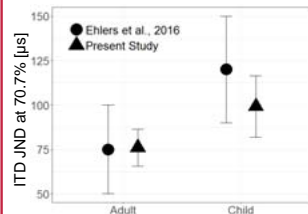
- 1st Interval, |ITD| = 0 μs
- Inter-Stimulus Interval (ISI) = 300 ms
- 2nd Interval, |ITD| = 0 μs
- ISI = 300 ms
- 3rd Interval, |ITD| ≠ 0 μs (e.g., right-leading target ITD)
- Eye gaze tracking begins 50 ms prior to the onset of the 3rd interval
- ITDs tested: ±5, ±20, ±80, ±140, ±200, ±400 & ~JND
- Subject provides response via mouse-click
- Eye gaze tracking ends
- Visual feedback (e.g., right-leading target ITD)

Simultaneous Behavioral Responses

- Mouse-Click Data**
 - Participants provided response with mouse-click
 - To derive just-noticeable-difference (JND) threshold at 70.7%
- Gaze Data**
 - Participants' gaze position (horizontal coordinate only) on screen recorded at 1 kHz sampling rate (EyeLink 1000)
 - To infer processing delay and uncertainty from time-course gaze trajectories

RESULTS: Mouse-Click Data

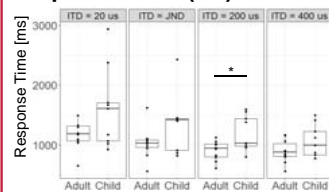
ITD JND



- No significant difference in ITD JNDs between children and adults ($p > 0.05$, Wilcoxon Test)
- Present study also replicates results from Ehlers et al. (2016) using a 2I-2AFC, static response interface, and adaptive procedure

Figure 1. ITD JND thresholds (\pm standard error) measured in present study and in Ehlers et al., 2016 (replotted with permission).

Response Time (RT)



No significant difference in RTs between children and adults in most ITD conditions ($p > 0.05$, Wilcoxon Test)

Figure 2. Response time (from stimulus offset to mouse-click) between children and adults under different ITD conditions

Fitting Model to Gaze Trajectories

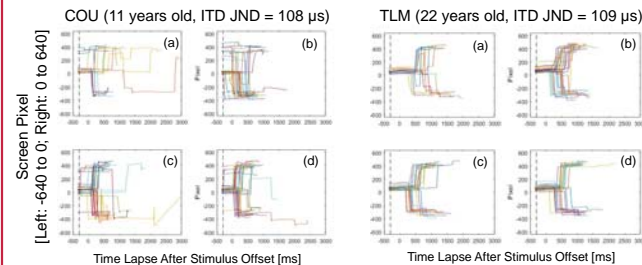


Figure 3. Individual gaze trajectories of correct responses for ITDs at (a) 20 μs, (b) 120 μs, (c) 200 μs, and (d) 400 μs for one child (COU) and one adult (TLM) with similar ITD JND thresholds

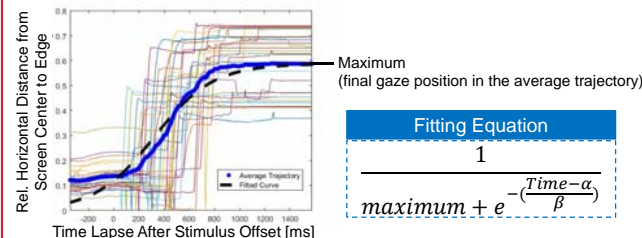


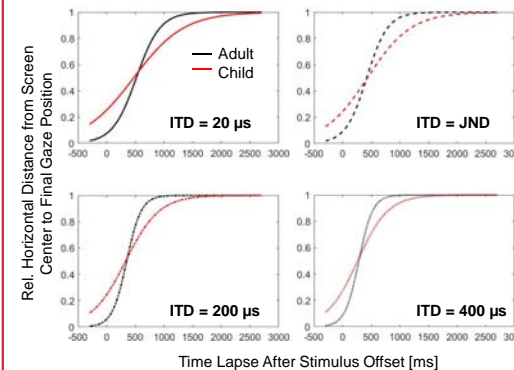
Figure 4. Example curve fitted to a participant whose tested ITD nearest JND (ITD = 120 μs). All model fits $R^2 > 0.9$

Parameter Estimates in Model (Wichmann and Hill, 2001)

α – Linear offset at 75% threshold on fitted gaze curve (Processing delay or time it took participant's gaze to reach 75% of the final position in the averaged trajectory)

β – Inversed slope of the linear rise on fitted gaze curve (Switching between two response locations and pausing during gaze trajectories prior to arriving at the final position resulted in shallower fitted curve)

RESULTS: Gaze Data

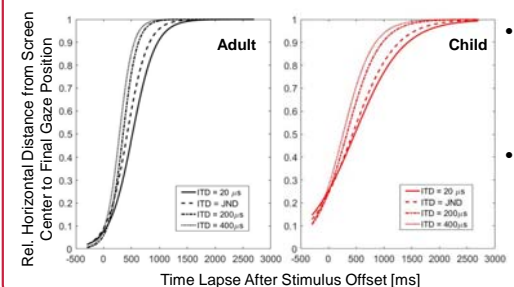


- Gaze curves for children have consistently shallower slopes ($1/\beta$) than those for adults, but not in the 75% offsets (α); see Table 1
- Larger deviation from center fixation in children's gaze data at stimulus offset

Figure 5. Fitted curves for children and adults, grouped in different panels by ITD conditions

ITD	α (75% offset)	β (slope)
20 μs	$p > .05$	$p = .0076$
at JND	$p > .05$	$p = .0021$
200 μs	$p > .05$	$p < .001$
400 μs	$p > .05$	$p = .004$

	α (75% offset)	β (slope)
Adult	$p < .001$	$p < .001$
Child	$p > .05$	$p = .0073$



- Significant effect of ITD magnitude in slope ($1/\beta$) for both children and adults and in offset (α) but only for adults; see Table 2
- Gaze curves become consistently steeper with increasing ITD

Figure 6. Fitted curves replotted as grouped by participants to show effect of ITD magnitude

CONCLUSIONS

- As the ITD becomes more salient, both children and adults processed the cue with greater certainty (steeper fitted curves); but only adults demonstrated faster processing speed
- Children exhibited higher degree of uncertainty from switching and pausing during the gaze trajectories, but not necessarily longer processing delay, than adults before arriving at the final gaze position under all tested ITD conditions

Table 3. Mean processing delay (from stimulus offset) to reach 75% of the final gaze position

ITD	Adult	Child
20 μs	743 ms	950 ms
at JND	622 ms	852 ms
200 μs	486 ms	650 ms
400 μs	416 ms	555 ms

REFERENCES

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