Development of Speech perception In Noise: Role of sensory factors and central inefficiencies

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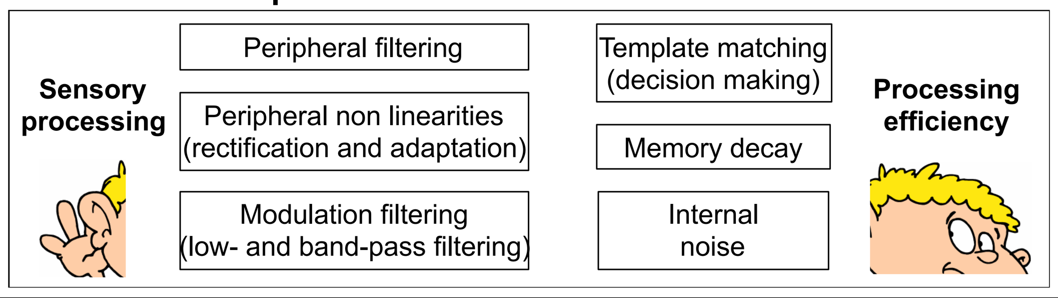
Introduction

Main question: Does the perception of speech in noise relate to the maturation of auditory temporal processing in childhood?

Background: Speech understanding in noise is limited throughout childhood [1]. This may be constrained by sensitivity to speech-relevant acoustic information like **amplitude modulations** (AM). Recent studies conducted with adults showed that the temporal modulations belonging to a background noise interfere with the temporal modulations of speech [2]. As AM sensitivity improves until 10 years of age [3], the present study assessed the relationship between consonants in noise identification and AM detection between 6 and 9 years. A previous study in children showed a relationship between AM detection thresholds in children (8 Hz modulation rate) and consonant identification thresholds. However, auditory models suggest that AM detection is not only constrained by the filtering properties of **sensory mechanisms** in the modulation domain, but also by "**processing efficiency**", the ability to make optimal use of the available sensory information [4, 5]. As shown in this schematic representation of AM processing, several stages are involved in AM detection and may develop at different pace.

Hypotheses: Speech-in-noise abilities in childhood (Task #1: consonant identification in noise) may be related to the development of sensory mechanisms for AM cues (Task #2: AM sensitivity and AM masking) and/or to processing efficiency of AM cues (Task #3: Internal Noise).



Methods

Participants: 86 children with normal hearing: *29* 6-7 yrs; *30* 7-8 yrs; *32* 8-9 yrs. They were also tested for receptive vocabulary (EVIP) and non-verbal reasoning (WISC IV).

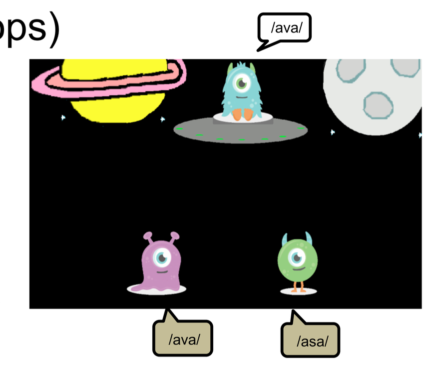
Stimuli & Procedure: Testing took place at school in a quiet room. Sounds were played at 70 dB SPL through headphones.

Task #1: CONSONANT IDENTIFICATION IN NOISE

Noise = stationary speech-shaped

Speech = /aCa/ syllables produced by 3 speakers (1 male 2 females)

• Stops ([b], [p], [d], [t], [g], [k]) & Fricatives ([f], [v], [s], [z], [ʃ], [ʒ])
Contrasted on:
PLACE (PLACE Fricatives; PLACE Stops)
MANNER (Fricatives *vs* Stops)
VOICING (VOICING Fricatives; VOICING Stops)
→ 6 phonetic conditions



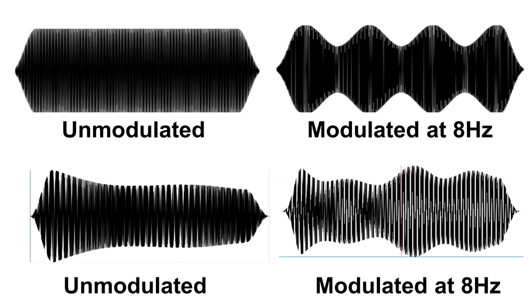
Procedure: XAB adaptive
X = male in quiet; A-B = females in noise
Starting Signal-to-noise ratio (SNR) = +20 dB
1st step size = 5 dB, after 2 reversals = 2 dB
Measure = Consonant identification thresholds in noise (dB SNR)

Task #2: AM SENSITIVITY & MASKING

2 AM carrier conditions =

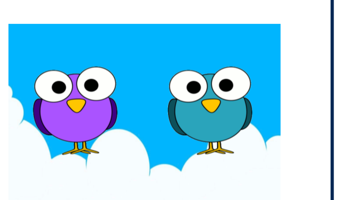
• **No AM masking** Pure Tones 500 Hz

• **AM masking** Narrowband Noises of 4Hz-bandwidth, centered at 500 Hz
→ *the inherent amplitude fluctuations of the noise carrier may mask the target AM*



Stimulus duration = 500 ms; Target AM rate = 8 Hz

Procedure: 2I AFC adaptive
Transformed and weighted up/down methods. Stop after 50 trials or 8 reversals. Feedback on each trial.



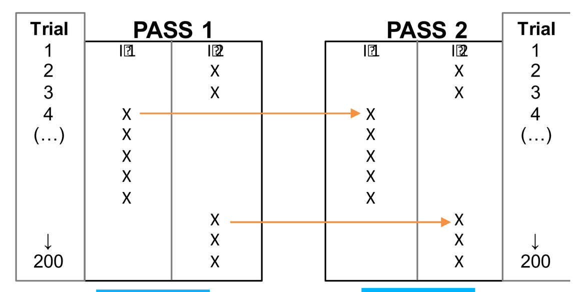
Measures = AM detection thresholds (dB)
- *Sensitivity* (thresholds in condition No masking)
- *AM masking* (difference in thresholds between the 2 conditions)

Task #3: INTERNAL NOISE ESTIMATION

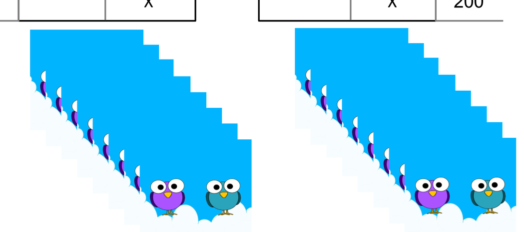
AM masking stimuli from Task 2
Procedure: 2I AFC constant stimuli = Double-pass consistency [6]

The AM masking stimuli are **played at threshold** for each child**,** within 2 passes of the same 200 test trials, divided into 10 blocks.

Here, the target modulated stimulus is played in one internal (I1 or I2) in 200 trials in Pass 1. The same trials are repeated in Pass 2 for each participant. No feedback.

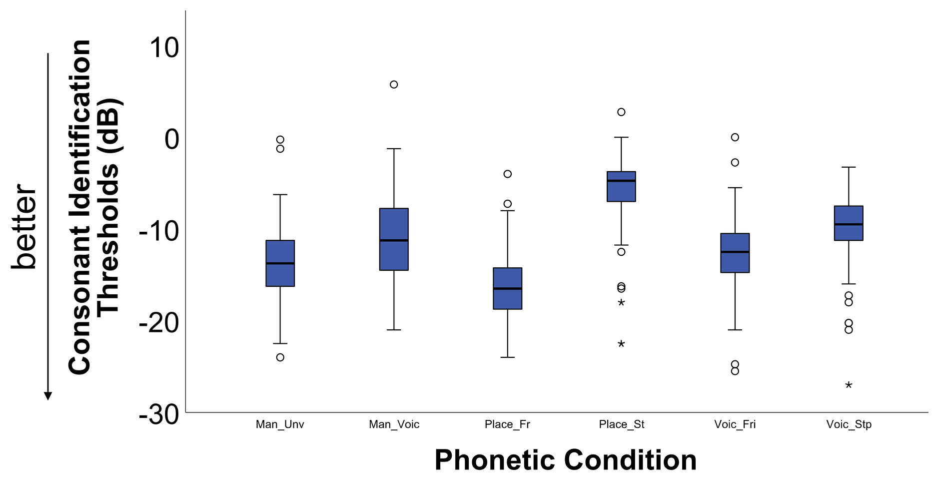


Measures =
% correct AM detection in each pass
% agreement between pass 1 and 2 (estimate of internal noise)



Results

Task #1

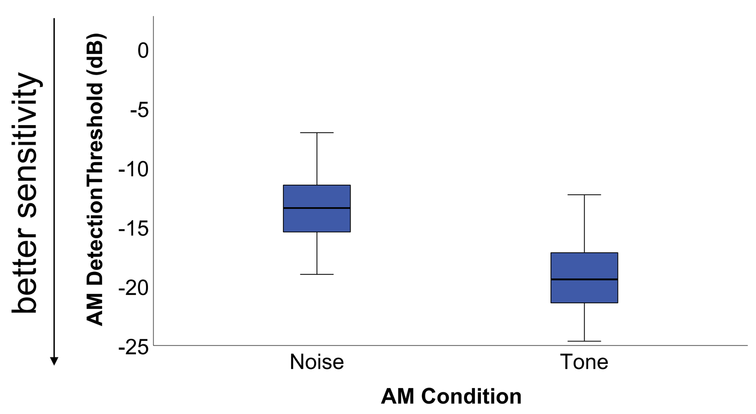


LMM Phonetic Condition (6) * Age:
Main effect of Phonetic Condition *p* < .001
Main effect of Age *p* = .011
No interaction *p* = .91

→ Overall consonant-identification thresholds decrease with age. Further analyses are required to understand the effect of the phonetic condition.

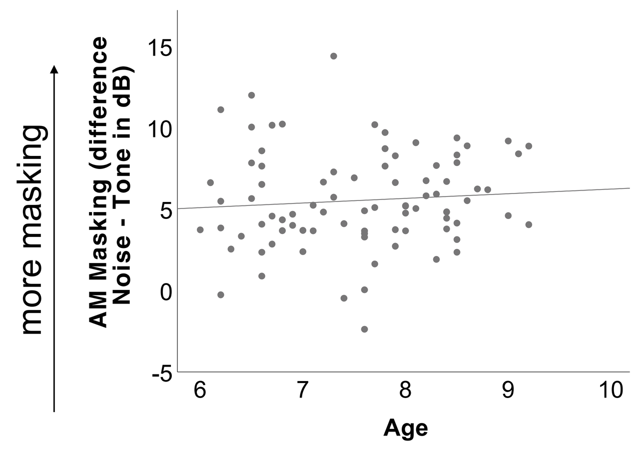
Task #2

AM sensitivity in the two carrier conditions



ANCOVA AM condition (3) * Age:
Main effect of AM condition (*p* < .001): Noise > Tone
No effect of Age, nor interaction (*ps* > .37)

AM masking as a function of age



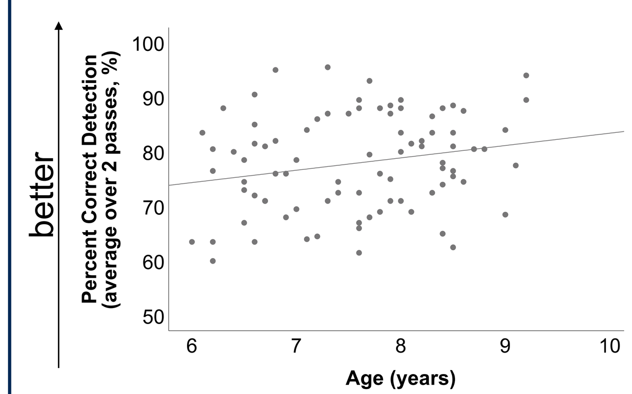
No relationship between Age and AM masking scores (*p* = .44)

→ AM filtering is probably not affected by age between 6 and 9 years.

Task #3

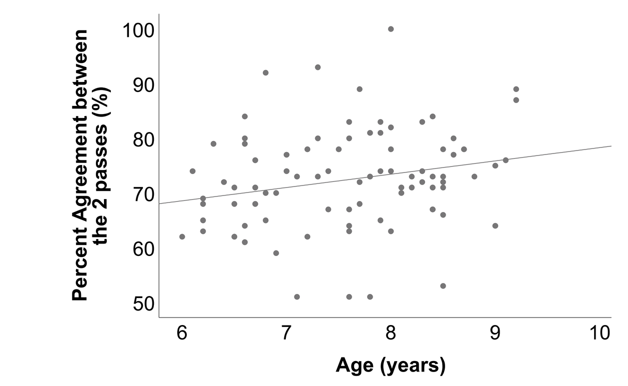
AM detection performance at threshold as a function of age

% correct of AM detection



Correlation Percent Correct vs Age
p = .043

% agreement between the 2 passes



Correlation Percent Agreement vs Age
p = .038

→ Aspects of processing efficiency for AM detection are affected by age between 6 and 9 years.

Backward Regression models

SIN Threshold: MANNER VOICED (Best-fit model)				SIN Threshold: VOICING STOP (Best-fit model)			
R^2	Adjusted R^2	Sig model		R^2	Adjusted R^2	Sig model	
[redacted]							
Coefficients				Coefficients			
Signif Predictor	β	t	Sig.	Signif Predictor	β	t	Sig.
[redacted]							

Notes

•All scores are age-normed and log-transformed; **only significant models are reported here**
•9 Outliers removed

•Given the Main effect of Condition in SIN, regressions are run for each condition (no significant predictor when regressions are run on total speech in noise thresholds)

→ Further analyses are required to understand why predictors vary with Phonetic Condition

Discussion

• **Consonant identification in noise significantly improved between 6 and 9 years age** and **identification thresholds were affected by phonetic feature**.

• As shown in our previous study [4], **some aspects of modulation processing are developed by 6 years:** AM sensitivity (no effect of age on AM detection thresholds at 8 Hz) and AM masking (degradation of AM detection thresholds in the presence of random intrinsic envelope fluctuations in the carrier).

• **However, processing efficiency for AM detection seems affected by age** as internal noise (% agreement) in AM detection tends to reduce with age.

• Processing efficiency, modulation filtering and linguistic/cognitive levels relate to some extent to consonant identification in noise in childhood (preliminary analyses).

References & Acknowledgments

[1] Nishi et al., (2010). *JASA, 127(5).* [2] Stone et al., (2011), *JASA, 130(5). [3] Hall & Grose, (1994), JASA, 96(1).* [4] Cabrera et al., (2019). *JASA*, 146(4). [5] Dau et al., (1997), *JASA,102(5).* [6] Green, 1964, Pycho Rev, 71(5).

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