How do cognitive factors interact with speech-in-noise segregation in normal hearing children and adults?

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ABSTRACT

Background: In noisy environments, it is difficult to attend to a talker while simultaneously ignoring background speech and noise. Compared to adults, children have more difficultly extracting target speech from interfering noise, and demonstrate greater variability in performance on source segregation tasks. Little is known about auditory or non-auditory factors accounting for this variability. This study tested the following novel hypotheses: semantic content of target speech influences speech intelligibility for children; measures of cognitive assessment predict performance on speech-in-noise tasks; and cognitive measures are inversely correlated with informational masking.

Methods: Four groups of normal hearing (NH) listeners were tested: Elementary school (7-10yrs), Middle school (11-14yrs), High school (15-17yrs) and Post-Secondary (18-23yrs). The auditory task consists of subjects repeating target sentences that are either semantically coherent or anomalous. Target speech is presented in quiet and with interfering speech or noise at four signal-to-noise ratios (SNRs) (-16, -8, 0, 8dB), representing the target level relative to the interferer. The target and interferers are either collocated or spatially separated. Cognitive tests assess working memory (WM) and attention, and are administered through computer-interactive methods. WM is assessed using a List Sorting Test requiring recall and sequencing. Attention is assessed using the Flanker Test, involving focusing on one stimulus while inhibiting another, and the Dimensional Change Card Sort Test (DCCS), measuring flexibility by matching pictures according to various dimensions (e.g. color, shape).

Results: Preliminary results indicate the percentage of words correctly identified at each SNR, in each spatial configuration, is greater for target sentences that are semantically coherent than those that are anomalous. Percent correct decreases at lower SNRs, especially when both the target and interferers are speech and sources are collocated. Data from cognitive measures will be reported to determine whether the hypotheses are confirmed.

Conclusions: This is the first study to evaluate how children's WM and attention predict individual differences in ability to hear speech in noisy environments. Consistent with adult data, semantically coherent sentences are more accurately reported, indicating semantic content influences intelligibility of target speech. Performance on these tests improves with age, suggesting they might provide a useful tool for tracking the developmental trajectory of source segregation in NH listeners. The tests used in this study may be informative in assessing individuals with hearing impairment and who use assistive listening devices.

PURPOSE

Auditory

Previous studies have used either single-word or closed-set stimuli to investigate the ability of children to hear target speech in the presence of background noise. The current study uses an *open-set* corpus of sentences that vary in semantic content, being either coherent or anomalous.

Hypothesis: Because semantic content elicits higher order auditory mechanisms, "top-down" processes will impact performance on the auditory task, such that semantically coherent sentences should be easier to identify than anomalous, especially in conditions with less favorable signal-to-noise ratios (SNRs).

Cognitive

For children with NH, there is a wide range in ability to selectively attend to a target source in noisy environments. There is evidence to suggest that variable performance derives from central, rather than peripheral auditory processes.

Hypotheses:

• Cognitive load increases in challenging listening situations; therefore, children with higher performance on the cognitive measures (i.e. those who can maintain a greater cognitive load) should be better able to segregate target speech in adverse listening conditions.

• Those who are better able to inhibit interfering stimuli (i.e. DCCS), shift attention (i.e. Flanker), and retain important verbal information while stimuli is constantly changing (WM) should be better at identifying target speech in the most challenging conditions (i.e. anomalous sentences, low SNRs, and with stimuli spatially collocated).

PARTICIPANTS

- All normal hearing (NH), recruited from the local Madison, WI area
- Total sample size(N)= 96, Sample size per group (n)= 24
  - Data collection ongoing

Group	Noise condition	Speech condition	Total
7-10 yrs	4 males	3 males, 2 females	9 / 24
11-14 yrs	1 male; 2 females	1 male; 4 females	8 / 24
15-17 yrs	2 females	1 female	3 / 24
18-23 yrs	4 females	2 males; 1 female	7 / 24
Total	13 / 48	14 / 48	27 / 96

AUDITORY MEASURES

Method

➢ Speech-in-noise task

Stimuli

- *Target*: 200 sentences (100 coherent, 100 anomalous)
  - Recorded from a male speaker of standard American English (see Davis, *et al*., 2011)
  - Length: 6-13 words, Duration: 1-3s
  - *Signal-to-noise ratio (SNR)*= target level relative to the level of the interferers
  - Signal-to-noise ratios (dB): -16, -8, 0, +8

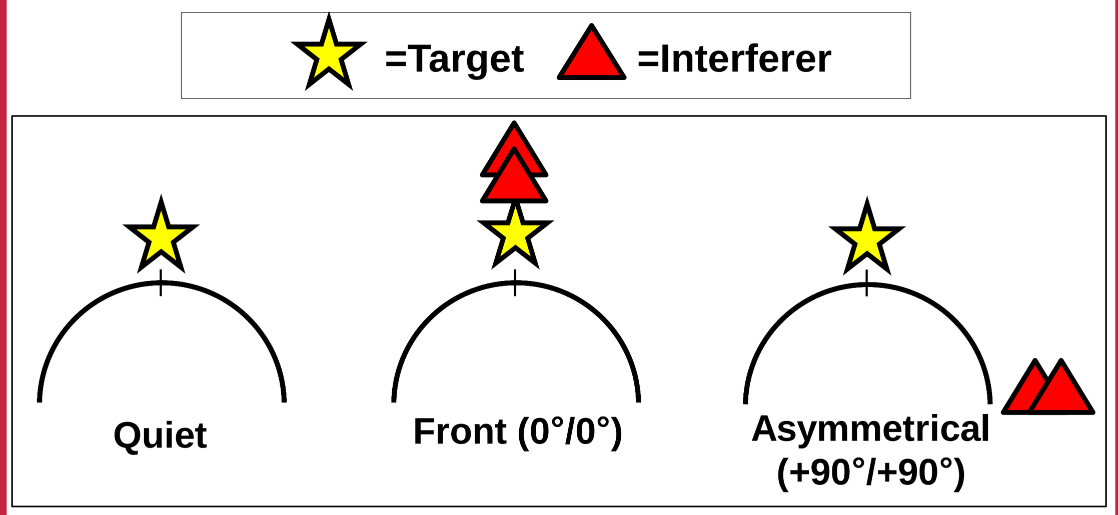
•*Interferers*:

- Held constant at 55dB SPL

1. Noise: Amplitude modulated speech-shaped noise (MSSN)
2. Speech: Sentences taken from the corpus of target sentences, and recorded from a female speaker of Standard American English (2-talker interferer created by overlaying two recordings from the same talker).

Environment/Conditions

- Participants sit in the center of a loudspeaker array facing a computer monitor at 0° azimuth
- All stimuli presented through loudspeakers



Design and Procedure

- Each listener is tested in Quiet and with *either* the noise *or* the speech interferer, at each SNR, in both the FRONT and ASYMMETRICAL conditions.

- Participants are instructed to listen for the man's voice and repeat (if <15 years old) or type (if >15 years old) exactly what they hear, no feedback is given.
- *Percent correct (PC)*= number of words correctly repeated in all sentences for each trial, divided by the total number of possible words.

Results: AUDITORY MEASURES

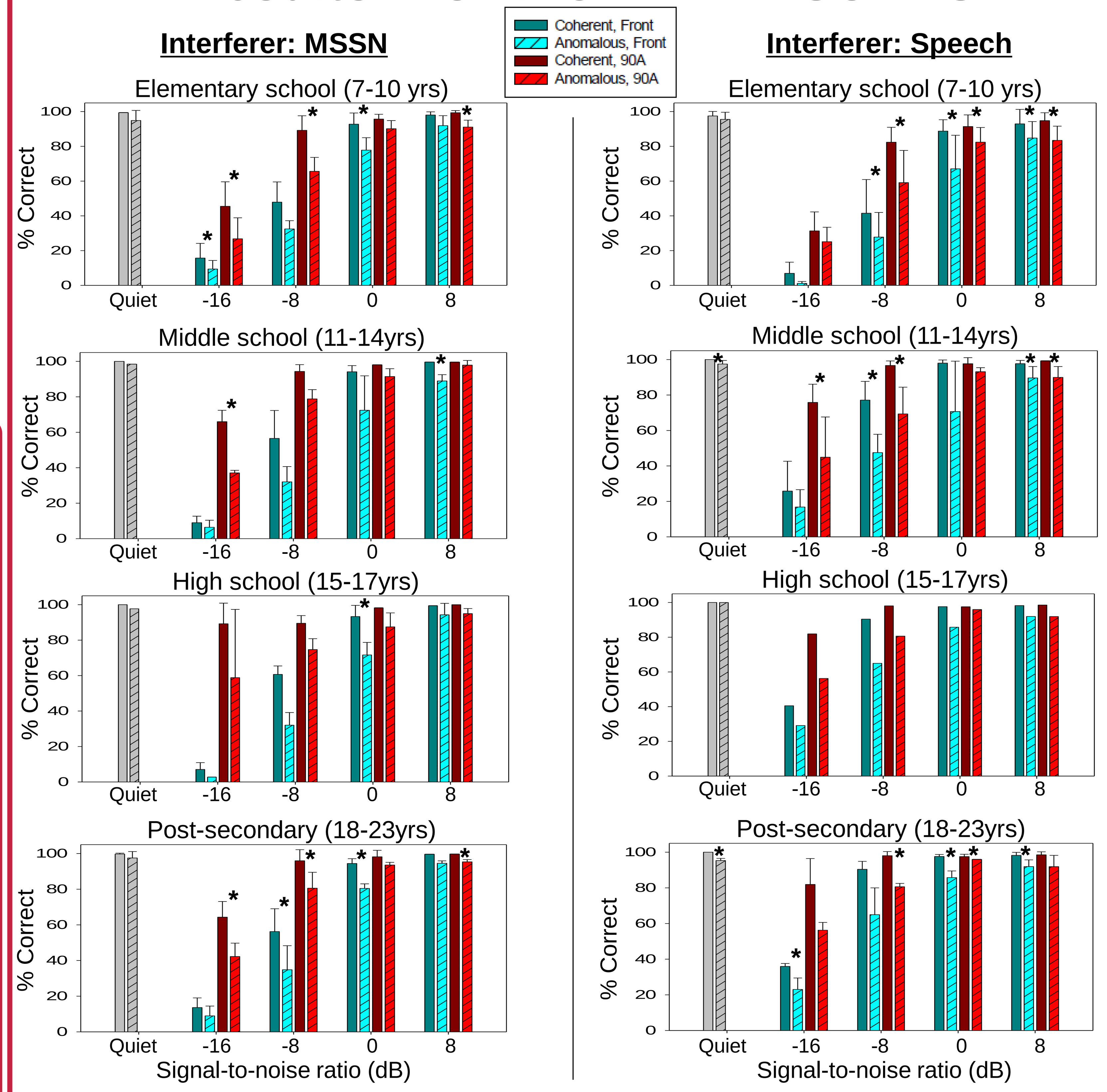


Fig. 1. Percent correct (PC) is plotted for each group in Quiet and at each SNR with either the MSSN (left) or Speech (right) interferers. Within each SNR, blue bars represent PC with the target and interferers collocated and the red bars represent PC with the target and interferers spatially separated. Solid bars indicate PC with coherent sentences. Dashed bars indicate PC for anomalous sentences. Significant differences (p <0.05) between coherent and anomalous sentences , within each group at each SNR, are indicated with an asterisk (*).

COGNITIVE MEASURES

Method

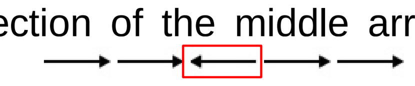
➢ NIH Toolbox-Cognition (all computer-based, www.nihtoolbox.org)

Working Memory

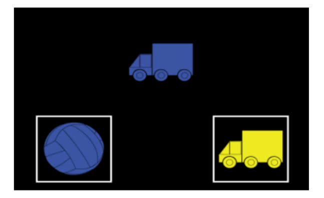
List Sort: Participants are presented with a series of items (food and/or animals in random size order) and instructed to verbally repeat the items in size order from smallest to largest. When both animals and food are shown within the same trial, the participant must first repeat the food items from smallest to largest then the animals.

Attention

1.) Flanker (Inhibitory control): Participants indicate the direction of the middle arrow, while simultaneously inhibiting the other arrows.



2.) Dimensional Change Card Sort (DCCS) (Cognitive flexibility): Target pictures that vary along two dimensions (color, shape) are presented. Participants match target pictures to test pictures for either color or shape, depending on if the prompt is "shape" or "color".



Scoring for cognitive assessments: **Age-adjusted (National percentile)**=percentage of people, nationally, within the participant's age who ranked *BELOW* the participant's score.

RESULTS: COGNITIVE MEASURES

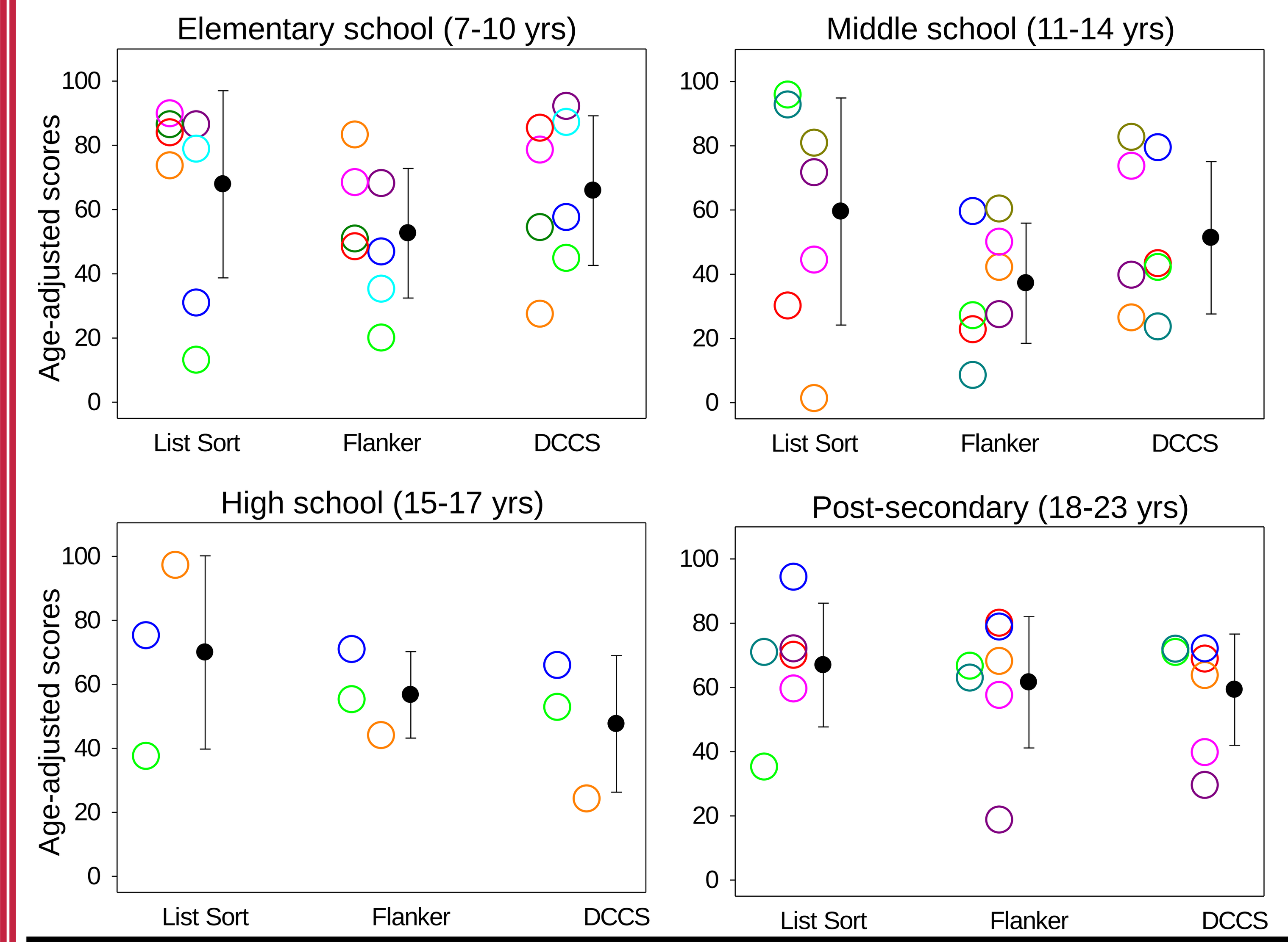


Fig. 2. Age-adjusted scores are plotted for each group (Elementary school, Middle school, High school, and Post-secondary) for each of the cognitive assessments (List Sort, Flanker, DCCS). Within each group individual subjects are represented by a different color. Group means (± SD) are shown to the right of the individual scores in each group.

CONCLUSIONS & FUTURE DIRECTIONS

- All groups identify semantically coherent sentences more accurately than anomalous sentences at all SNRs, with both MSSN and Speech interferers, in both conditions (Front, Asymmetrical).
- The ability to hear speech in noise improves with an increase in age, particularly in the most challenging conditions (i.e. negative SNRs and/or with sources spatially collocated).
- Results indicate similar mean scores (adjusted for age) for each of the cognitive measures in all groups. Preliminary results show variable performance within each measure. With additional participants (N=96) we expect that the variability within each group, for each of the cognitive measures, will help predict the ability to use spatial cues for source segregation in complex listening environments (i.e. SRM). Further research will be done to investigate specific cognitive mechanisms that best predict performance when listening to speech in noise.
- In order to more thoroughly investigate the relationship between cognitive mechanisms and source segregation, we will add measures that assess non-verbal IQ (*Kaufman Brief Intelligence Test), *expressive vocabulary *(Expressive Vocabulary Test*), and a non-linguistic measure of working memory *(Weschler Intelligence Scale*, backward digit span).
- Results from NH participants in this study may be used as a comparison for individuals with hearing impairments to better predict successful use of assistive listening devices.

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