Energetic/Informational Masking and Listening Effort, as Measured by Electroencephalography and Pupillometry

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INTRODUCTION

- Attending to target speech in the presence of auditory maskers may result in decreased understanding of target information (lower speech intelligibility scores).
- However, intelligibility scores do not provide information about how much ***listening effort*** the task elicits.
- Even if a listener can understand 100% of the target speech, the task of doing so may be extremely effortful (Rennies & Kidd, 2018), which may have negative effects for the listener (Peelle, 2018).

STUDY AIMS

- To compare the amount of listening effort elicited in young, normal-hearing subjects under carefully-controlled **high-informational masking** (IM) versus **high-energetic masking** (EM) conditions, at equivalent reference points (TMRs).
  Hypothesis: A high-IM condition will require more effort.
- To compare listening effort data obtained by two different widely-used physiological indices: 1) pupil size, and 2) alpha power as measured by electroencephalography (EEG).
  Hypothesis: Results from the two indices will not be correlated but may reveal different insights about components of listening effort.

PARTICIPANTS

- 15 young, normal-hearing listeners 5 M, 10 F
- mean age = 20.8, range = 18-24
- normal hearing in both ears (20 dB HL or better at 250, 500, 1K, 2K, 4K, and 8K Hz)
- native English speakers
- no diagnosis of ADD/ADHD or TBI

EXPERIMENTAL STIMULI

Target speech consisted of 5-word matrix-style sentences, always beginning with the word Sue:

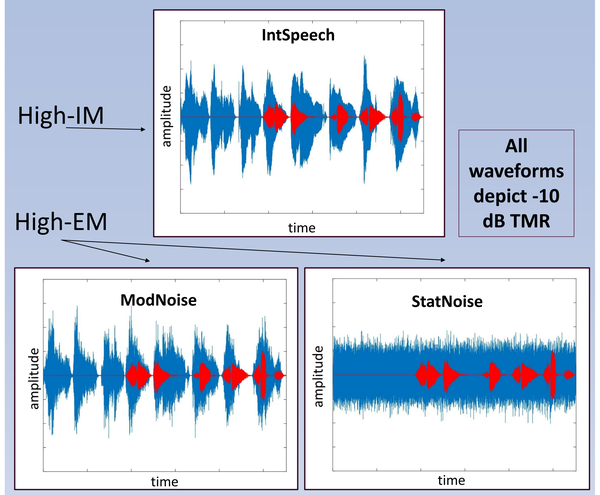
Names	Verbs	Numbers	Adjectives	Objects
Bob	bought	two	big	bags
Jane	found	three	cheap	cards
Jill	**gave**	four	**green**	gloves
Lynn	held	five	hot	hats
Mike	lost	**six**	new	pens
Pat	saw	eight	old	shoes
Sam	sold	nine	red	**socks**
Sue	took	ten	small	toys

Masker sentences were drawn from the same matrix, as well as from a list of 2-syllable names:

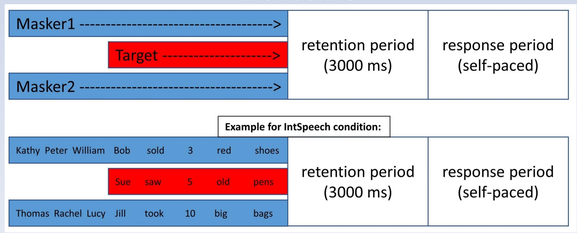
Allen
Doris
Kathy
Lucy
Peter
Rachel
Thomas
William

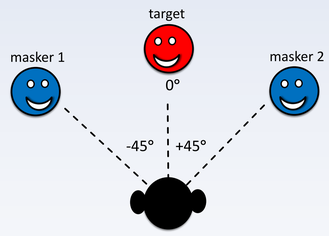
PUPILLOMETRY RESULTS

3 Masking conditions:
IntSpeech: intelligible speech
ModNoise: speech-shaped, speech-envelope-modulated noise
StatNoise: speech-shaped, unmodulated noise



Trial Structure





Stimuli were presented in a sound-attenuated booth from three loudspeakers, each located approximately 1.5 meters from the listener's head.

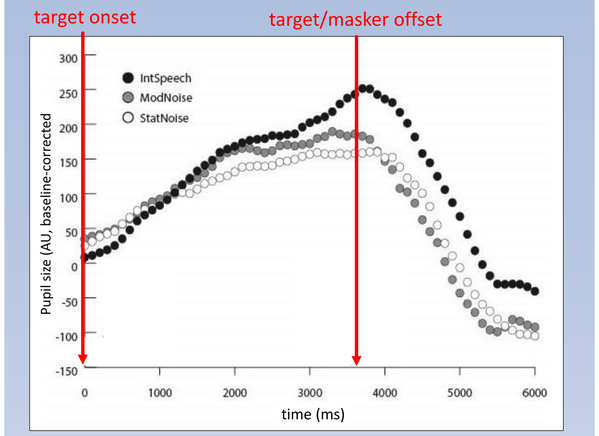
Part 1: Behavioral Testing

- Participants completed three adaptive tracks in each condition using a procedure adapted from Brand & Kollmeier (2002).
- These adaptive procedures were designed to estimate the TMR at which the participant could achieve 75% correct performance.

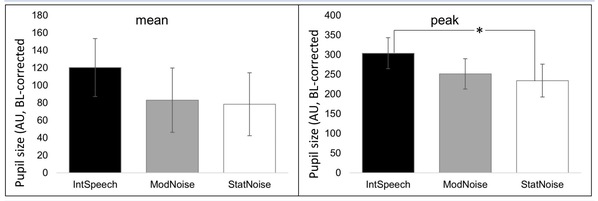
Part 2: Pupillometry/EEG recording

- Participants completed 2 blocks (24 trials) in each condition, with stimuli presented at their individually-estimated 75% correct TMRs.
- An SR Research Eyelink 1000 was used to collect pupil diameter measurements.
- A 32-scalp-channel BioSemi ActiveTwo system was simultaneously used to collect EEG data.

- For pupil size analysis, a subtractive baseline correction was performed for each trial, with the median of the last 1000 ms of the masker-only, pre-target listening portion of each trial serving as the baseline.

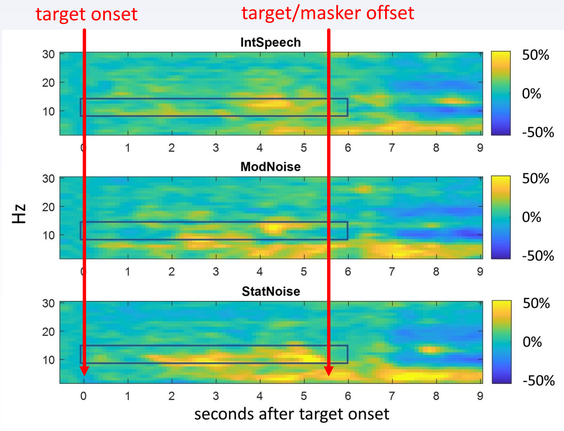


- Two 1 x 3 RM-ANOVAs examining the effect of condition on (1) mean change in pupil diameter during the 0-6000 ms period after target onset, and (2) peak change in pupil diameter, were performed. The RM-ANOVA examining peak pupil diameter was found to be significant: $F(2,28) = 5.26$, $p < 0.05$



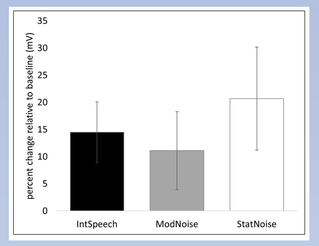
Error bars indicate standard error

- For EEG analysis, a divisive baseline correction was performed for each trial, with the last 1000 ms of the masker-only, pre-target listening portion of each trial serving as the baseline. Values in subsequent time-frequency bins were calculated as the percent change from the mean value during the trial's baseline.



Black rectangles indicate alpha (8-13 Hz) during listening

- A 1 x 3 RM-ANOVA examining the effect of condition on mean change in alpha (8-13 Hz) during the 0-6000 ms period after target onset was found to be non-significant, possibly due to high variability in the data or insufficient power.
- Additional analyses, possibly with a different baseline and/or time-frequency region of interest, may be performed in order to better understand these data.



Error bars indicate standard error

ASSOCIATIONS BETWEEN PUPILLOMETRY & EEG

- Three Pearson correlations were performed (one per condition) to check for associations between change in alpha power & change in pupil size from 0-6000 sec after target onset.
- Results were non-significant.

CONCLUSIONS

- Data collected on peak pupil size suggests that the intelligible speech masking condition elicited a higher degree of listening effort than a noise condition.
- This finding suggests that greater effort is involved in ignoring acoustically and linguistically similar sources than highly dissimilar, low-information value sources.
- Analysis of EEG data did not reveal a significant difference between conditions, possibly due to high variability.
- No association was seen between the pupillometry & EEG results, consistent with results of previous work suggesting that listening effort is multidimensional (Alhanbali et al., 2019).
- These results lay the groundwork for future investigations into listening effort under high-IM vs. high-EM listening conditions, in clinical populations including aphasia.

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