Effects of voice continuity and stimulus rate on auditory working memory

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Introduction

- Speech processing can be cognitively demanding, especially when the acoustics of incoming speech signals have high variability [1].
- The human auditory system perceptually adapts to speech characteristics of a talker (i.e., talker adaptation), which facilitates rapid and accurate speech recognition [2, 3].
- However, it is unknown (i) whether the facilitatory effects of talker adaptation persist beyond immediate speech recognition, and (ii) how the effects change when listeners have more time to process individual speech tokens.
- Research Questions:
  - Does talker adaptation lead to perceptual benefits in speech encoding or recall of speech information maintained in working memory?
  - Do the facilitatory effects from talker adaptation change with the amount of time to process incoming speech?

Methods

Participants

- 27 young adults with normal hearing (age: 18–30 years)

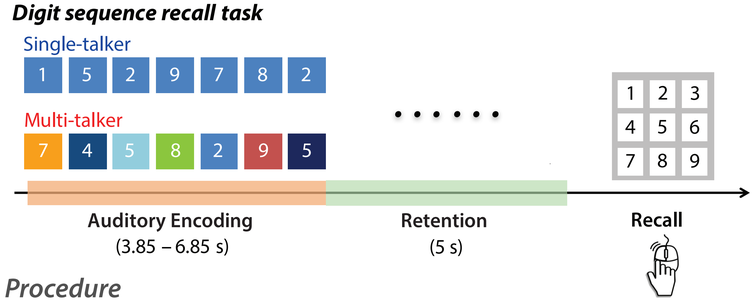
Stimuli

- Naturally-spoken digits (1–9), recorded by eight native American-English talkers (4 female; 4 male)
- Durations of all recordings were normalized to 550 ms (Praat ver. 5.3).

Task design

- Encode a sequence of seven, randomly selected digits, and recall the sequence in the order of presentation after a 5-s delay.
- Design (2 *talker* × 3 *stimulus rate)*:
  - *Talker* conditions: digits spoken by one single talker vs. multiple talkers
  - *Stimulus rate* conditions: 0-, 200-, and 500-ms inter-stimulus intervals (ISIs) between the digits in the sequence during encoding

Digit sequence recall task



Procedure

- 24 trials per block (× 6 blocks); blocked stimulus rate conditions; semi-randomized talker conditions (3 consecutive trials of a single talker or multiple talkers)

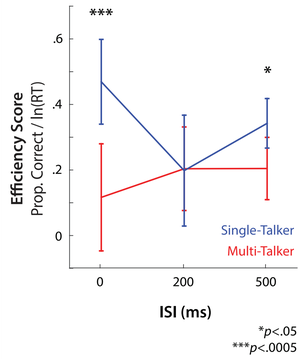
Behavioral data

- Proportion of correct recall; log-transformed onset response time
- Efficiency score = proportion correct / ln (onset RT)

Preliminary EEG experiment:

- EEG recording & analyses: a 64-channel active EEG system (BioSemi) sampling at 2000 Hz; average mastoids reference; 1–100 Hz filtered

Voice continuity leads to efficient recall



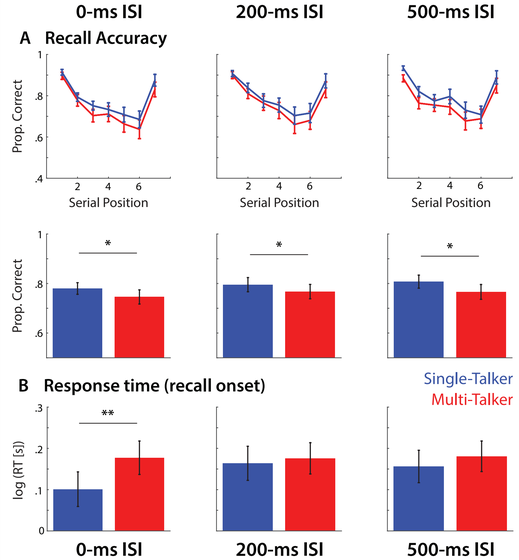
*p<.05
***p<.0005

Figure 1. Efficiency of digit sequence recall. Recall efficiency was computed as the average accuracy of sequence recall weighted by onset response speed (log-transformed inverse response time). Higher recall efficiency indicates more accurate and faster recall of digit sequences. For the faster presentation rate (0-ms ISI), listeners were significantly more efficient (i.e., faster and more accurate) in recalling sequences spoken by a single talker than multiple talkers.

Talker: $\chi^2(1) = 12.80$, $p = .00035$***
ISI: $\chi^2(2) = 0.58$, $p = .75$ (n.s.)
Talker × ISI: $\chi^2(2) = 9.90$, $p = .007$ **

ISI effect in the Single-talker: $\chi^2(2) = 9.80$, $p = .007$ **
ISI effect in the Multi-talker: $\chi^2(2) = 1.51$, $p = .47$ (n.s.)

Performance benefits from voice continuity



Talker: $F(1,26) = 13.65$, $p = .001$**
ISI: $F(1.9,50.3) = 1.56$, $p = .22$
Position: $F(1.7,44.7) = 27.5$, $p < .0005$***
Talker × ISI: $F(1.9,49.5) = .28$, $p = .75$
Talker × Position: $F(4.6,119) = .52$, $p = .75$
ISI × Position: $F(7.9,204.5) = 1.94$, $p = .06$
Talker × ISI × Position: $F(7.5,194) = .74$, $p = .65$

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Talker: $F(1,26) = 7.47$, $p = .011$*
ISI: $F(1.6,41) = .99$, $p = .36$
Talker × ISI: $F(1.9,49.1) = 2.0$, $p = .15$

*p<.05
**p<.005
***p<.0005

Figure 2. Digit sequence recall performance in 2 (*talkers*) × 3 (*stimulus rate; ISI*) conditions. (A) Response recall accuracy. (Top) average recall performance across participants (N=27) as a function of digit position in the sequence. (Bottom) average recall performance across digit positions. Across all ISIs, participants exhibited consistently higher accuracy in recalling digit sequences spoken by a single talker than multiple talkers. **(B)** Response onset time. At the fastest presentation rate (0-ms ISI), listeners responded faster for sequences spoken by a single talker vs. multiple talkers. Error bars: ± 1 SEM.

References

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Neurophysiological signatures

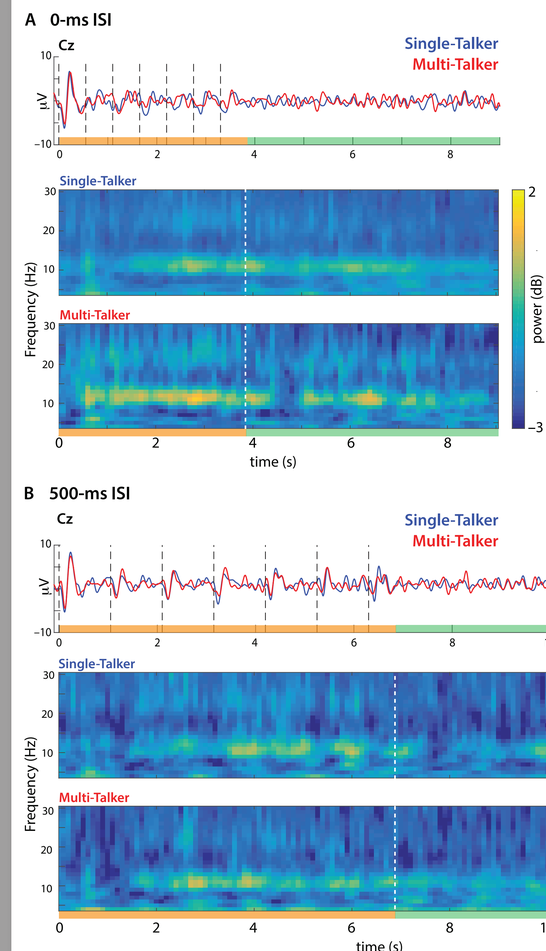

Figure 3. Preliminary EEG responses throughout the trial. The EEG experiment tested two stimulus presentation rates (0- and 500-ms ISIs). Grand average neural responses for the faster **(A)** and slower **(B)** presentation rates. (Top panels) evoked response potentials relative to the trial onset in the single vs. multiple talker conditions. (Bottom panels) time-frequency representations during task performance in the single vs. mulitple talker condition. Modulations of neural oscillatory power in the alpha range (~10 Hz) [4] seem to be greater at the faster presentation rate (A) during both stimulus encoding and memory retention phases.

Discussion

- Talker adaptation enhances accuracy and leads to faster recall during working memory for speech.
- Talker adaptation promotes efficient working memory for speech information, especially when listeners must process speech rapidly.
- Talker adaptation potentially reduces cognitive demands during speech encoding and memory retention as reflected in reduced parietal alpha oscillatory power.
- Our results suggest that voice continuity in fast speech allows auditory streaming [5] and reduces cognitive load, whereas non-continuity and slower speech rate may lead to the formation of multiple auditory objects in memory.

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