EEG differences between perceiving speech versus noise in physically identical sine-wave speech stimuli

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Background & Rationale

To identify neural correlates of speech perception, changes to the physical stimuli are typically required to elicit a perceptual transition from hearing noise to hearing speech.

The current study capitalized on sine-wave speech (SWS), which allows for physically identical stimuli to be perceived as noise vs. speech depending on perceptual priors.

Previous studies[1-5] have employed SWS to measure neural differences between perceiving noise vs. speech, but the key contrasts were:

- task-irrelevant noise vs. task-relevant speech

OR

- task-relevant noise vs. task-relevant speech

The current study aimed to isolate neural differences linked with speech perception from those related to the task by utilizing a 3-phase design:

Phase 1: task-irrelevant noise
Phase 2: task-irrelevant speech
Phase 3: task-relevant speech

Main Contrasts (across physically identical stimuli)
- perceiving speech vs. noise [phase 2 vs. 1]
- task-relevant vs. irrelevant [phase 3 vs. 2]

Methods: Participants, Stimuli, EEG

Subjects (N=21)

healthy college students naïve to the speech content of the stimuli

Stimuli

SWS stimuli: 3 monosyllabic words – brain, wave, yard – task-relevant in phase 3

Control stimuli (noise "flipped"): created by inverting the frequencies of the 2nd & 3rd formants of the SWS to destroy intelligibility while preserving the speech envelope

Pure tone stimuli: 3 tones – low, med, high – task-relevant in phases 1 & 2

Stimuli per phase

SWS: 300 (100 per word)

noise: 300 (100 per noise)

tones: 300 (100 per tone)

One-backs per phase

SWS: 30 (10 per word)

noise: 30 (10 per noise)

tones: 30 (10 per tone)

EEG/ERP methods

96 channels, equidistant

500Hz sampling rate

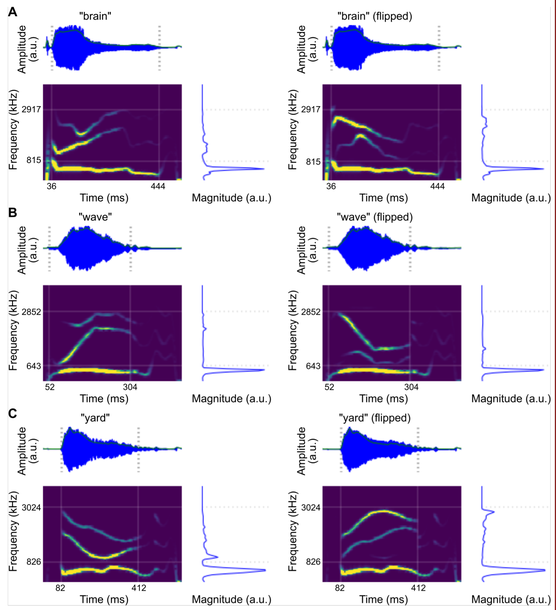
hardware filter: 0.1 – 150Hz

offline filter: 30Hz lowpass

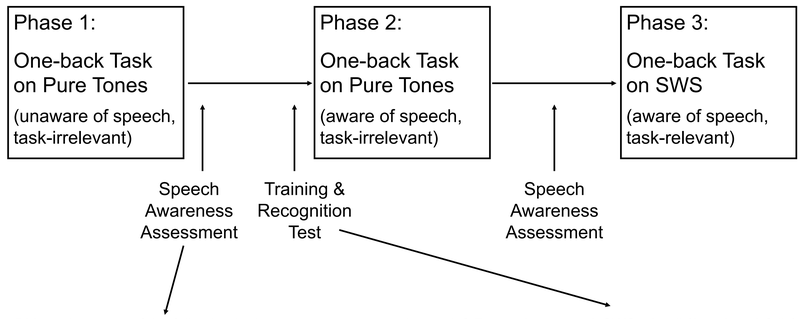
average referenced

artifacts rejected: >70μV

baseline correction: -200–0ms



Methods: Procedure, Assessments, Training



Did you hear any of the following in the computer-generated sounds? For each of the categories in the table below, circle a number representing your experience.

1=very confident I did not hear it
2=confident I did not hear it
3=uncertain
4=confident I did hear it
5=very confident I did hear it

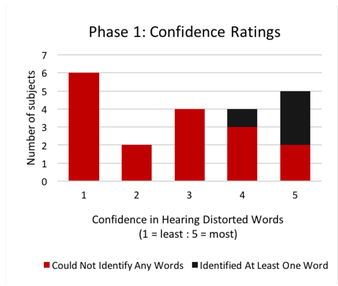
Distorted music	1	2	3	4	5
Distorted words	1	2	3	4	5
Distorted environmental sounds	1	2	3	4	5
Distorted animal sounds	1	2	3	4	5

If you marked a "4" or "5" for hearing the computer-generated noises as "distorted words", please write down the words you heard.

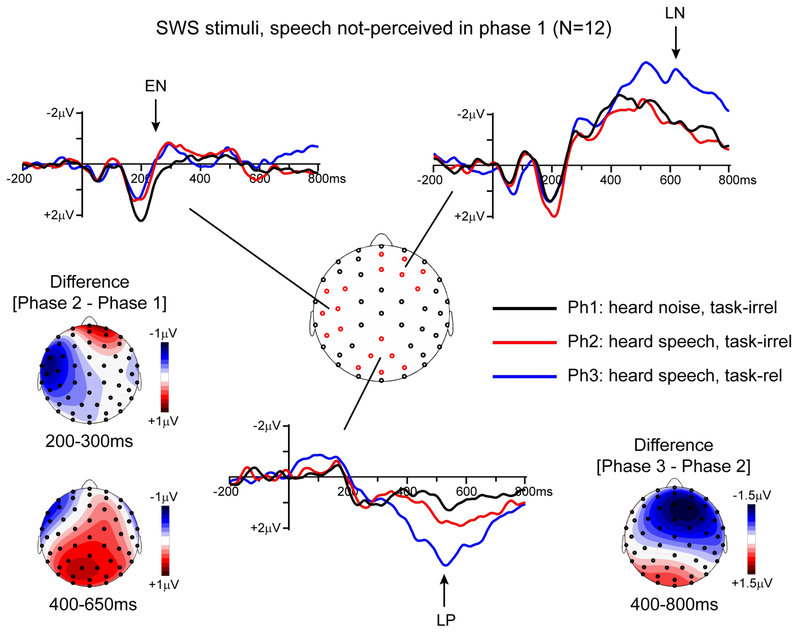
9 SWS stimuli (3 main + 6 foils)

Self-paced training
- SWS → Original → SWS
- repeat until SWS clearly perceived as speech

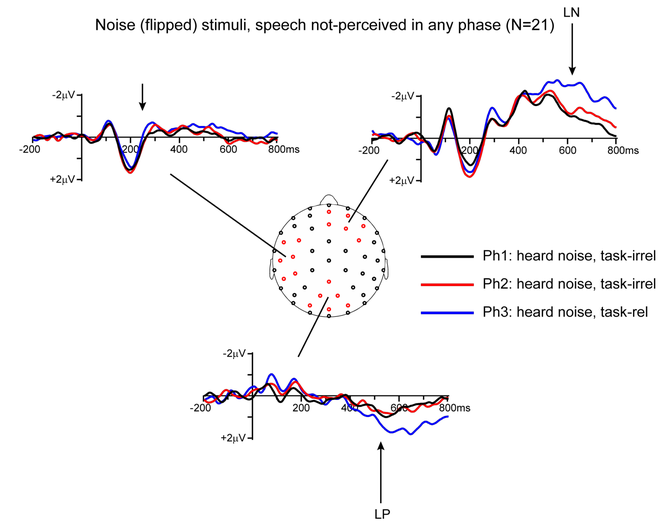
Speech recognition test
- 10 AFC (9 words, 1 no word)
- total accuracy = 94%
- accuracy for brain, wave, yard = 99%

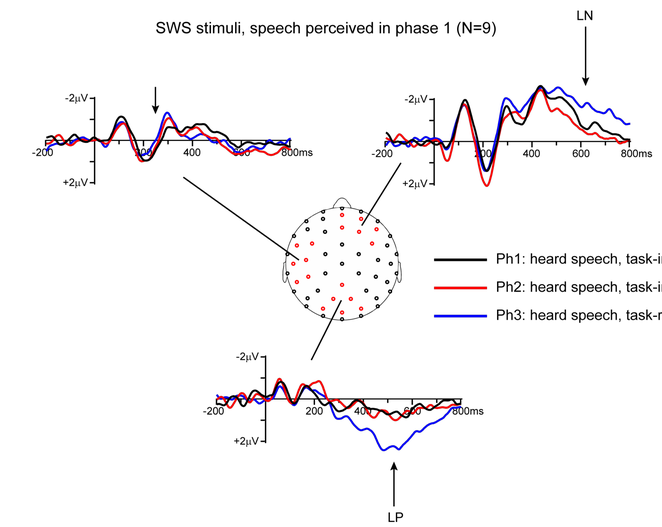


Main ERP Results



Control ERP Results





Summary / Discussion

Perceiving speech vs. noise [phase 2 vs. 1]
- EN: early negativity (200-300ms), left frontal distribution
- LP: late positivity (400-650ms), P3b-like distribution, small amplitude

Task-relevant vs. irrelevant [phase 3 vs. 2]
- LP: late positivity (400-650msec), P3b-like distribution, large amplitude
- LN: late negativity (>400ms, sustained), frontal distribution

Follow-up experiments underway to determine if small LP in phase 2 vs. 1 is related to speech perception or task relevance

References

[1]Liebenthal et al. (2001). Sinewave speech / nonspeech perception: An fMRI study. *JASA, 109*, 2312-2313.
[2]Liebenthal et al. (2005). Neural substrates of phonemic perception. *Cerebral Cortex, 15*, 1621-1631.
[3]Dehaene-Lambertz et al. (2005). Neural correlates of switching from auditory to speech perception. *NeuroImage, 24*, 21-33.
[4]Mottonen et al. (2006). Perceiving identical sounds as speech or non-speech modulates activity in the left posterior superior temporal sulcus. *NeuroImage, 30*, 563-569.
[5]Khoshkhoo et al. (in press). Neural correlates of sine-wave speech intelligibility in human frontal and temporal cortex. *Brain & Language*