Role of listening effort in an objective correlate of speech understanding

Lien Decruy, Jonas Vanthornhout, Jan Wouters, Tom Francart

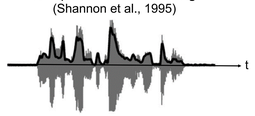
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1. Introduction

Objective correlate of speech understanding

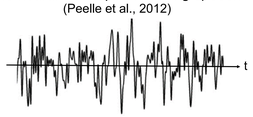
Amplitude envelope of speech

Speech envelope is a primary cue for speech understanding (Shannon et al., 1995)

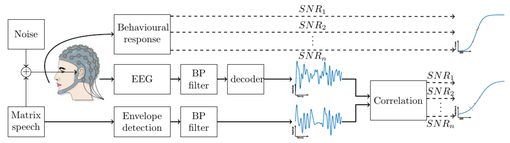


Speech envelope entrainment

Cortical neural activity tracks the neural envelope of running speech (Peelle et al., 2012)



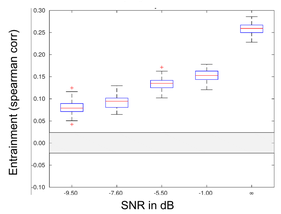
Objective correlate of speech understanding?
Correlation between reconstructed and real speech envelope (~ entrainment) in function of signal-to-noise ratio (SNR)



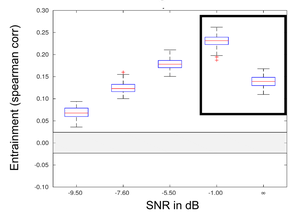
Reconstruction of speech envelope from EEG-signals by using a linear decoder

Research question

Entrainment ↑ with SNR ↑
~ Behavioral psychometric function



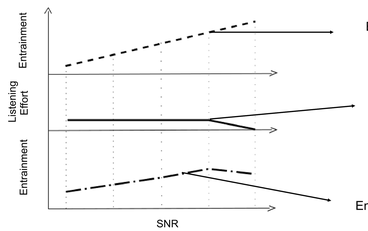
Fluctuations in entrainment
~ Listening Effort?



Listening effort refers to the cognitive resources which are needed to understand speech

SNR ↓ or Hearing impairment ↑ => Speech Understanding ↓ => Entrainment ↓
SNR ↓ or Hearing impairment ↑ => Listening Effort ↑ => Entrainment ↑

Research Question: Does listening effort explain the fluctuations in speech envelope entrainment on high speech intelligibility levels (Hypothesis: listening effort ↓ at high SNRs => Entrainment ↓)



Entrainment with constant Listening Effort and variable speech understanding

+

Listening Effort with variable speech understanding

↓

Entrainment with variable Listening Effort and variable speech understanding

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2. Methods

Behavioral correlate of Listening Effort - Dual Task

To measure listening effort, we developed a Dual Task paradigm

- 1st task = Speech in noise test (~ at 6 SNRs + silence)
- 2nd task = Response time (RT) on memory task (recall position of word/number)

Assuming that our **cognitive system has a limited capacity of resources** =>
The **performance on the 2nd task** will reflect the **listening effort of the 1st task** when both tasks require the same cognitive resources (~ verbal working memory)

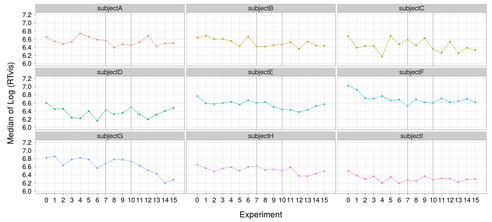
Pilot study - Validation 2nd task

1. Learning effect - RT

- 9 NH subjects
- Subject had to remember the position of three numbers (training + 15x10 trials)
- RT ↓ with experience
- For most subjects, stable reaction time between 7 and 10 experiments (figure)

2. Memory task - numbers versus words

RT is higher when recalling position of words (=> visualization of numbers?)



Participants

- 5 young NH subjects, aged 22– 28 years
- 2 young HI subjects (moderate SNHL), aged 28 years (subject 2 and 7)

Montreal Cognitive Assessment (MoCA)

- All subjects (NH & HI) have a normal cognition.

Eén minuut test (EMT)

- All subjects (NH & HI) have a normal reading ability.

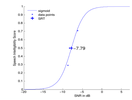
Reading Span test (RST)

- Subject 2 (HI) and subject 5 (NH) score very low for verbal working memory. The other subjects have a normal verbal working memory.

Subject-specific psychometric curve

To compare NH and HI, we measured at **fixed speech intelligibility (SI) levels**

- Stimuli: Flemish Matrix sentences (norm: SRT= -9.5 dB, slope= 13.9%/dB)
- Masker: Speech Weighted Noise (SWN)
- Monaural presentation, right ear
- Fixed speech level, NH: 65 dBA, HI: 75-80 dBA
- Adaptive procedure, 3 lists for 3 different SIs



=> For each subject, 6 SNRs were interpolated based on the 3 SNRs obtained from the Adaptive procedure

EEG

- Biosemi system - 64 electrodes
- Decoder (integration window: 0 - 75ms, bandpassfilter: 0.5 - 4 Hz)
- Flemish Story (15 min silence, 15 min 95% SRT) ~ training decoder
- Flemish Matrix sentences at 7 SNRs (7 x 2 minutes) x 3

Listening Effort - final protocol

Protocol

1. Speech in noise test

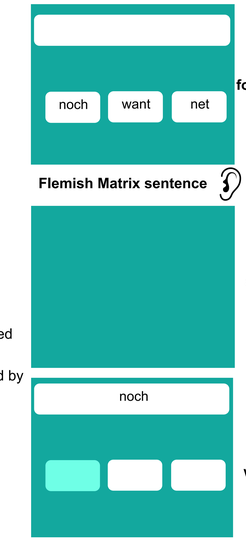
- 7 lists (6 subject-specific SNRs + silence)
- presented in random order
- Constant procedure

2. Training 2nd Task (~ Learning Effect)

10x 20 trials to achieve a stable RT

3. Dual Task

- 1st task and 2nd task simultaneously
- 7 lists (6 subject-specific SNRs + silence)
- presented in random order
- Constant procedure



Analysis

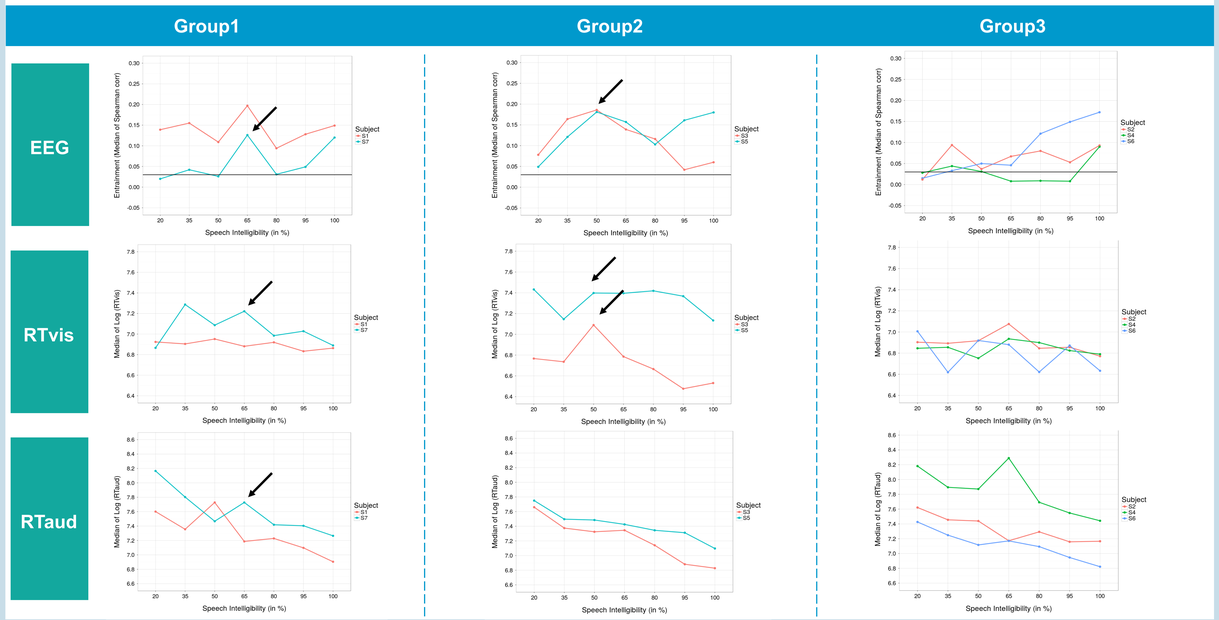
- RTs of incorrect responses on memory task were removed
- All RTs were log transformed
- Outliers were removed based on the MAD-rule described by Wilcox and Clark (2013).

Correlates of Listening Effort

- **RTaud**: time between end of stimulus and push on middle button
- **RTvis**: time between 3rd screen and push on button

3. Results

Based on our EEG-data, we made three groups where each group represents subjects who show similar patterns of speech envelope entrainment. For each group, first the EEG-results are presented where chance level (spearman correlation = 0.03) is also shown (—). The next figures represent respectively RTvis and RTaud, obtained from our Dual Task paradigm.



4. Discussion

Effect of Hearing on speech envelope entrainment

- Most subjects show correlations above chance level (except subject 4)
- For all subjects, entrainment ↑ for low speech intelligibility levels
  => promising results for objectively estimating SRT
- Similar patterns in speech envelope entrainment across subjects
  => fluctuations in entrainment can be categorized?
- NH and HI have similar patterns (N = 2)
  => This is normal since we used fixed speech intelligibility levels

Link between Speech envelope entrainment and Listening Effort

To explain the fluctuaties in entrainment, we developed a Dual Task paradigm where the primary task is a speech-in-noise test and the secondary task a memory task where the subject has to recall the position of the word. Response time was measured in two ways.

- In general, RTaud ↓ with SI ↑ ~ less effort needed when speech is intelligible
- For subjects 7 (HI), 3 and 5 (NH):
  fluctuations in RTvis ~ fluctuations in entrainment (⟶)

Future plans

- Confirm first results by collecting more data
- Explore other correlates of listening effort, such as pupillometry

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lien.decruy@kuleuven.be