

Electroencephalography (EEG) Signatures of Induced Auditory Verbal Hallucinations

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Introduction

Auditory Verbal Hallucinations (AVH): when an individual perceives hearing a voice that is not their own in the absence of any voice present.

AVH occur in healthy populations at a lower frequency than clinical populations.

Powers et al. (2017) conditioned participants with a visual cue (checkerboard) and auditory tone at the same time. **Conditioned hallucinations** occurred when the tone was detected when only the cue was present. Therefore, AVH may be induced in the same way, which would be an objective method to study auditory hallucinations.

AVH may:

- be explained by **inner speech**- the silent process of thought.
- occur due to the false **misattribution of inner speech** to an external source accompanied by **additional attempts at processing speech**.

Figure 1: model of how **brainwaves facilitate speech processing**- *theta* and *gamma* wave bands are important in both the **power** (magnitude) as well as the **phase coherence** (brainwaves alignment) modalities during speech processing.

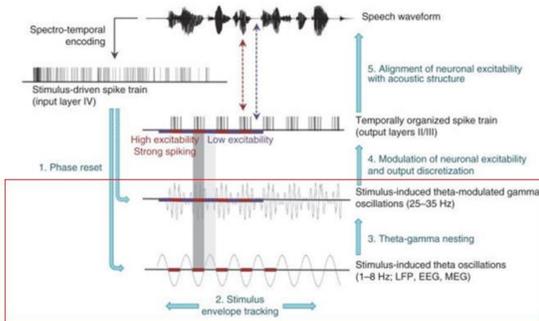


Figure 1: Neural Oscillation Speech Processing Framework (Taken from Giraud et al. (2012))

Aims

Is it possible to induce AVH in healthy participants?

Is there increased theta and gamma activity and inter-trial phase coherence associated with AVH?

Method

Experiment 1

Signal detection task (Shown in Figure 2) made up of 3 types of blocks:

- **Thresholding** to determine an individual's hearing
- **Conditioning** of the auditory phrase "The grass is green" with white noise at full volume
- **Testing:** white noise is present and the auditory phrase may or may not be present.

A false positive represented an **AVH** experience while the opposite was a **correct reject**.

Experiment 2

Those with highest AVH rates were invited back to complete experiment 2 with EEG (64 electrodes-10-20 international system) to increase statistical power.

Trials with no auditory stimulus were isolated and analysed the second after stimulus presentation, looking at both the **evoked power** and **inter trial phase coherence** during **AVH** compared to **correct reject**.

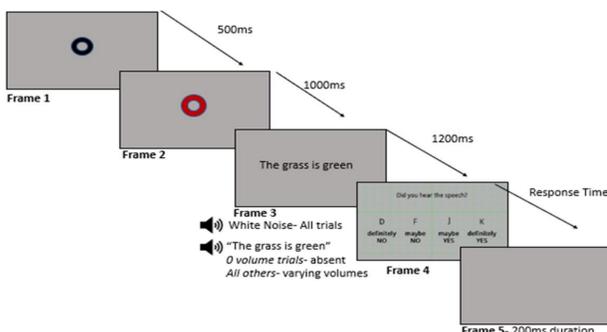


Figure 2: Diagrammatic representation of a single trial in the testing blocks

Results-Experiment 1

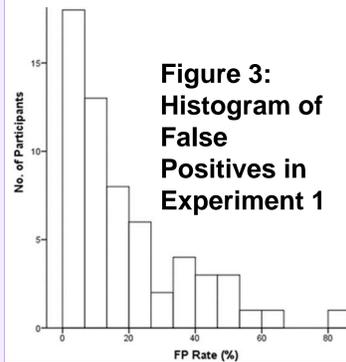


Figure 3: Histogram of False Positives in Experiment 1

60 participants completed experiment 1. **Figure 3** shows AVH rates are greater than zero indicating it is possible to induce AVH in healthy participants. This was confirmed with the *wilcoxon signed rank test* ($z = 6.63, p < .001, r = .849$) Median (20): the cut off for asking individuals back for experiment 2.

Results- Experiment 2

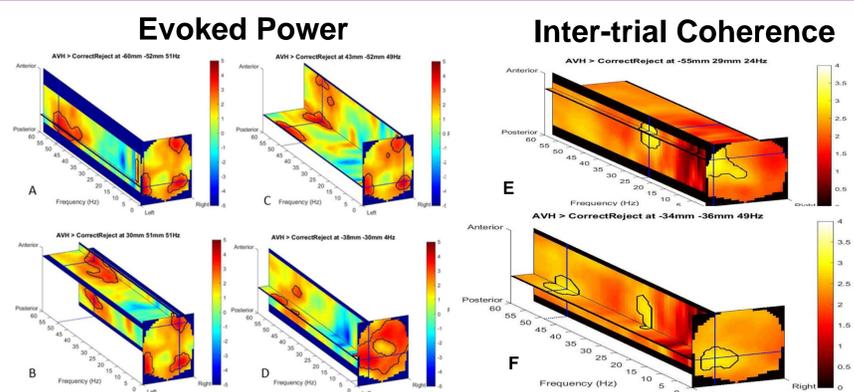


Figure 4: EEG Frequency Maps: the averaged EEG activity within 1 second of stimulus onset. Significant areas ($p < .001$) are represented as black circles.

Evoked power calculations looked at the total activity across all trials, across frequency bands comparing AVH to correct rejects

Four main significant areas of greater activation were revealed:

Gamma frequency: left temporal (4A)
right frontal (4B)
right temporal (4C)

Low frequency(3-5Hz):
left centro-parietal area (4D)
right frontal area(4D)

Inter-trial phase coherence revealed two areas of increased phase locking across all trials and frequency bands:

- left frontoparietal region (4E) in the beta frequency band (20-27Hz)
- left temporoparietal region (4F) in the gamma frequency band (43-53Hz)

There was also a gradual decrease in the degree of phase locking across conditions; greatest during actual speech and the least during correct reject.

Discussion

- It seems to be possible to induce AVH in healthy participants.
- An increase in EEG activity during AVH compared to correct reject may represent an active perceptual experience in response to the same stimulus. This could potentially support the misattribution of inner speech during AVH.
- EEG data seems to mimic speech processing framework (Giraud et al. 2012)- gamma and low frequency reflect phonemic and syllabic rates respectively.
- Increased beta inter phase coherence and frontal gamma could indicate AVH involves additional mechanisms, potentially the influence of predictions.
- Unfortunately, our study only used male voice as stimulus and the male sample size was small.

Conclusion

Overall our study provides a foundational basis to investigate induced AVH in healthy participants and indicates that speech processing pathways could potentially interact with predictions and to influence source attribution as a potential mechanism driving AVH.

Further research should:

- Counterbalance speech recordings of both males and females
- Induce AVH in Clinical-High risk and clinical patients

References

- Giraud, A., and Poeppel, D. (2012). Cortical oscillations and speech processing: emerging computational principles and operations. *Nature Neuroscience*, 15(4), 511-517. doi: 10.1038/nn.3063
- Powers, A., Mathys, C., and Corlett, P. (2017). Pavlovian conditioning-induced hallucinations result from overweighting of perceptual priors. *Science*, 357(6351), 596-600. doi: 10.1126/science.aan3458