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Linking Visual Gamma Oscillations to Oculomotor Variability Across Stimulus Contrast: A Pilot Study

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It is generally assumed that brain rhythms reflect the neural processes required to perform the cognitive operations demanded by the experimental task. This assumption has led to theories assigning a specific role of gamma oscillations (30-90Hz) involved in information binding[1], thereby enabling higher-order cognitive functions[2]. However, it remains unclear as to why gamma activity variation in the visual cortex primarily depends on stimuli properties[3].

It has been reported that **perception of gratings entails eye movements across the contrast border**[4]. Assuming the premise that oculomotor action control is a continuous process monitored by brain circuits, it appears relevant to consider to what extent eye movements, and the control thereof bears some informative value of why and how **contrast of the stimulus affects measures of gamma oscillations**. Here, the aim is to explore this by varying the contrast while keeping other stimulus parameters constant.

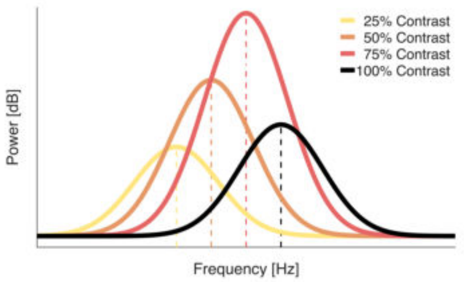

Fig. 1: Visualization of the main hypothesis: Increase of gamma frequency with increasing contrast. It is assumed that the change in gamma frequency influences microsaccadic activity responsible for successful contrast perception.

Methods

Sample

N = 10 pilot participants (M = 25.9, SD = 5.57, 40% f.)

Grating Task

- Concentric inward moving grating (2000ms)
- Conditions: 25, 50, 75 and 100% luminance contrast
- Exclusion of grating presentation periods with button presses (10% of trials)
- 160 trials per condition for analysis

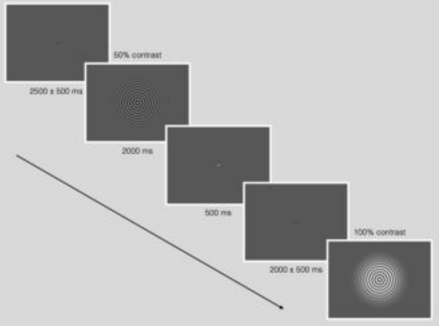

Fig. 2: Concentric grating task paradigm. Black fixation crosses and grating stimuli are shown alternatingly. Red fixation crosses prompt the participant to respond by button press. After a jittered interval of 2000ms - 3000ms of fixation cross presentation, a concentric grating stimulus with varying contrast intensity and orientation is presented for 2000ms.

Eye-Tracking

- Contrast-dependent modulations in microsaccades and eye velocity during stimulus presentation
- Eye-tracker EyeLink 1000 Plus (sampling rate 500 Hz)
- Baselined to pre-stimulus interval (-1.5s to -0.25s)

EEG

- Contrast-dependent modulations of posterior gamma frequency and power during stimulus presentation
- 128-channel ANT Neuro EEG system, sampling rate 500 Hz
- Preprocessing with Automagic[5]: removal of noisy/outlier channels, high pass filter 0.1 Hz, ZapLine 50 Hz, artifact removal with ICLabel, ocular correction with OPTICAT
- Baselined to pre-stimulus interval (-1.5s to -0.25s)
- Removal of the aperiodic component in the power spectrum using the SpecParam algorithm[6]

References

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Results

Eye-Tracking

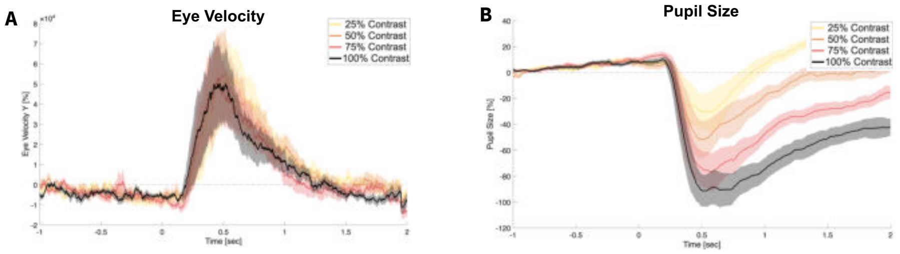


Fig. 3: Time courses of grand averages for the gaze measures over all contrast conditions. Eye velocity (**A**) on the vertical axis of the screen is shown as percentage change from baseline. Pupil size (**B**) is also shown as as percentage change from baseline. Pupil size serves as manipulation check for the contrast conditions.

EEG

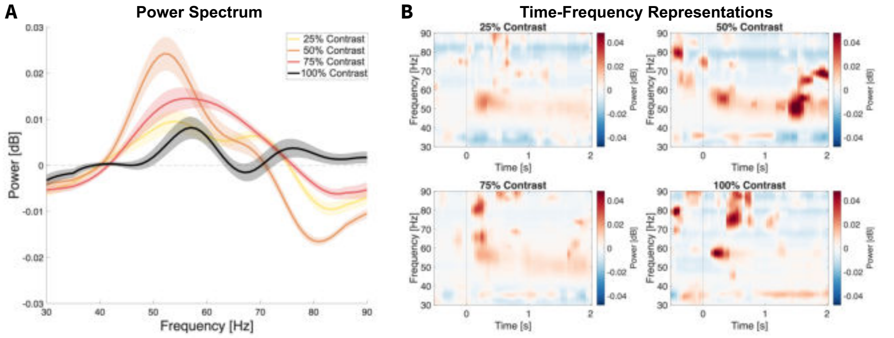
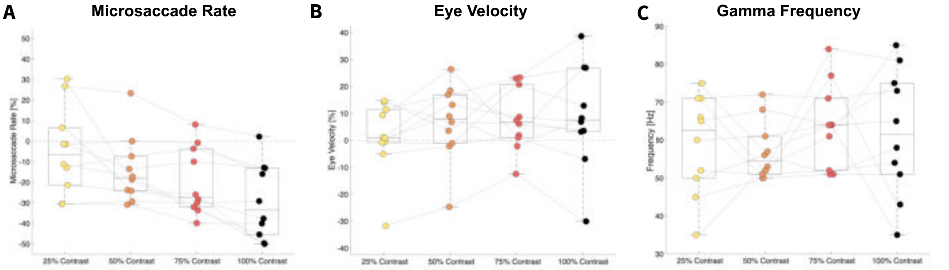


Fig. 4: Visualizations of the grand averages for the EEG measures within the gamma range (30-90Hz) over all the contrast conditions. Power spectral density (**A**) for occipital gamma power. Frequency in Hz is displayed on the x-axis with power in dB on the y-axis. Shaded areas around each line depict the standard error of the mean. Time-frequency representations (**B**) with the analysis time window (300ms – 2000ms) indicated.

Outlook: Linking Gamma Oscillations to Oculomotor Activity



D Statistical Models

[Gamma Frequency] ~ Microsaccades * Contrast + (1|Subject)
[Gamma Frequency] ~ Eye Velocity * Contrast + (1|Subject)

Fig. 5: Boxplots for (**A**)) microsaccade rate, (**B**) eye velocity, and (**C**) gamma frequency. Dots show individual participants' values connected with grey lines over conditions. Microsaccades and eye velocity are shown as percentage change compared to the baseline rate. Statistical models (**D**) to be performed with the full data set. Linear mixed effects models with gamma frequency as the dependent variable. The contrast condition and the gaze metric (microsaccades or eye velocity), as well as their interaction, are added as fixed effects. Subjects are included as random effects.

Conclusion

Preliminary results indicate potential trends in the relationship between oculomotor activity and gamma oscillations, with variation observed across contrast conditions. Importantly, **microsaccade activity is strongly linked to changing contrast conditions**. These exploratory findings highlight a potential connection between gamma oscillations and oculomotor control, suggesting directions for future research to better understand the role of eye movements in modulating brain activity during cognitive tasks. However, due to insufficient statistical power, no definitive conclusions can yet be drawn regarding the relationship between gamma frequency and gaze variability. This study sets the stage for a future registered report with an adequately powered sample size.