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

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Intro

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 gamma oscillations (30-90 Hz) a specific role in information binding,[1] thereby enabling higher-order cognitive functions.[2] However, visual cortical gamma activity is strongly modulated by basic stimulus properties such as luminance contrast,[3] raising the question of whether gamma activity exclusively reflects cognitive processing. It has been reported that **viewing grating stimuli elicits eye movements across contrast borders**.[4] Given that oculomotor control is continuously mediated by cortical circuits, the neural processes underlying these eye movements may contribute to the gamma activity measured over visual cortex. This raises the possibility that **the effect of stimulus contrast on visual gamma activity partly reflects oculomotor processes**. Here, we test this hypothesis by systematically varying stimulus contrast while keeping all other stimulus parameters constant.

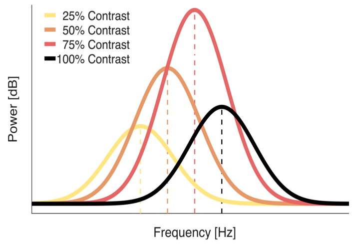

Fig. 1: Visualization of the main hypothesis: Increase of gamma frequency with increasing contrast. Changes in gamma frequency are assumed to influence microsaccades responsible for contrast perception.

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) due to motor responses
- 160 trials per condition for analysis

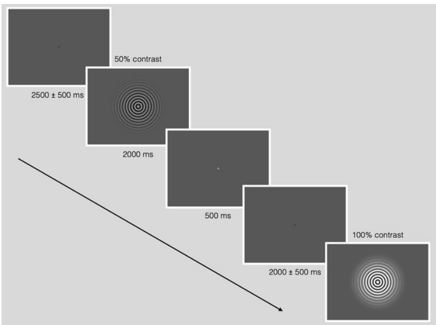

Fig. 2: Concentric grating task paradigm. Black fixation crosses and grating stimuli are shown alternatingly. Red fixation crosses prompt the participant to respond by button press. After a jittered interval of 2000ms - 3000ms of fixation cross presentation, a concentric grating stimulus with varying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

Eye-Tracking

- Contrast-dependent changes in microsaccades and eye velocity during stimulus presentation; pupil size as manipulation check
- Eye-tracker EyeLink 1000 Plus (sampling at 500 Hz)
- Baselined to pre-stimulus interval (-1.5s to -0.25s)

EEG

- Contrast-dependent changes in gamma power and peak frequency during stimulus presentation
- 128-channel ANT Neuro EEG system (sampling at 500 Hz)
- Preprocessing with Automagic[5]: removal of noisy channels, high pass filter 0.1 Hz, ZapLine 50 Hz, artifact removal with ICLabel, ocular correction with OPTICAT
- General eigendecomposition[6, 7]: Gamma spatial filter (30–90 Hz covariances; stimulus vs baseline (-1.5s to -0.25s; dB)), occipital component selection, component back-projection, peak power (±5 Hz) and frequency extraction on multi-tapered spectra

Results

Eye-Tracking

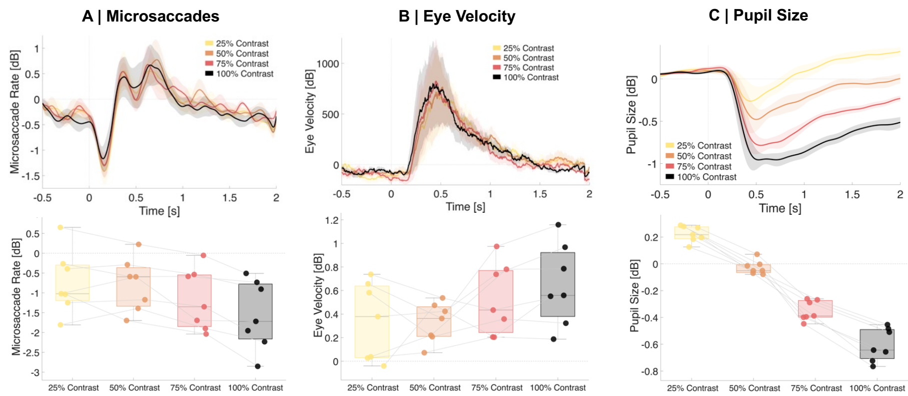

Fig. 3: Time courses of grand averages and boxplots for the gaze measures microsaccade rate (**A**), eye velocity (**B**), and pupil size (**C**), relative to stimulus onset. Shaded areas indicate standard error of the mean. Boxplots show median, IQR, and participant mean data points. Connected points belong to the same participant.

Electroencephalography

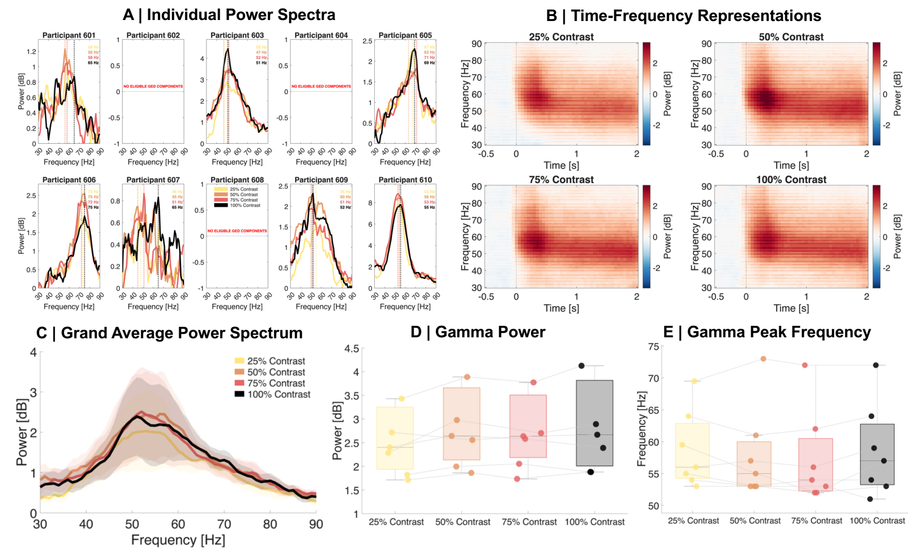

Fig. 4: Visualizations of EEG measures within the gamma range (30-90Hz). Power spectra for individual subjects (**A**) from back-projected GED components. Three subjects did not yield valid GED components and thus have no power spectrum. Grand average time-frequency representations (**B**). Grand average power spectrum (**C**). Shaded areas indicate standard error of the mean. Boxplots of gamma power (**D**) and peak frequency (**E**) show median, IQR, and participant mean data points. Connected points belong to the same participant.

Outlook: Linking Gamma Oscillations to Oculomotor Activity

Statistical Model: [Gamma Frequency, Gamma Power] ~ Gaze * Contrast + (1|Subject)

Fig. 5: Statistical model to be performed with the full data set. Linear mixed effects models with gamma frequency and power as the dependent variables. 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 co-variations between oculomotor activity and gamma oscillations, with variation observed across contrast conditions. Notably, both **microsaccade activity and eye velocity are linked to contrast changes**. Furthermore, gamma power and frequency likewise seem so show differences induced by contrast. 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. However, due to insufficient statistical power, no definitive conclusions can yet be drawn regarding the relationship between gamma oscillatory measures and gaze variability. This study sets the stage for a future registered report with an adequately powered sample size.

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