# Effects of memory load on the contralateral delay activity and induced alpha power in the EEG: studied with a virtual reality setup

Felix Klotzsche<sup>1,2</sup>, Michael Gaebler<sup>1,2</sup>, Arno Villringer<sup>1,2</sup>, Werner Sommer<sup>1,3</sup>, Vadim Nikulin<sup>1</sup>, and Sven Ohl<sup>3</sup>

<sup>1</sup> Max-Planck-Institut für Kognitions- und Neurowissenschaften, Leipzig, Deutschland <sup>2</sup> Humboldt-Universität zu Berlin, Faculty of Philosophy, Berlin School of Mind and Brain, Germany <sup>3</sup> Humboldt-Universität zu Berlin, Department of Psychology, Germany



MIND AN BRAIN

#### klotzsche@cbs.mpg.de

### Introduction

EEG markers of visual Short-Term Memory (vSTM) processes are well studied in conventional lab settings.

**Contralateral Delay Activity (CDA)** 





(s) Leenders et al., 2016

Virtual Reality (VR) technology offers new possibilities to study these processes (e.g., in naturalistic settings),



VR combining but а EEG with headset measurements introduces new challenges. The weight of the headset and its contact with the electrodes can lead to





additional noise. The thereby lowered signal-to-noise ratio (SNR) might render the components of interest untraceable. Multivariate analysis approaches can help to increase the sensitivity of these measures.

Furthermore, VR offers a wide field of view, but vSTMcomponents in the EEG have mostly been studied at small eccentricities (<5°).



#### **Research questions:**

- Do we find **EEG markers of vSTM** when using a **VR headset** instead of a desktop monitor?
- Do they change when presenting the stimuli at **larger eccentricities** than previously studied?

# Results



**CDA amplitude** varies with memory load but not with stimulus eccentricity

CDA per memory load



Lateralized alpha power varies neither with memory load nor with eccentricity

lateralized alpha power per **memory load** 

ize Memory Array







per eccentricity

**2**B

Size Memory Array

+ 2

|2A

#### Memory load can be **decoded** from **alpha power** for all eccentricities



across all eccentricities



Memory load can be **decoded** from **voltage data** for all eccentricities

## across all eccentricities





**Top**: Avg. decoding performance (ROC AUC) of the sliding classifier (log. regression) over time. **Bottom:** Spatial pattern weights of the classifier (normalized & averaged across subjects).

most discriminative CSP component.

# References

Adam, K. C. S., Vogel, E. K., & Awh, E. (2020). Multivariate analysis reveals a generalizable human electrophysiological signature of working memory load. *Psychophysiology*, 57(12). https://doi.org/10.1111/psyp.13691 Blankertz, B., Tomioka, R., Lemm, S., Kawanabe, M., & Muller, K. (2008). Optimizing Spatial filters for Robust EEG Single-Trial Analysis. *IEEE Signal Processing Magazine*, 25(1), 41–56. https://doi.org/10.1109/MSP.2008.4408441 Brookes, J., Warburton, M., Alghadier, M., Mon-Williams, M., & Mushtaq, F. (2020). Studying human behavior with virtual reality: The Unity Experiment Framework. Behavior Research Methods, 52(2), 455-463. https://doi.org/10.3758/s13428-019-01242-0 Jas, M., Engemann, D. A., Bekhti, Y., Raimondo, F., & Gramfort, A. (2017). Autoreject: Automated artifact rejection for MEG and EEG data. NeuroImage, 159, 417–429. https://doi.org/10.1016/j.neuroimage.2017.06.030 Leenders, M. P., Lozano-Soldevilla, D., Roberts, M. J., Jensen, O., & De Weerd, P. (2018). Diminished Alpha Lateralization During Working Memory but Not During Attentional Cueing in Older Adults. Cerebral Cortex, 28(1), 21–32. https://doi.org/10.1093/cercor/bhw345 Vogel, E. K., & Machizawa, M. G. (2004). Neural activity predicts individual differences in visual working memory capacity. Nature, 428(6984), 748–751. https://doi.org/10.1038/nature02447

## Discussion

- $\checkmark$  We replicated the effects of memory load on CDA amplitude. Therefore, using a VR headset does not cause a detrimental decrease of the SNR.
- $\checkmark$  We show this for **stimulus eccentricities of up to 14**°.
- ✓ A more sensitive, **multivariate decoding** approach confirmed these findings.

✓ We replicated the **lateralization of induced alpha power** in response to the cue and during memory retention.

✓ This alpha lateralization was modulated neither by memory load nor by stimulus eccentricity.

✓ Using **spatial filters** and a **multivariate classifier**, we could decode memory load from (unlateralized) alpha power for all eccentricities.