Effects of interictal epileptiform discharges on cognitive performance and pupillometry in pediatric epilepsy: a multi-modal deep learning approach

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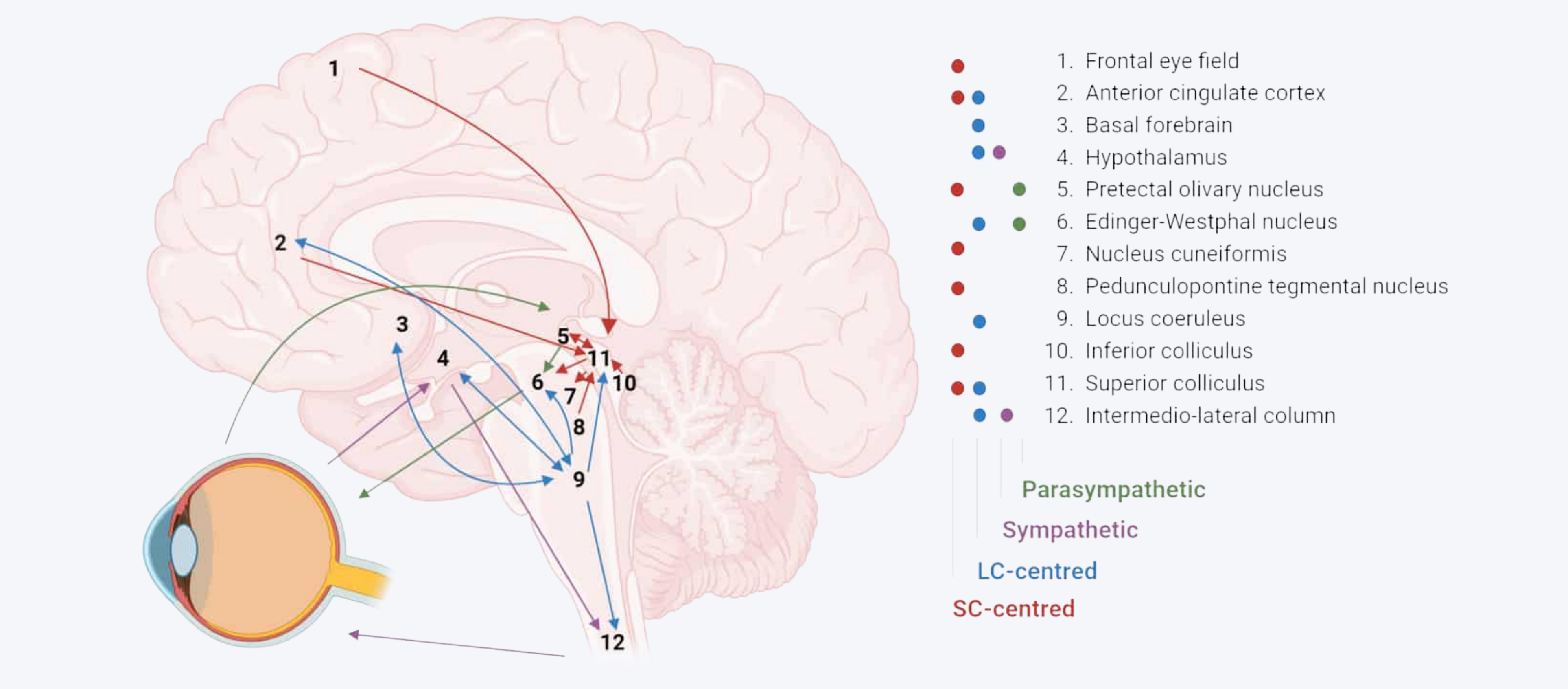
At-a-glance

Using intracranial recordings from children with epilepsy, we leverage deep learning to model pupillary time courses and explore the relationship between neural activity, pupil dynamics, and cognitive performance. Our findings reveal that interictal epileptiform activity disrupts task performance but has a variable impact on the neural-pupil relationship across participants.

Introduction

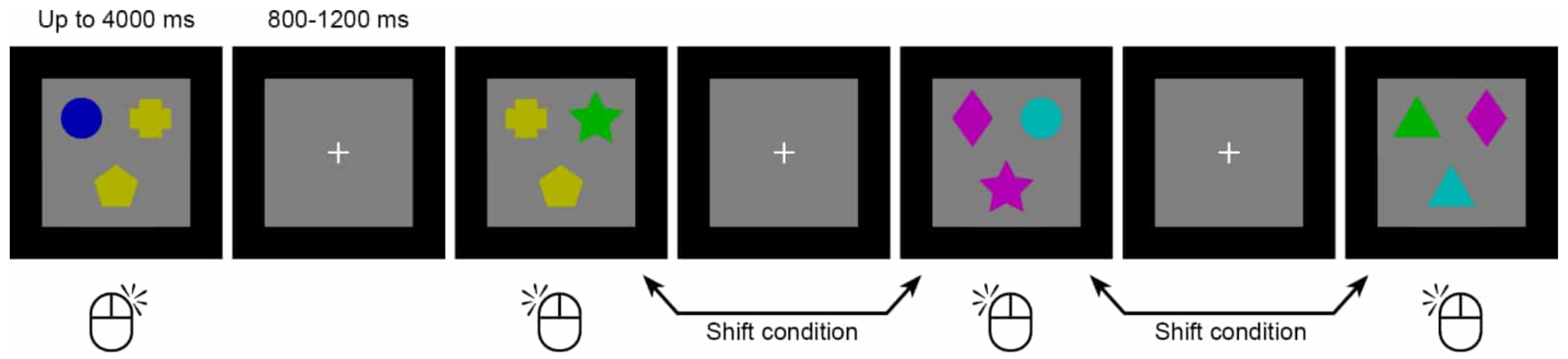


Attentional networks that affect pupil size. Adapted from Strauch et. al. (2022)[1].

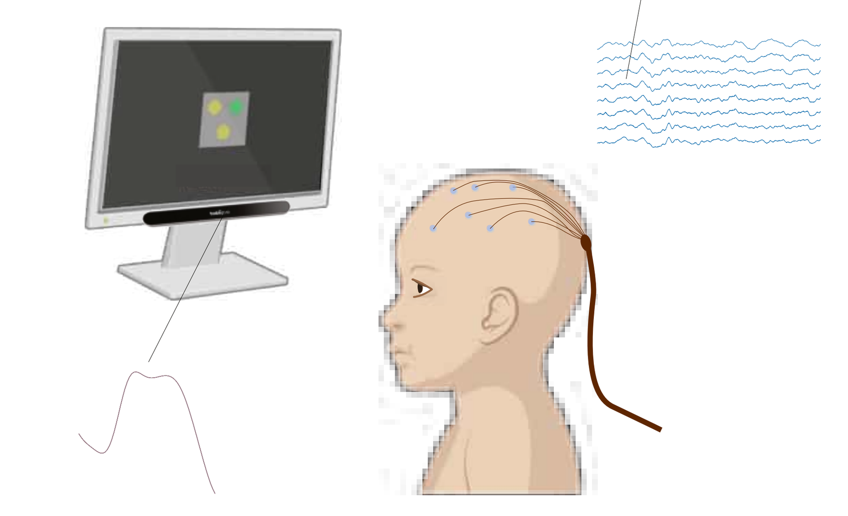
- **Pupillary response reflects** sensory and goal-oriented **cognitive processes**[1], but specific **contributions** of cognitive processing to pupillary dynamics **remains unclear.**
- Impact of **interictal epileptiform discharges (IEDs) on** these **relationships has not been thoroughly investigated.**
- We leverage **deep learning and statistical models** to **uncover relationships** between between **pupil size, neural activity, and behavioural outcomes** in the presence and absence of IEDs.

Methods

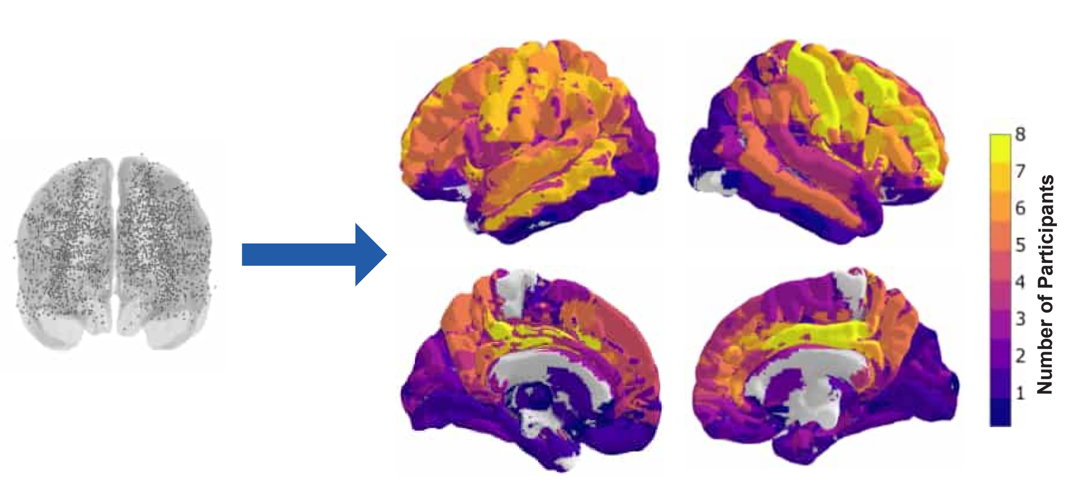
Attentional Set-Shifting Task



Intracranial electroencephalography and eye-tracking simultaneously recorded during cognitive task



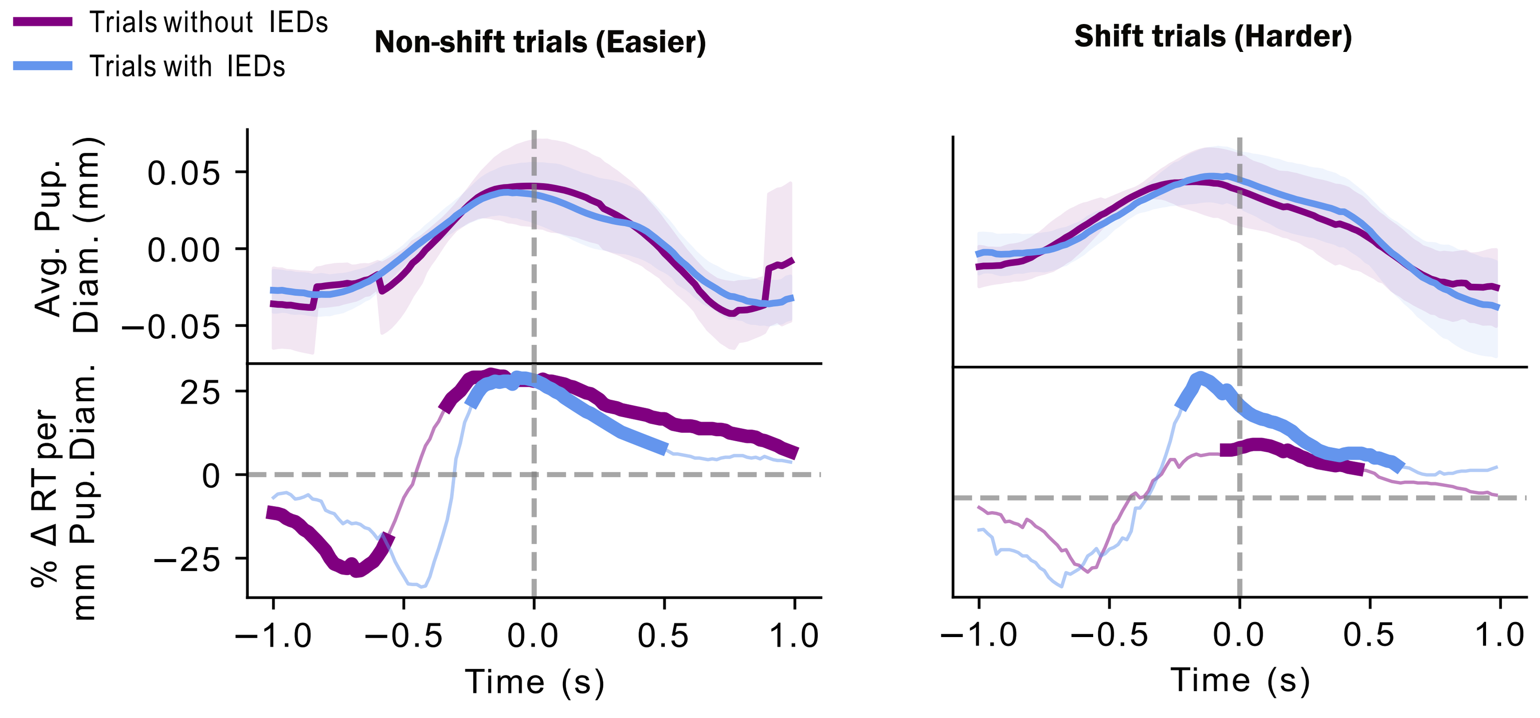
SEEG electrode distribution across participants (N = 13)



- **Mixed effects models** were used to identify relationships between task performance, pupil size, and neural activity.
- **Using EEG-ViT[2,3] architecture,** participant-specific models were trained to predict pupil diameter time courses from SEEG signals.

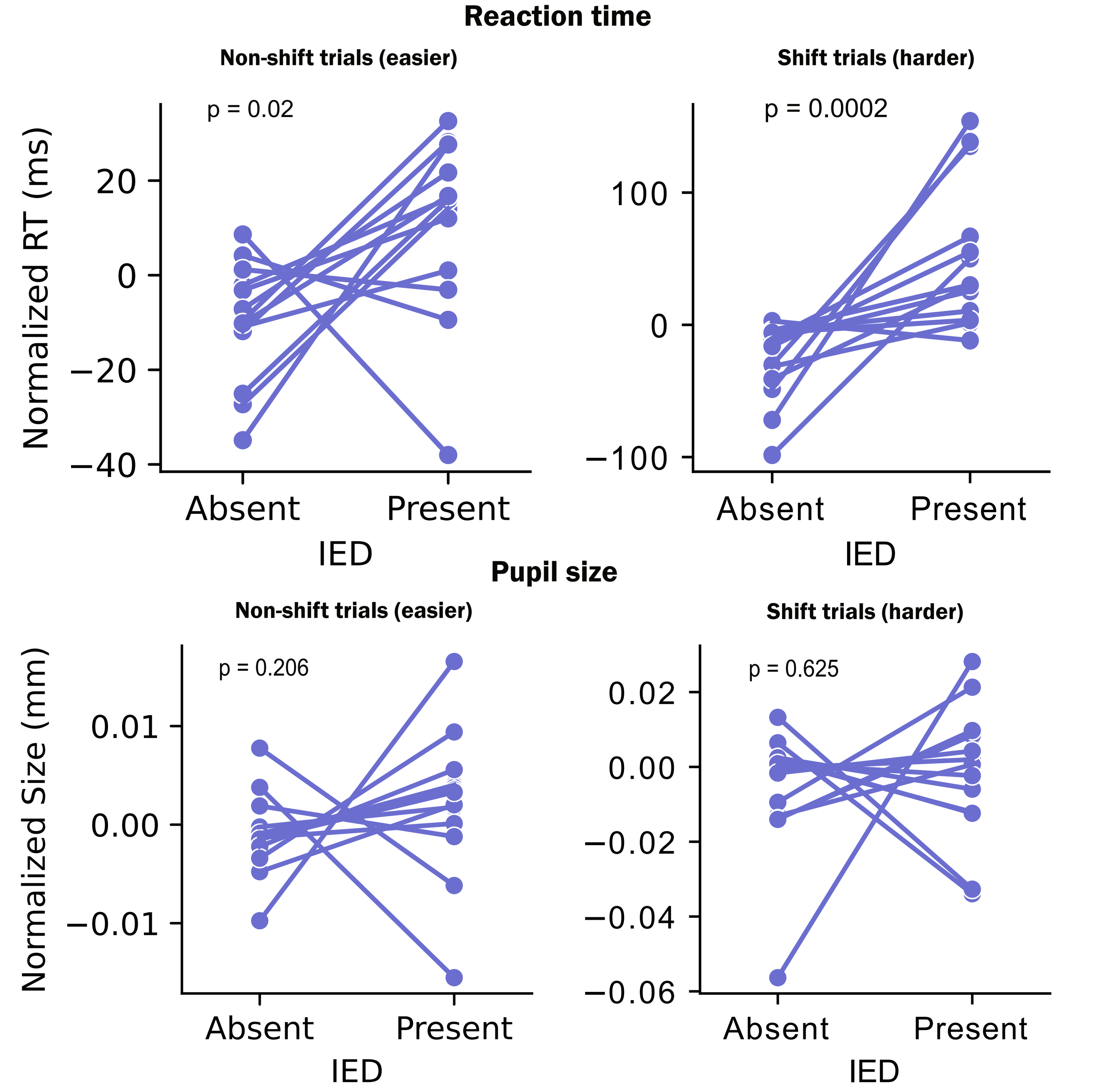
Results

1 Relationship between pupil size and reaction time is task-stage dependent

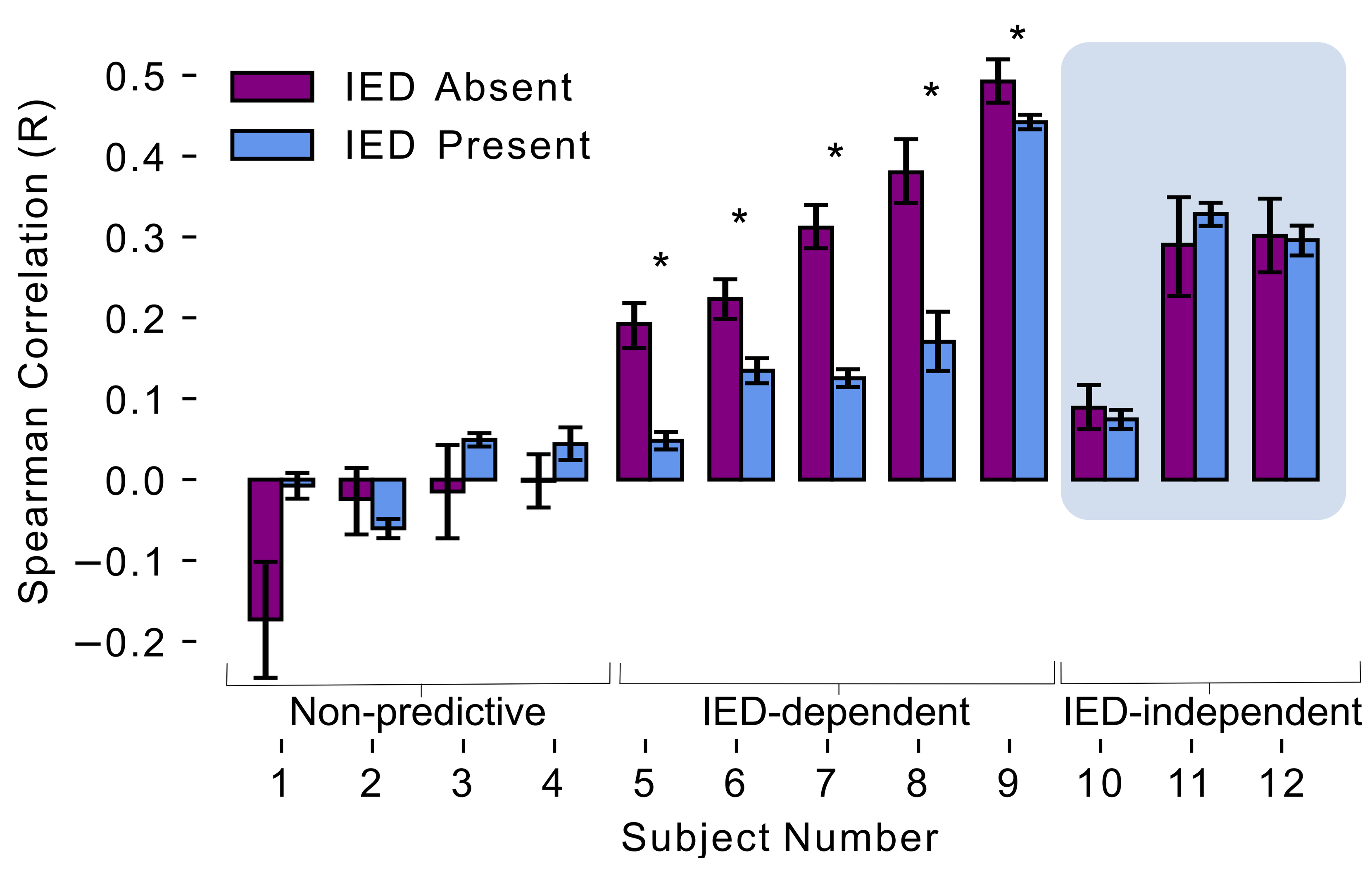


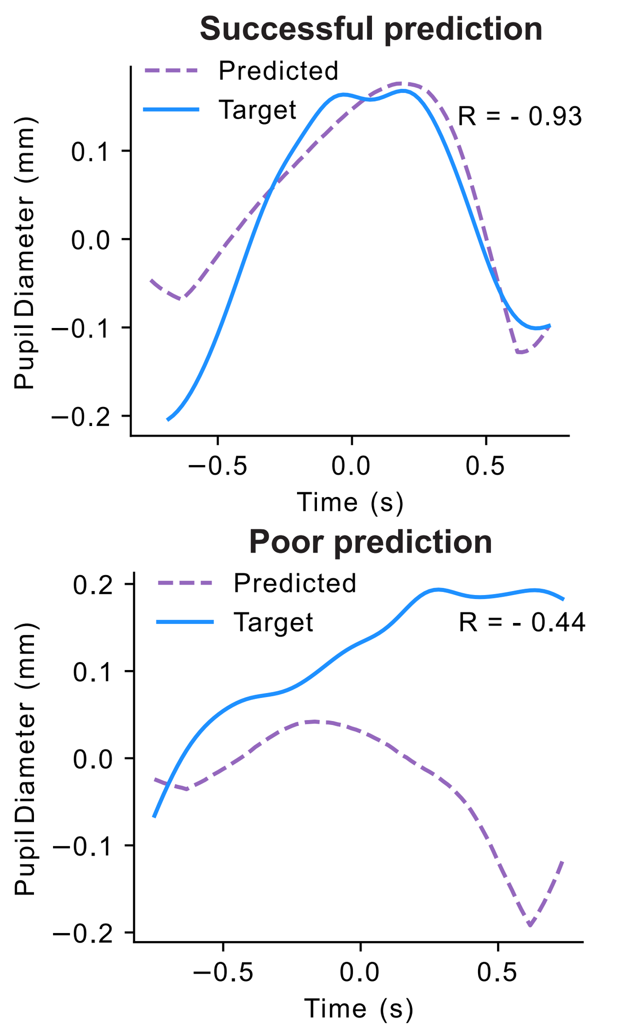
- Smaller pupils associated with faster RT during peri-stimulus period ($p < 0.05$ corrected, bold line).
- Larger pupils size associated with faster RT during inter-stimulus period ($p < 0.05$ corrected, bold line).
- Pupil size may reflect **attention in preparation for a task**, but reflect **cognitive load during a task.**

2 IEDs are significantly associated with increases in reaction time but not changes in pupil size

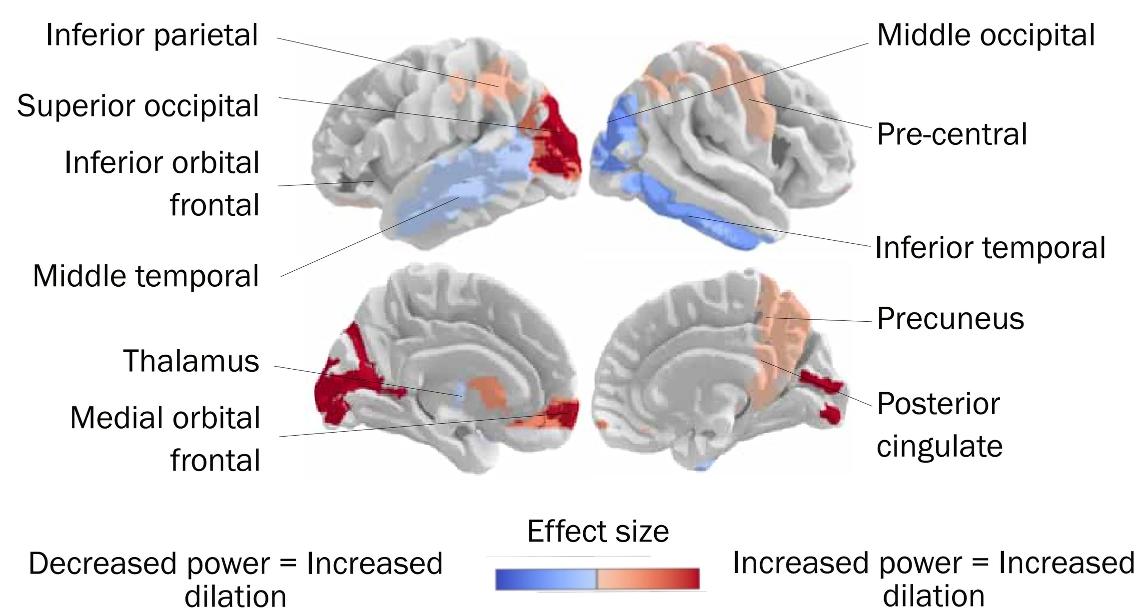


3 Impact of IEDs on deep learning model performance varies across participants

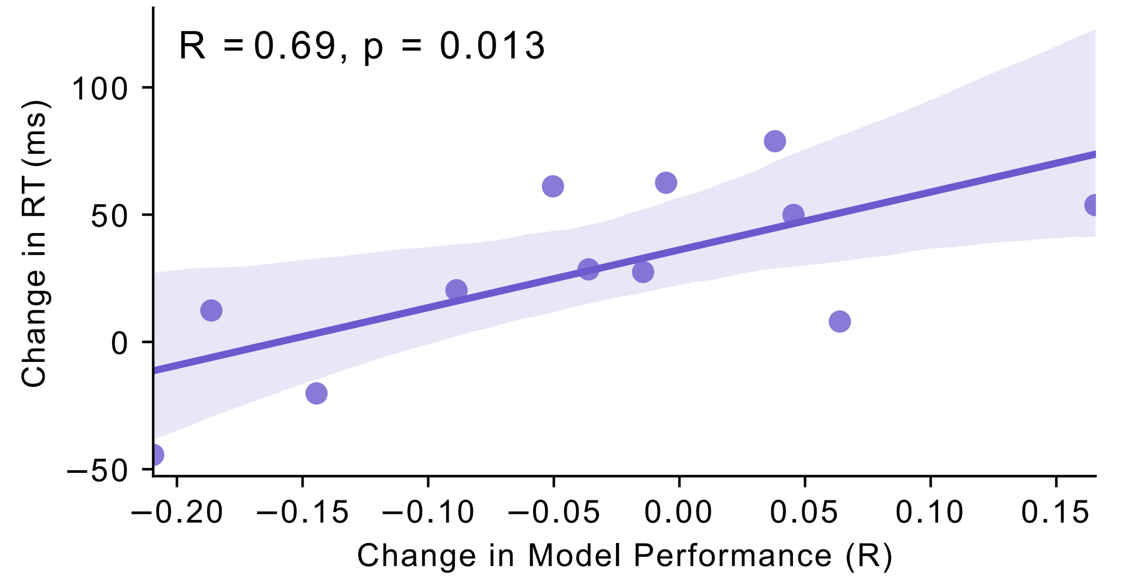




4 Task relevant regions are associated with changes in pupil size



5 IED impact on model performance is associated with change in reaction time



Conclusions

Complex relationship between cognitive processing, pupillary dynamics, and IEDs in children with epilepsy.

Pupillometry may serve as a **measure of cognitive function** in pediatric epilepsy.

Further research required to explore the observed **variability in IED effects on model performance** across participants.

References

1. Strauch C, Wang CA, Einhäuser W, Van der Stigchel S, Naber M. Pupillometry as an integrated readout of distinct attentional networks. *Trends Neurosci*. 2022;45(8):635-647.
2. Yang R, Modesitt E. ViT2EEG: Leveraging hybrid pretrained vision transformers for EEG data. *arXiv [csCV]*. Published online August 1, 2023. http://arxiv.org/abs/2308.00454
3. Lawhern VJ, Solon AJ, Waytowich NR, Gordon SM, Hung CP, Lance BJ. EEGNet: a compact convolutional neural network for EEG-based brain-computer interfaces. *J Neural Eng*. 2018;15(5):056013.

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