Direct electrical stimulation of the human amygdala enhances declarative memory

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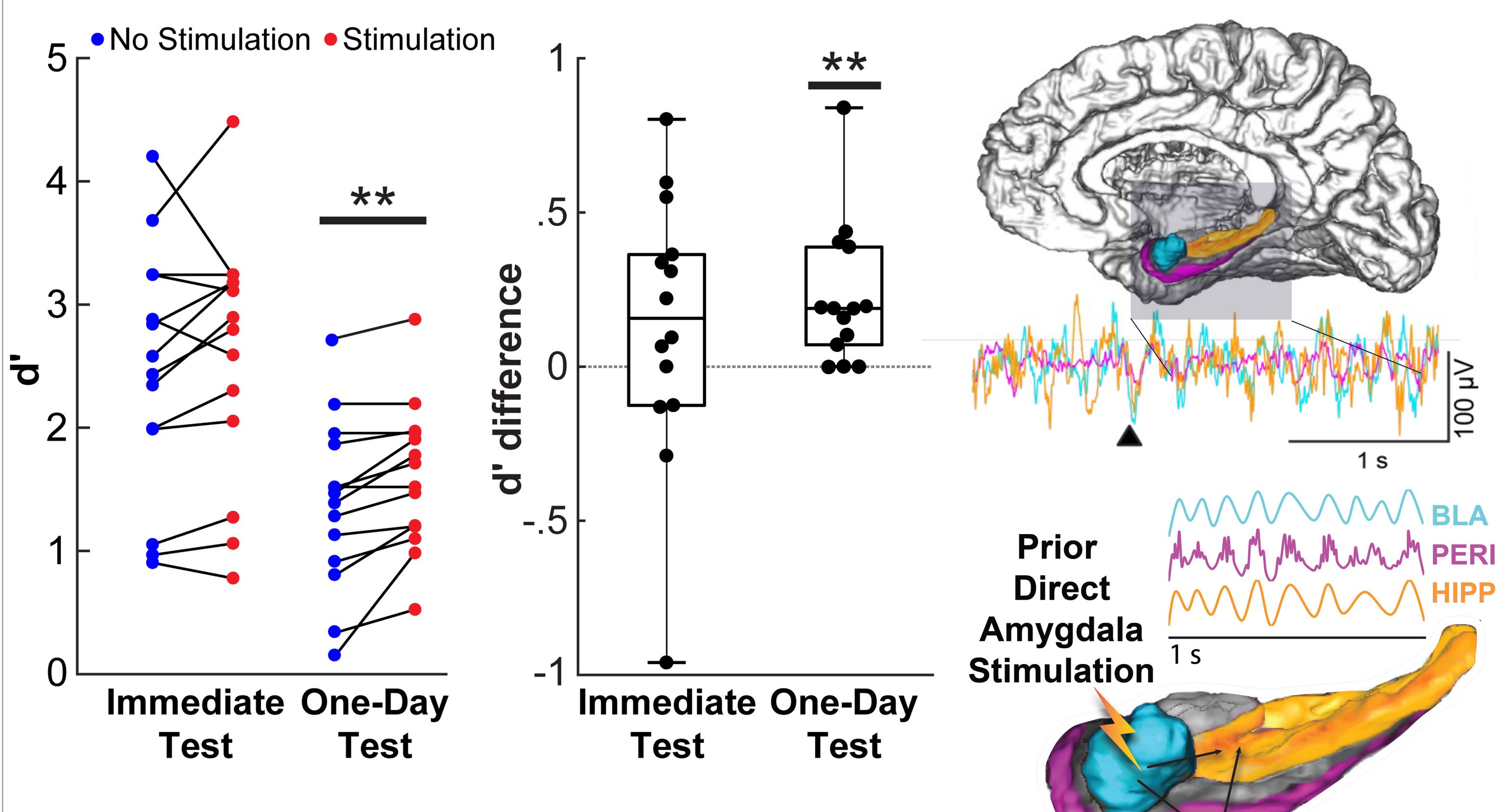
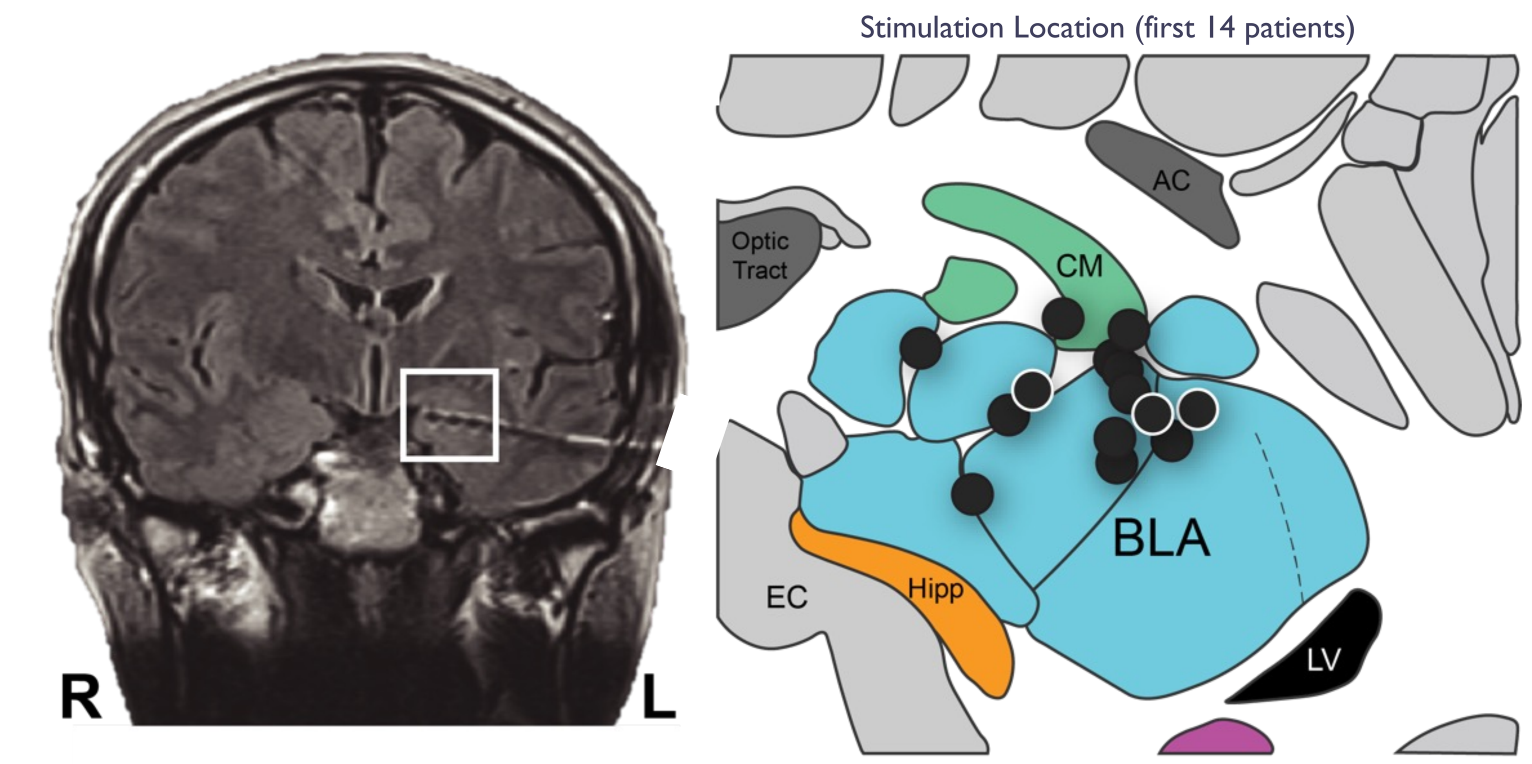
Background

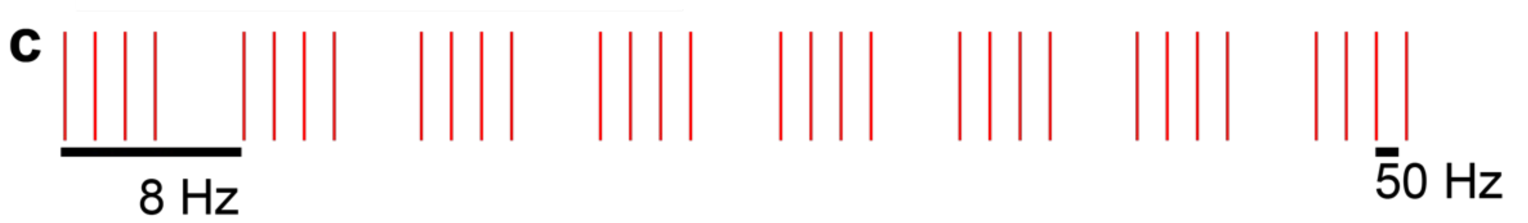
- Emotional events are often remembered better than neutral events[1,2].
- This emotional benefit to memory depends on the amygdala, a key brain region involved in both memory and emotion[1,2].
- We have previously demonstrated that brief basolateral amygdala (BLA) electrical stimulation enhances memory in rodents[3,4,5] and humans without eliciting an emotional response. [6]
- An electrophysiological marker of prior stimulation, theta and gamma synchronization and coherence, has been reported in medial temporal lobe (MTL) subregions at the 1-day delay. [6]
- *The present study examined the lasting behavioral effects of BLA stimulation on memory enhancement without evoking subjective emotional arousal.*

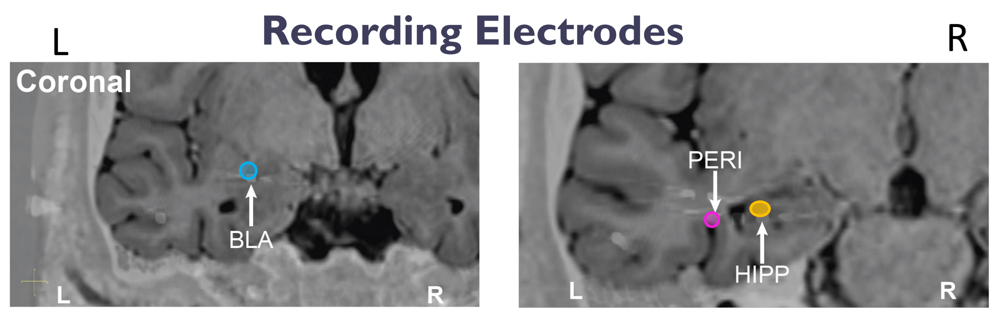
Previous Findings and methods



Inman, Manns et al., (2018)







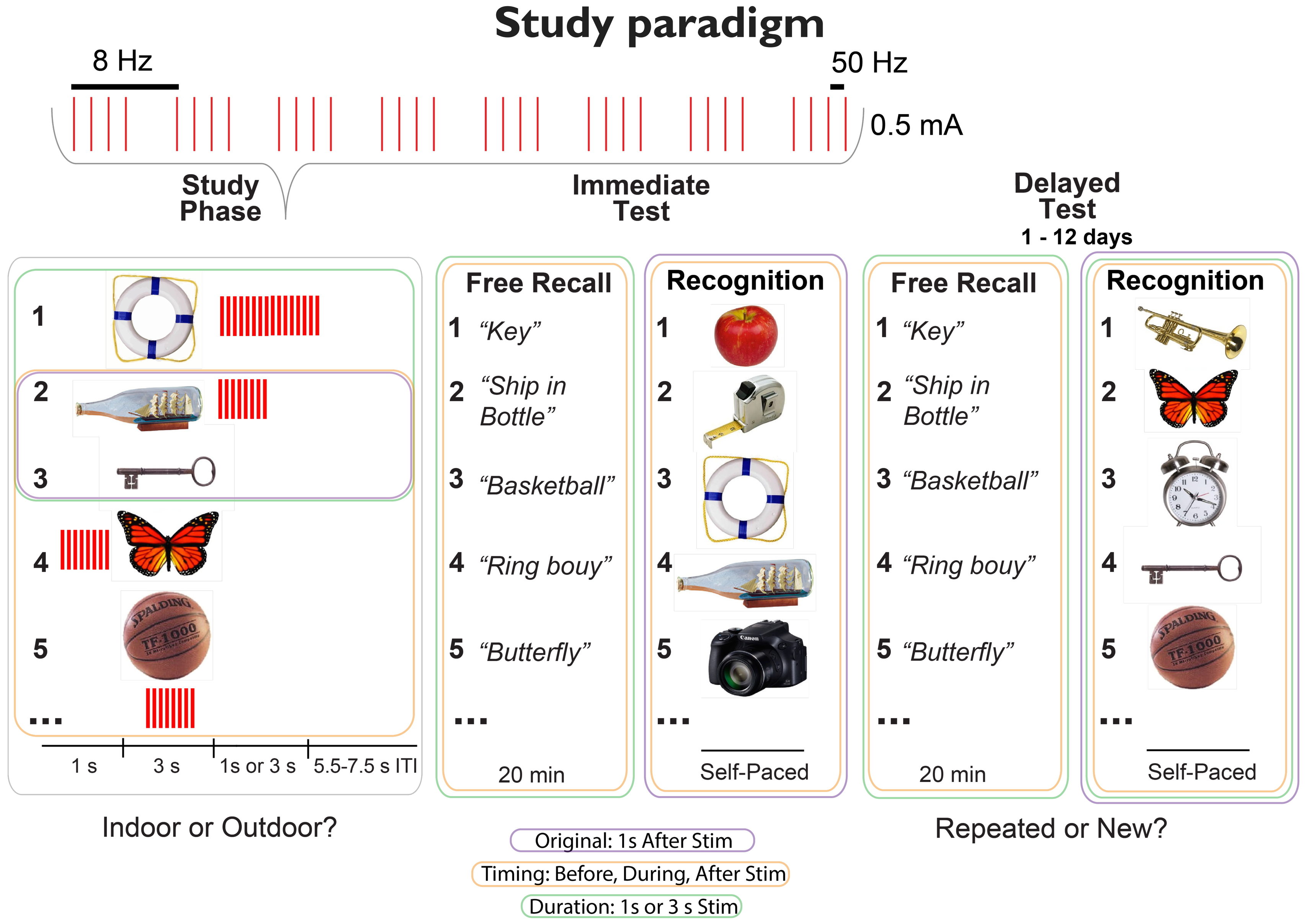
Methods

Participants

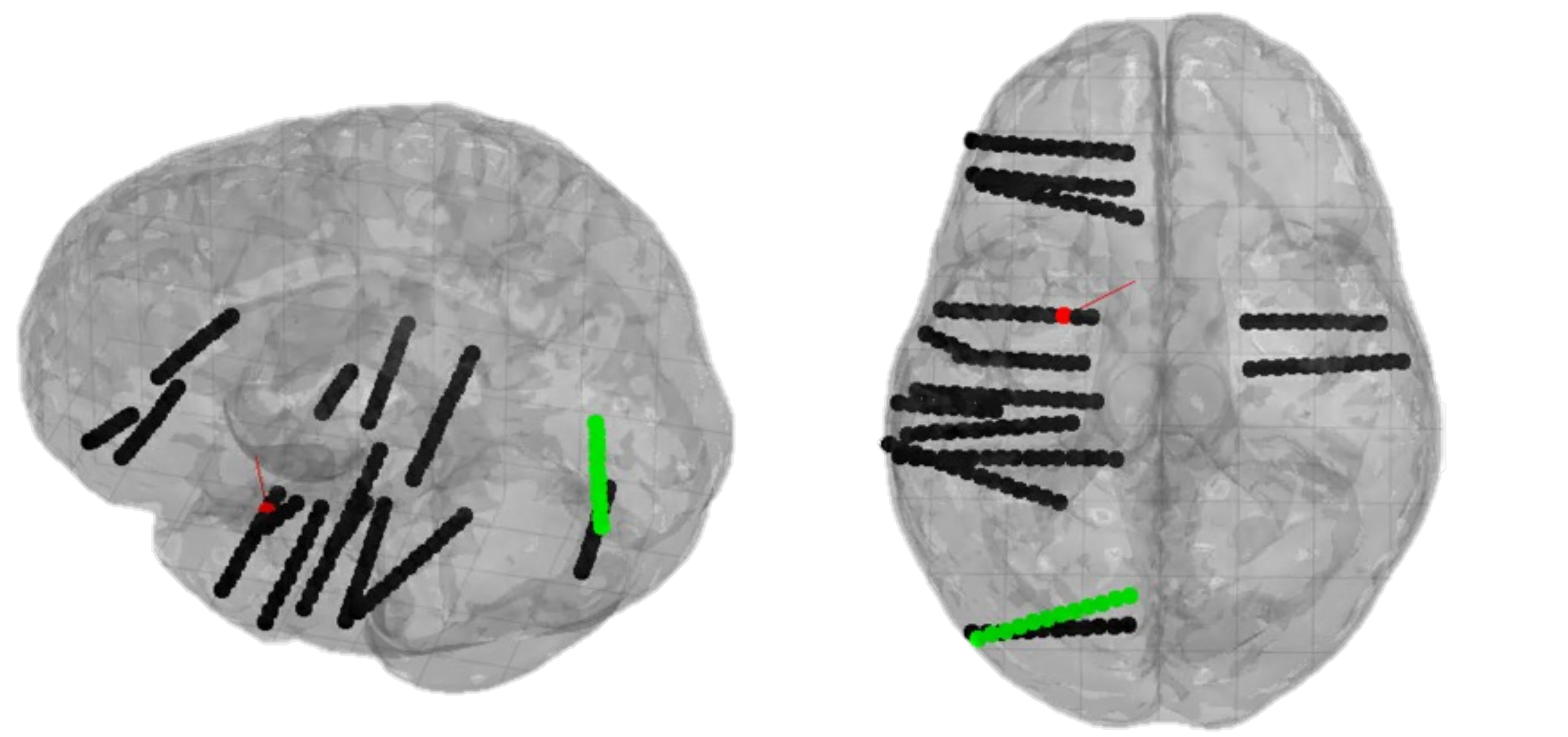
- 37 patients (21 female; $M(SD)_{age}$=34(12), FSIQ = 90(15)) with intractable epilepsy in the Emory University Hospital for intracranial monitoring (iEEG)
- Individual contacts implanted in both hemispheres in the basolateral amygdala
- No epileptiform activity or stimulation awareness was elicited by the stimulation
- Stimulation did not evoke emotional arousal in patients
- Stimulation parameters examined: Duration, Timing, and Time delay length

Experiments	Stimulation condition	Delay	N subjects	N sessions
Original	1 s after	1 day	14	14
Duration	1s or 3 s after	1 day	5	7
Timing	1s before, during,and after	1 day	12	15
Long Delay	1s before, during,and after	2-12 days	6	6
Total			**37**	**42**

Study paradigm

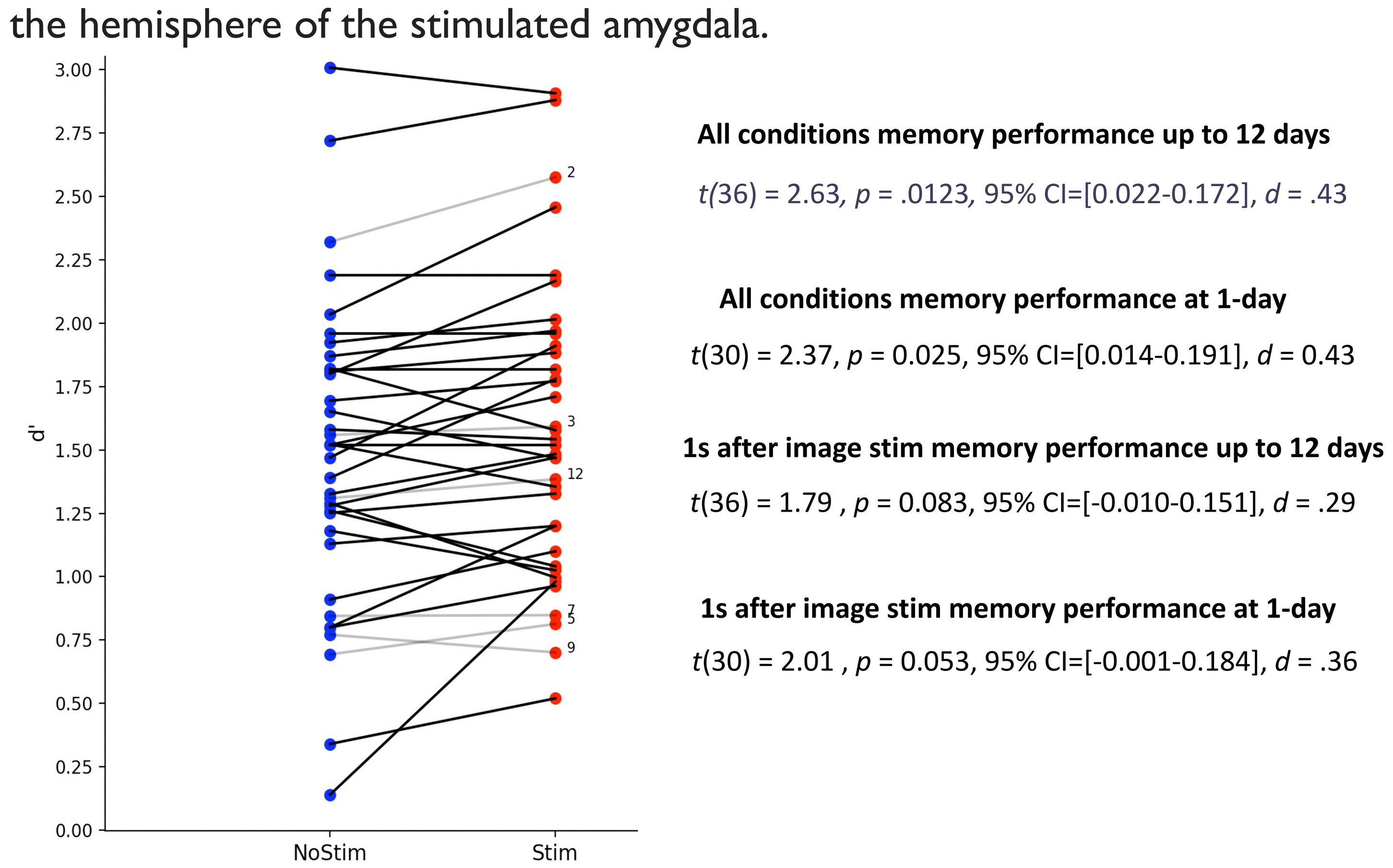


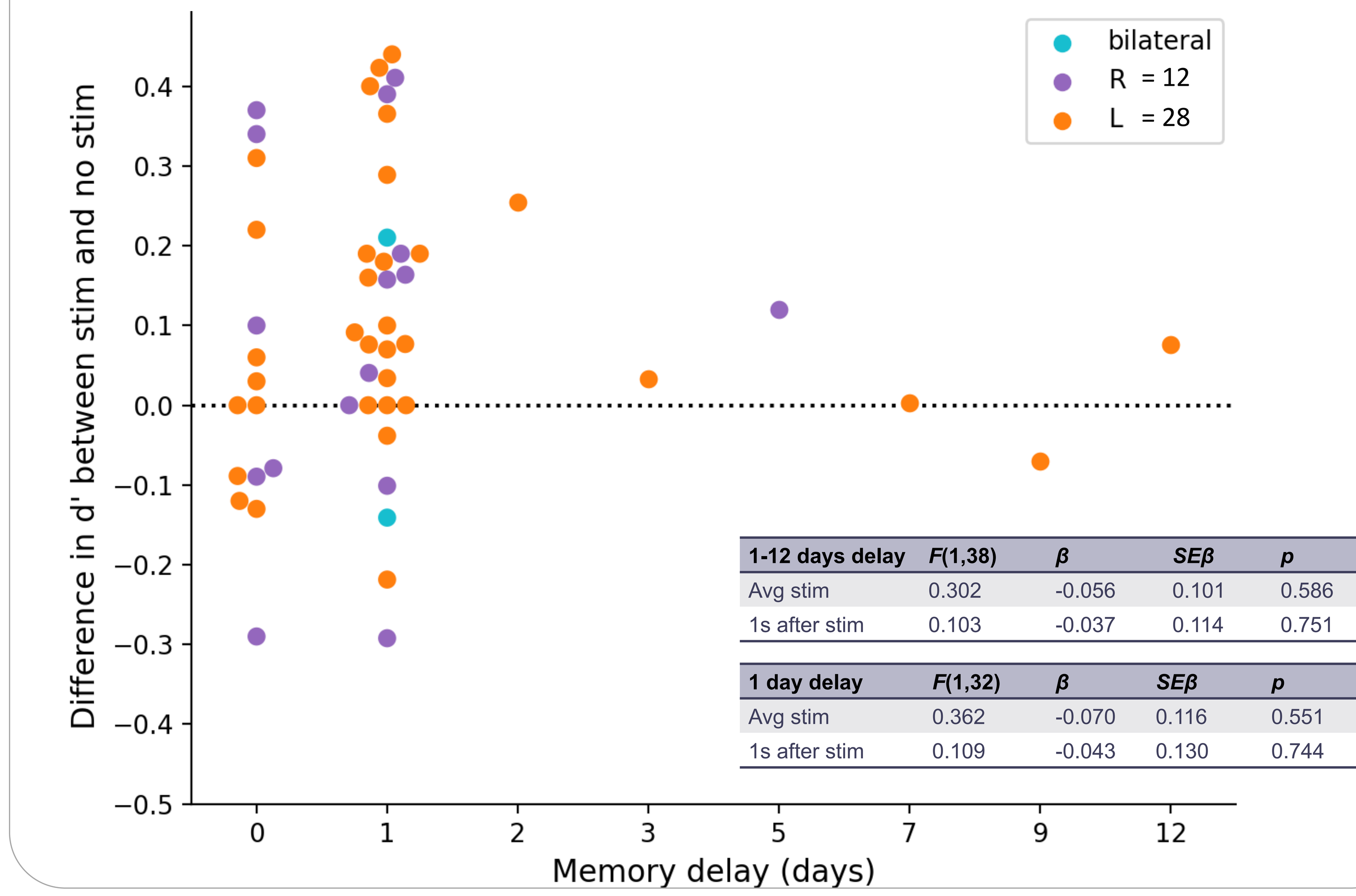
Ongoing analyses focus on examining the effects of amygdala stimulation on regions throughout the brain, beyond the MTL



Behavioral Results

- Building onto Inman, Manns, et al. (2018)[6] we found memory enhancement collapsing across conditions over all delays and at the 1-day delay for previously stimulated objects compared to previously not stimulated objects.
- For 1s after image stimulation we observed more variability in the effects of stimulation on memory and are investigating what factors might contribute to this variability (precise stim location, patient factors, etc.)
- We find no differences in stimulation-related memory enhancement based on the hemisphere of the stimulated amygdala.





1-12 days delay	$F(1,38)$	β	$SE\beta$	p
Avg stim	0.302	-0.056	0.101	0.586
1s after stim	0.103	-0.037	0.114	0.751

1 day delay	$F(1,32)$	β	$SE\beta$	p
Avg stim	0.362	-0.070	0.116	0.551
1s after stim	0.109	-0.043	0.130	0.744

Conclusion & Current Directions

- Brief electrical stimulation to the human amygdala reliably improves long-term declarative memory up to 12 days for images of neutral objects without eliciting an emotional response.
- Our team is currently examining amygdala stimulation on objects vs. scenes, with closed loop stimulation, and up to 1 week delay.
- Ongoing neural analyses examine the lasting effects of amygdala stimulation inside and outside of the medial temporal lobe up to 12 days.
- Ongoing analyses investigate amygdala stimulation parameters like electrode location, stimulation timing, and stimulation duration to better understand its memory modulatory effects.

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Poster PDF

Acknowledgements

We are grateful for the patient's time and trust in completing this work. Thank you to John Janecek's help with some programming. We'd also like to thank the EEG technicians and neurology department physicians for their time and assistance in performing these experiments.

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