

Development and validation of a non-verbal consensus-based semantic memory paradigm in patients with epilepsy

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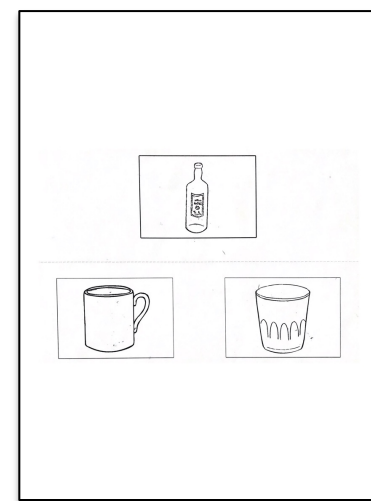
Introduction

- Semantic memory refers to long-term general knowledge in the form of facts, concepts, and associations. Prior non-invasive studies using fMRI, EEG, and MEG suggest semantic processing circuits are distributed throughout regions (“hubs”) across the cortex bilaterally.
- Some of these brain areas, such as the temporal lobe, can be disrupted by neurodegenerative conditions affecting semantic memory (Alzheimer’s disease and semantic variant primary progressive aphasia), as well as in epilepsy.
- However, it is challenging to delineate semantic deficits from other cognitive elements that may be affected in epilepsy, including episodic memory and linguistic/verbal aspects.
- We probed semantic memory through non-verbal means by developing a new Visual-based Semantic Association Task (ViSAT) to understand whether semantic processing is impaired in patients with epilepsy (PWE).

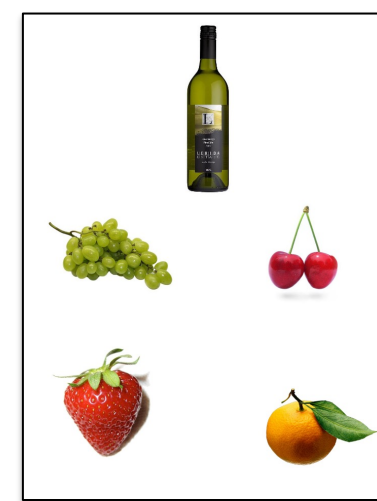
Methods

- We obtained data from 23 participants with epilepsy (PWE) and 24 control participants (CP). We also obtained crowdsourced normative data from 54 USA-based Amazon Mechanical Turk (MTurk) workers online. Participants across all groups ranged 18-80 years of age (median 38).
- The ViSAT was adapted from concepts and similar stimuli as the Pyramids and Palm Trees, in which a person matches a target picture (line-drawing) on top with one of two pictures below based on a semantic association. We adapted and expanded this by creating 100 trials with four answer choices using real-life color pictures, balancing visual features and improving generalizability.

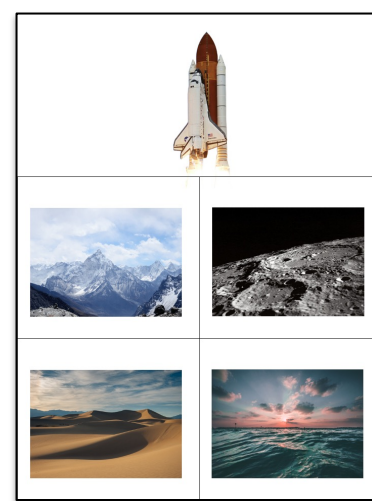
Pyramids and Palm Trees (PPT, 1992)



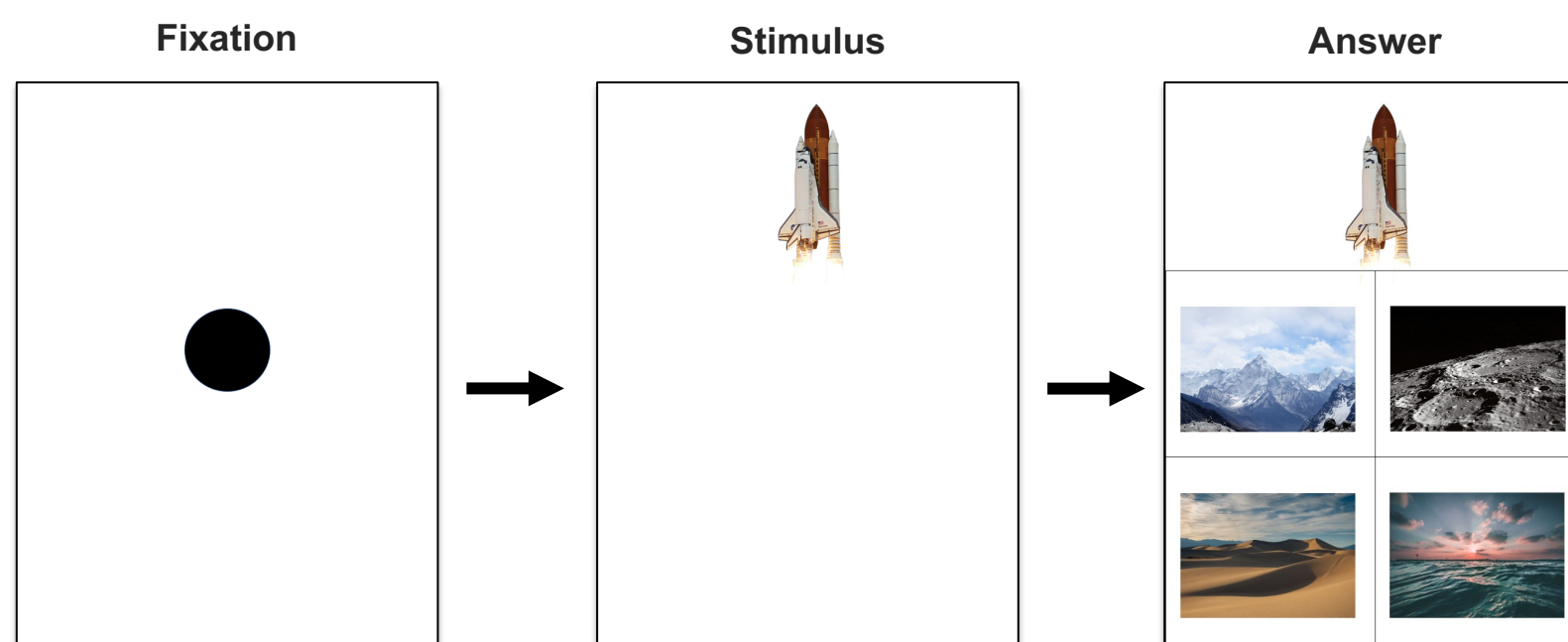
Modified Camels and Cactus (CCT, 2022)



Our Visual-based Semantic Association Task (2023)



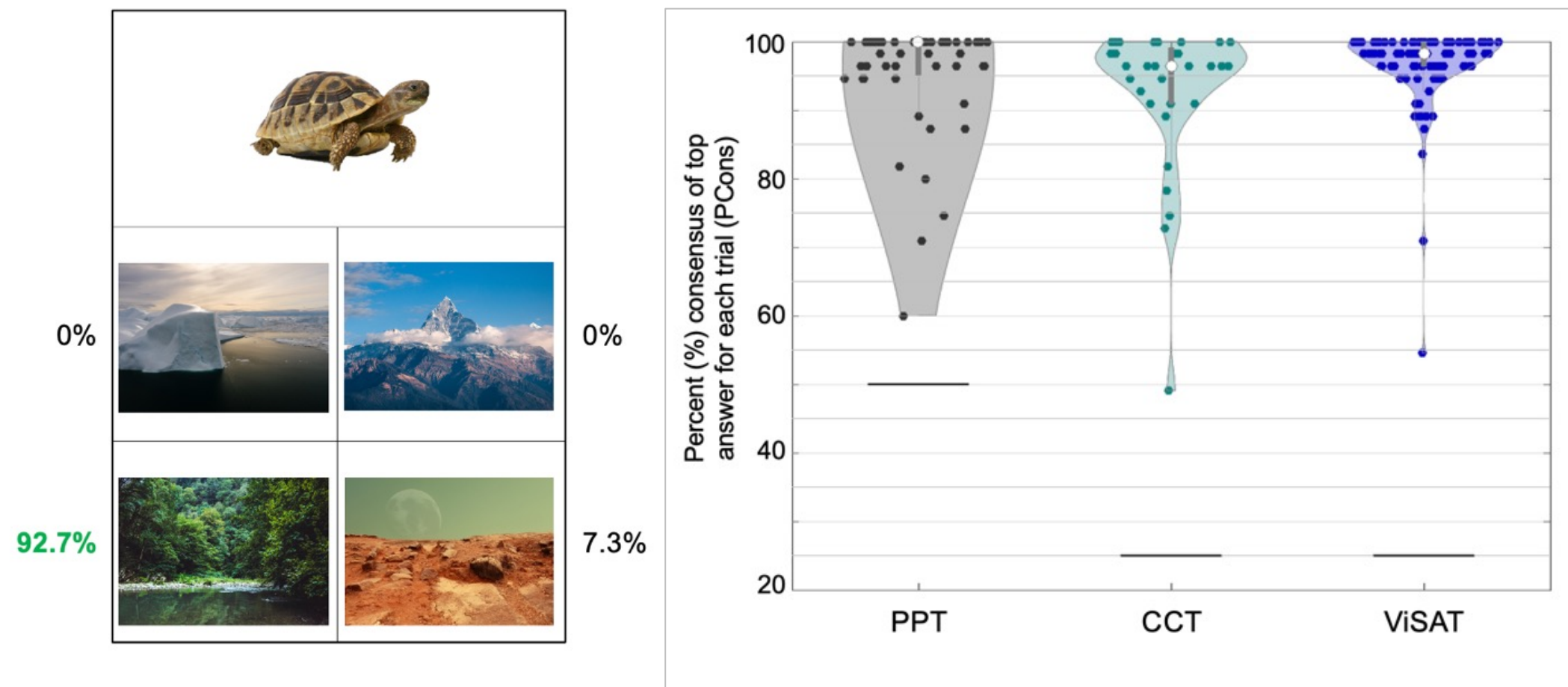
- The ViSAT is administered through a computer UI in which each trial is separated by a fixation point. The participant is asked to click on the stimulus to reveal the four answer choices.



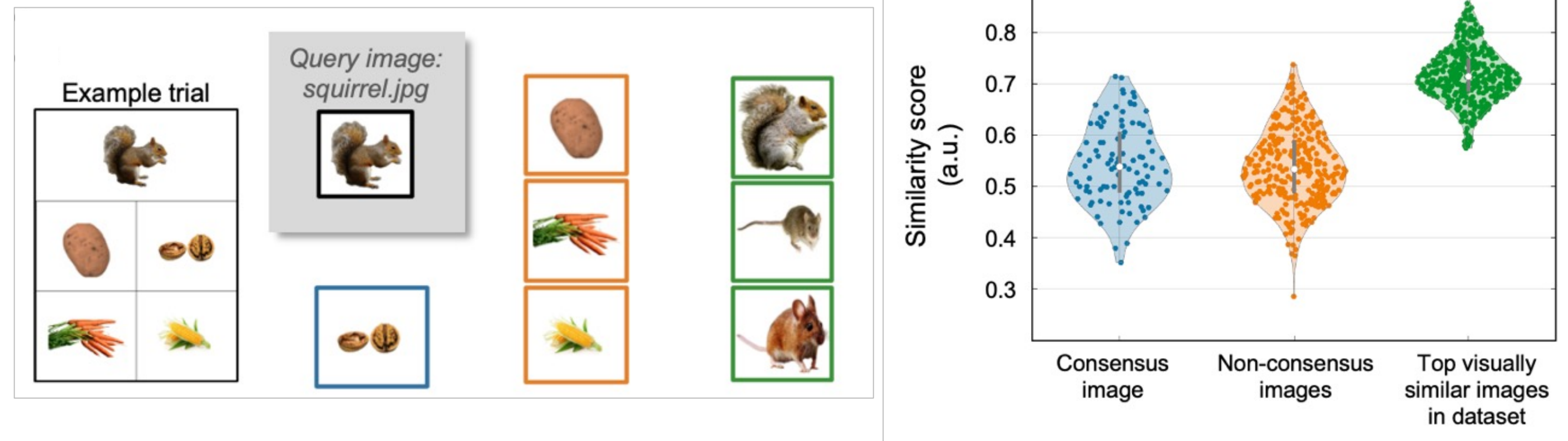
Results

Novel performance metric: percent consensus of the most popular answer choice among MTurk workers (PCons)

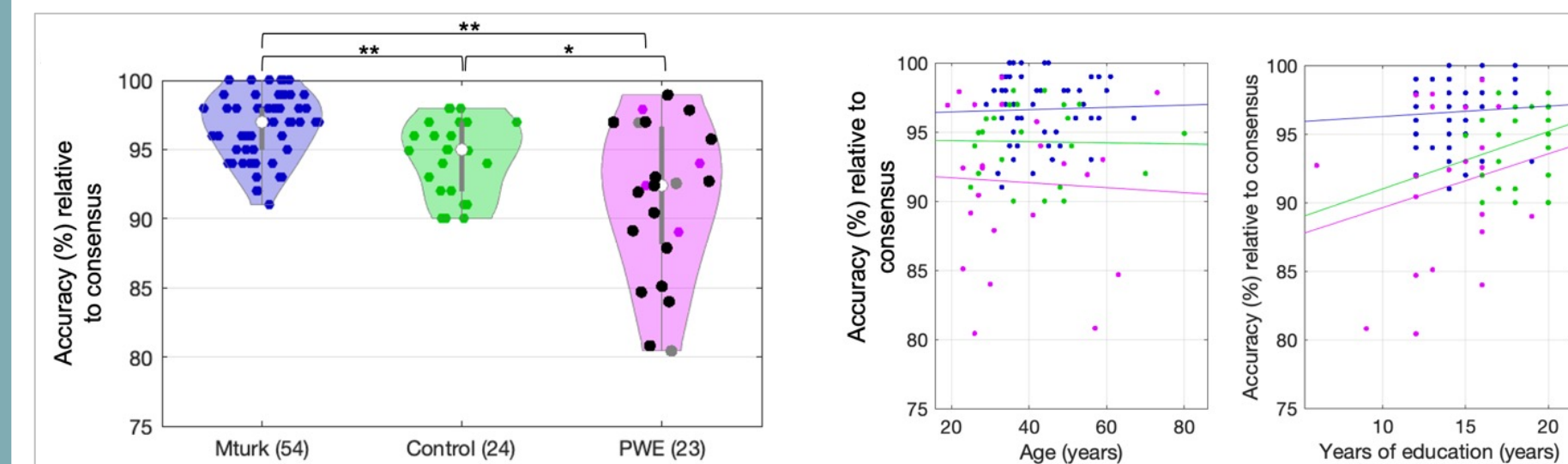
- Percent consensus (PCons) is defined as the most popular answer choice in a trial among the normative data group (in our case, the MTurk workers). For instance, the trial with the turtle has a 92.7% PCons.
- Based on MTurk data, the ViSAT was adapted to achieve high consensus rates for each trial, with 91.3% of all trials having a PCons > 90% (34% of PCons = 100%).
- In comparison, the MTurk data revealed a PCons of 83.6% for PPT and 82.9% for CCT.

Participant answer choices are semantically based, not solely based on visual features

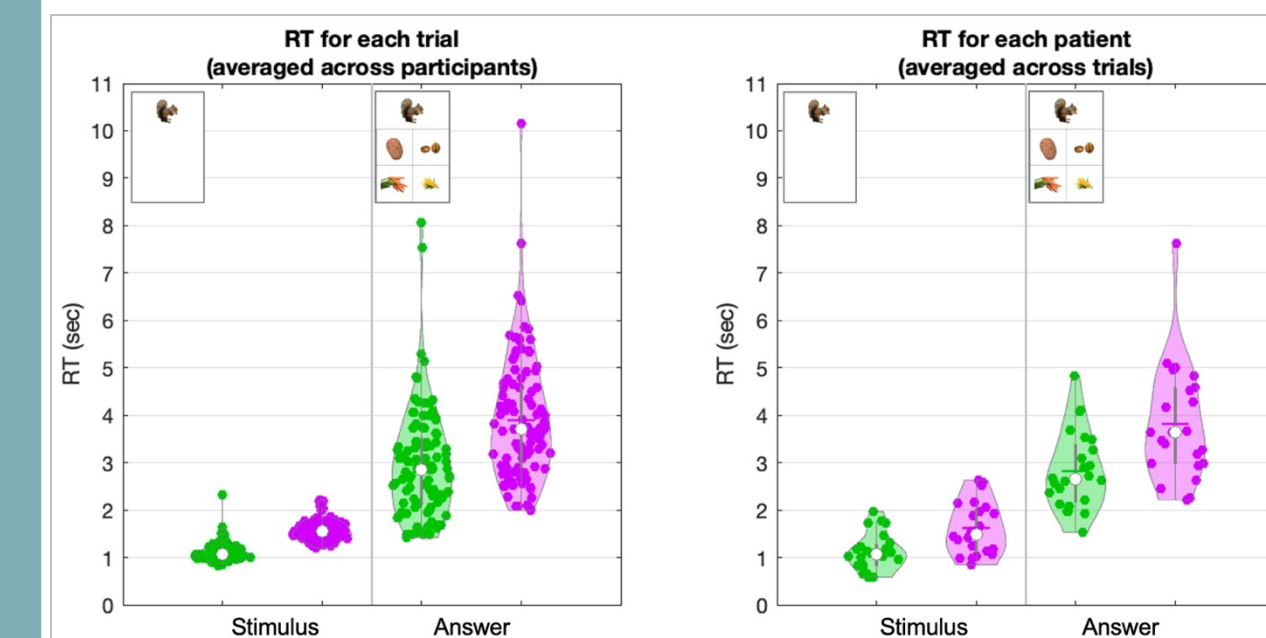
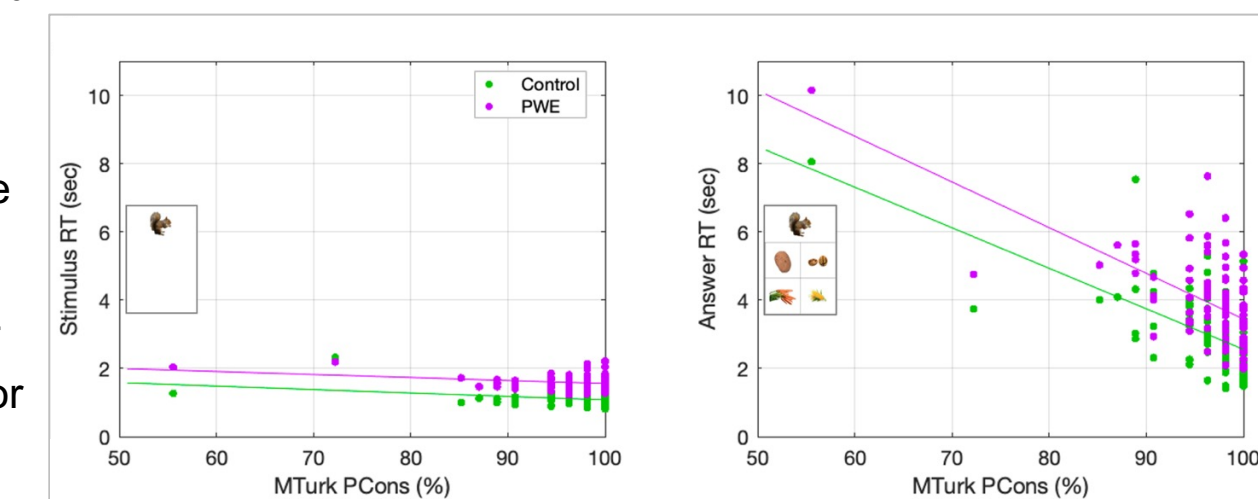
- We ran a deep neural network (ResNet-18) using an image feature similarity embedding model (image2vec) to validate that visual features alone (color, shape, texture, etc.) could not explain similarities between stimuli and PCons.
- Image similarity comparison scores (0 = no similarity, 1 = perfectly similar) between stimuli images vs consensus answer (blue) vs non-consensus answers (orange) and the top visually similar images among all stimuli as a control (green).

Comparing accuracy between MTurk, CP, and PWE groups

- Accuracy is defined as relative to the consensus answers (PCons).
- PWE had lower accuracy than the MTurk and CP groups (**p<0.001, *p=0.019; two-sample t-tests).
- Correlation scatterplots show lack of correlation between individual accuracy vs age or years of education among any group (p>0.05, Spearman).

PWE had longer response times (RT), particularly during the trial answer stage

- We compared our CP and PWE groups and found that while RT was not correlated with PCons during the stimulus stage (p>0.05, Spearman), increasing PCons were correlated with faster RT (r=-0.561 and p<0.001 for CP, and r=-0.546 and p<0.001 for PWE, Spearman).



- We evaluated RT for individual trials and each individual PWE as well.
- We found longer response times in the answer stage and PWE had longer response times for both stages in general (p<0.001, fixed effects from linear mixed effects model).

Conclusions:

PWE had lower ViSAT accuracy and took significantly longer to choose their answer, suggesting there may be subtle but potentially important difficulty with semantic memory processing in PWE. Our ViSAT task materials are freely available and may help delineate further intricacies of semantic processing from verbal impairments in future studies of epilepsy and neurodegenerative diseases.

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References

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