VISUAL HALLUCINATIONS IN PARKINSON'S DISEASE: ABNORMAL HIGHER-ORDER NETWORK INTERACTIONS IN THE RESTING-STATE

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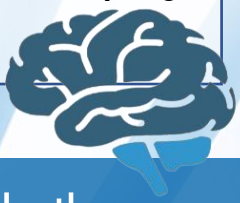
ABSTRACT

Hallucinations are complex and can be difficult to interpret through neuroimaging measurements. From fMRI measurements of Parkinson's disease patients susceptible to visual hallucinations, we applied dimensionality reduction techniques that break down complex data to their simplest form. By comparing these low-dimensional patterns against patterns found in Parkinson's disease patients without visual hallucinations and healthy controls, we observed disruptions in the balance between top-down and bottom-up processing. Patients susceptible to visual hallucinations had increased imbalances in their network hierarchy, suggesting that the increased influence from top-down processing overrides sensory information making patients susceptible to hallucinate.

BACKGROUND

- Perceptual processing framework hypothesizes that hallucinations occur due to an imbalance between top-down and bottom-up processing, resulting in the brain unable to differentiate between internal (i.e memories) and external (i.e hose) information[1,2].
- Functional magnetic resonance imaging (fMRI) provides non-invasive whole-brain activity measurements that are inherently high-dimensional and difficult to interpret.
- Dimensionality reduction techniques simplify high-dimensional data into patterns that are intuitive and provide meaningful insight.
- Hallucinations are present across neurodegenerative and neuropsychiatric diseases[4], therefore understanding low-dimensional patterns may provide a unifying framework for psychosis.



AIMS

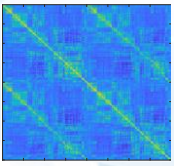
This study aimed to determine whether low-dimensional representations of hallucinations related to perception as a balance between top-down and bottom-up processing.

METHODS

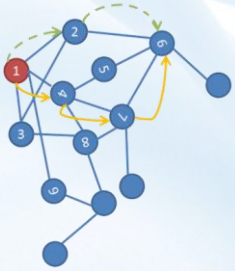
Healthy Control = 19

PD + Visual Hallucinations = 31

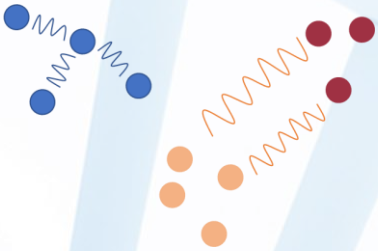
PD – Visual Hallucinations = 46



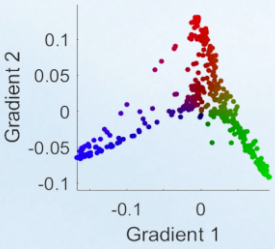
Connectivity Matrix
(Schaefer 400 ROIs)



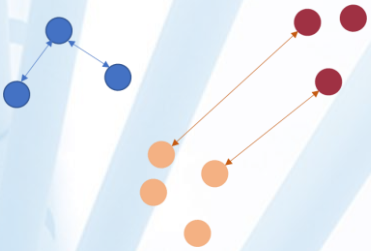
Diffusion Mapping - De la Porte et al. (2008)



t-distributed stochastic neighbour embedding (t-SNE)



Gradients – describe axes of largest variance



Euclidean distance measurement

Group differences unique to patients susceptible to hallucinations

RESULTS

Diffusion Map Embedding (Gradients)

Parkinson's disease patients susceptible to visual hallucinations (PD+VH) had a more compressed range of gradient scores compared to the other two groups.

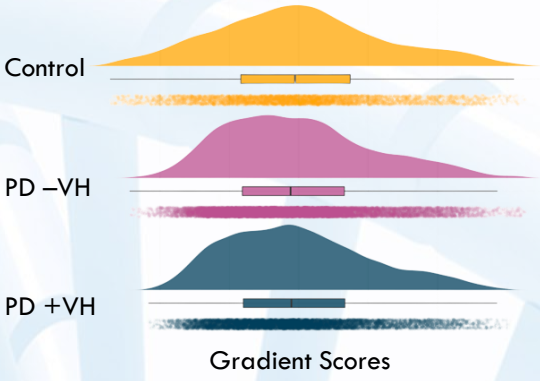


Figure 1. Raincloud distributions of gradient scores for each group

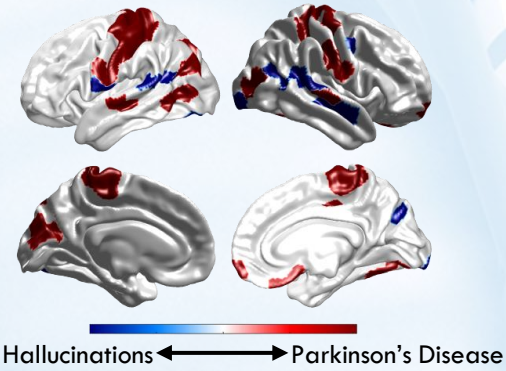


Figure 2. Gradient differences between brain regions (n = 400)

Gradient differences unique to hallucinations were found in regions near the temporoparietal junction ($p<0.05$).

Ventral Attentional Network (VAN) gradient score was significantly correlated with performance in part B of the Trail-Making Test (TMT-B) ($r = 0.2$, $p = 0.04$).

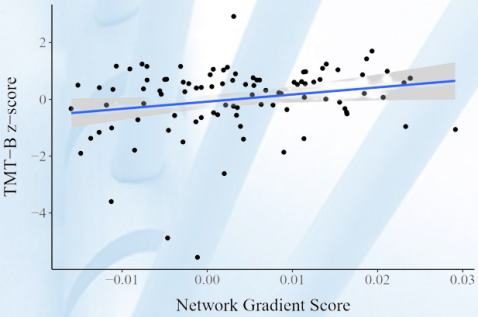


Figure 3. Plotting average VAN gradient score against performance in the TMT-B

RESULTS

T-SNE Embedding

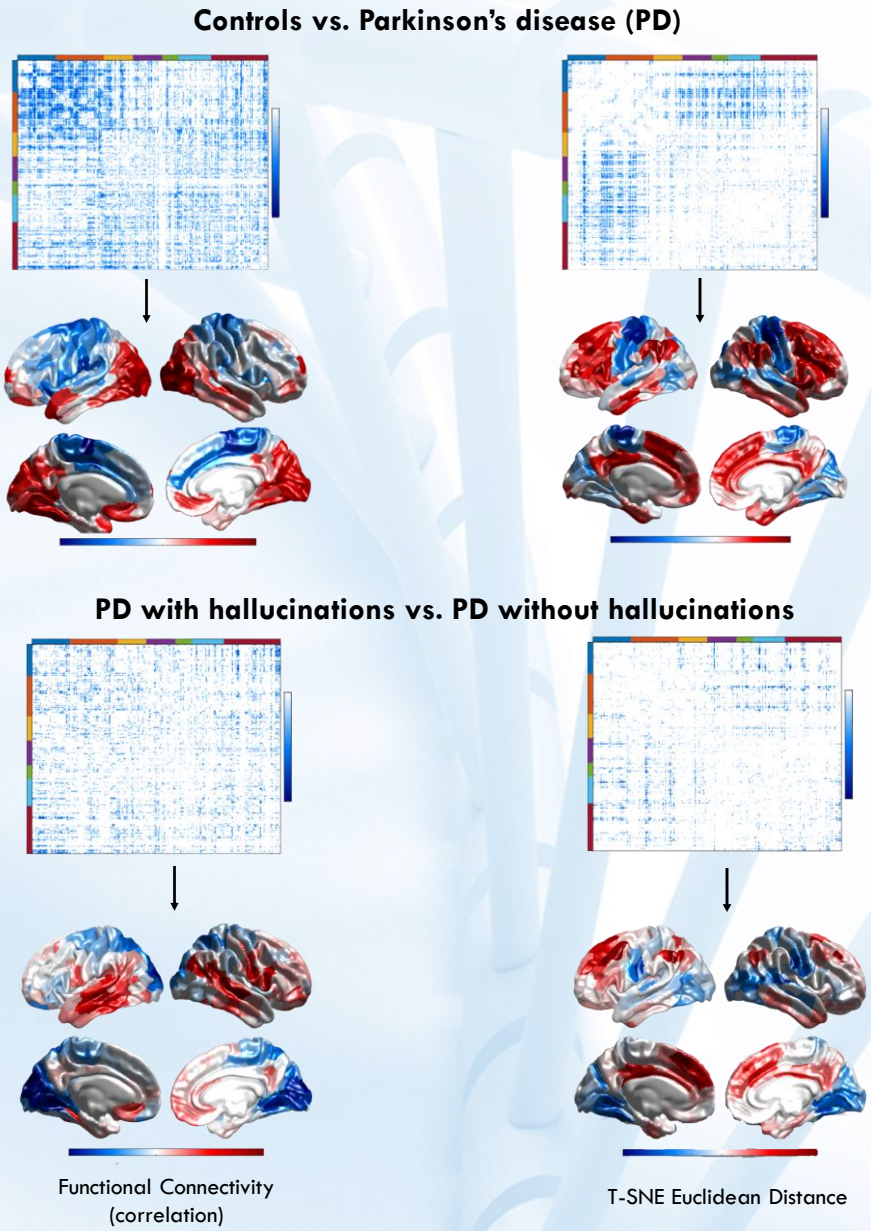


Figure 5. Low-dimensional patterns of traditional FC analysis and t-SNE distance analysis

CONCLUSION

- This study reveals low-dimensional patterns that are unique to Parkinson's disease patients susceptible to visual hallucinations.
- The gradients analysis demonstrated altered gradient scores in the visual, ventral attention, and frontoparietal control networks.
- The t-SNE analysis highlighted abnormal activity patterns in the visual, frontoparietal control, and default mode networks.
- These findings reaffirm ideas of imbalances in top-down and bottom-up processing as a key feature of hallucinations, possible treatment would aim to alleviate these imbalances.

REFERENCES

1. O'Callaghan, C., Kveraga, K., *et al.* (2017) 'Predictions penetrate perception: Converging insights from brain, behaviour and disorder', *Consciousness and Cognition*, 47, pp. 63–74. Available at: https://doi.org/10.1016/j.concog.2016.05.003.
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