LSD alters eyes-closed functional connectivity within the early visual cortex in a retinotopic fashion

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Human Brain Mapping–

Beckley / Imperial Research Programme

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What is this study about?

Retinotopy (from Greek τόπος, place) is the mapping from visual input in the brain. In lower visual areas (e.g., V1 through V5) the neurons are organized in an orderly fashion called topographic or retinotopic mapping, in the sense that they form a 2D representation of the visual image formed on the retina in such a way that neighbouring regions of the image are represented by neighbouring regions of the brain's visual area.

Why did we do this study?

- Eyes-closed visual hallucinations are among the most prominent features of the psychedelic experience, but *how* exactly they arise is poorly understood.
- Early studies suggested that under psychedelics, visual regions of the brain behaved 'as if' there is visual input. The current study aimed to test this idea empirically with modern brain imaging methods. Specifically the question of the study was if the early visual system behaves "as if" it were receiving spatially localized visual information.
- **We wanted to know: Would the visions experienced under the effect of LSD have similar neural underpinnings as when one is actually seeing things?**

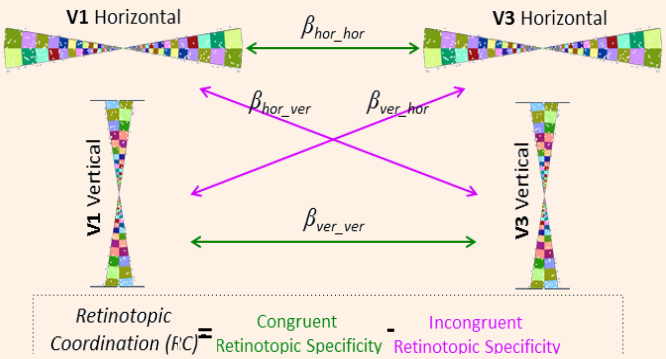
About the research team

Amanda Feilding is the founder and director of the Beckley Foundation. She and David Nutt are Co-Directors of the Beckley/Imperial Research Programme. Robin Cahart-Harris is the Programme's lead investigator. Leor Roseman led the study.

What did we do?

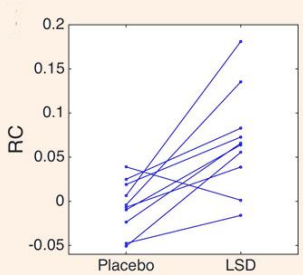
- 20 subjects completed the study, but only 10 produced data suitable for analyses.
- Subjects completed identical fMRI sessions on two separate occasions: once after LSD (75µg i.v.) and once after placebo (saline). Each fMRI session included ~7min of eyes-closed rest to measure connectivity among brain regions under task-free conditions (**termed 'resting-state functional connectivity,'** or **RSFC**), as well as a **'retinotopic localizer'** scan to map out each subject's visual cortex.
- This retinotopic localizer consisted of a video commonly used in vision science, which makes it possible to define specific visual regions of the brain: V1, V2, and V3. V1 and V3 were then further subdivided into 'patches' sensitive to horizontal (hor) vs. vertical (ver) stimuli, resulting in 4 patches: V1-horizontal, V1-vertical, V3-horizontal, and V3-vertical. Under normal circumstances of visual input, V1-hor patches project to V3-hor patches (V1-hor -> V3-hor), and V1-ver -> V3-ver.
- Finally, this information was combined to calculate an index of **'retinotopic** coordination.' First, we calculated **'congruent retinotopic specificity**' (resting-state functional connectivity (RSFC) between congruent patches, i.e., V1-hor -> V3-hor and V1-ver -> V3-ver) and **'incongruent retinotopic specificity'** (RSFC between incongruent patches, e.g., V1-hor -> V3-ver). **Retinotopic coordination (RC)** was then calculated as the difference between congruent and incongruent retinotopic specificity (see figure). This index was calculated separately for connectivity under LSD and under placebo.

What did we find?



1. Retinotopic coordination (RC) was greater under LSD than under placebo.

- That is, the connectivity between V1 and V3 was more coordinated under LSD. This means that while subjects had their eyes closed, their visual cortex behaved 'as if' it were receiving spatially localised visual information, based on its retinotopic architecture.



Retinotopic coordination for all 10 subjects for placebo and LSD

- Interestingly, this did not correlate with subjects' self-report of visual hallucinations.

Why is this study important?

This result gives us new insight into how psychedelics work in the brain, showing that they modulate activity in the visual cortex. In addition to improving our understanding of how the visual system functions, it gives a scientific basis for the common psychedelic experience of 'seeing with eyes shut.'.