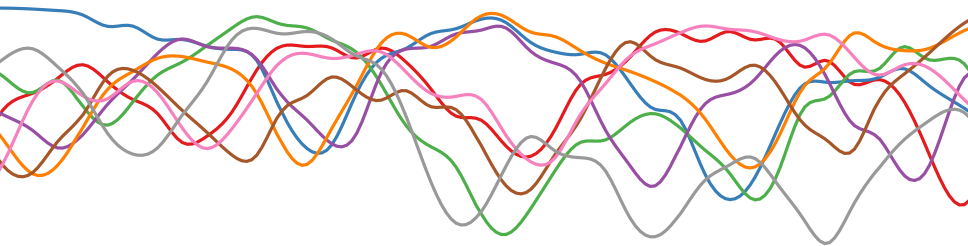


ALTERED STATES OF CONSCIOUSNESS

LINKING MIND AND BRAIN WITH NEUROIMAGING



Pedro A.M. Mediano

plogp@pm.me



UNIVERSITY OF
CAMBRIDGE

Imperial College
London

ACKNOWLEDGEMENTS



Fernando
Rosas



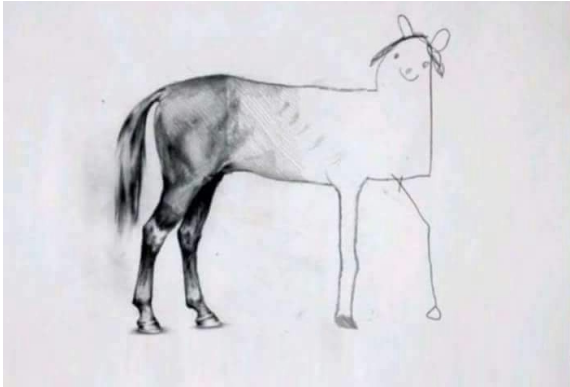
Rubén
Herzog



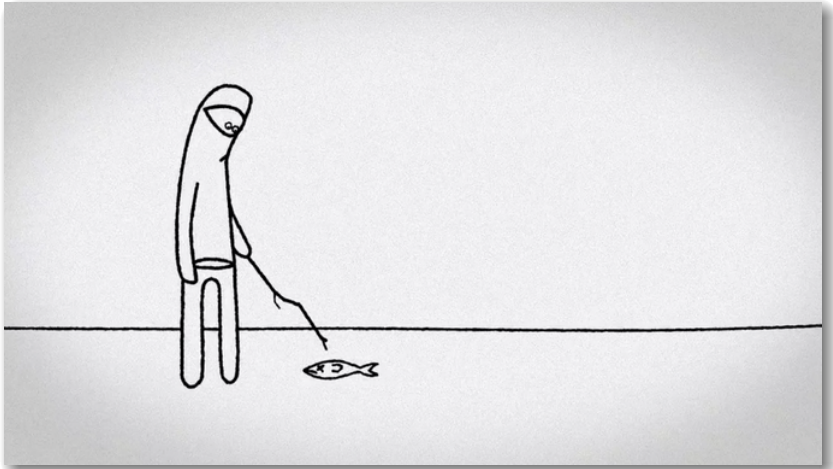
Robin
Carhart-Harris

- ▶ David Dolan
- ▶ Henrik Jensen
- ▶ Hardik Rajpal
- ▶ Rodrigo Cofré
- ▶ Chris Timmermann
- ▶ Adam Barrett
- ▶ Murray Shanahan
- ▶ Madalina Sas

HOW THIS TALK IS GOING TO GO



Time

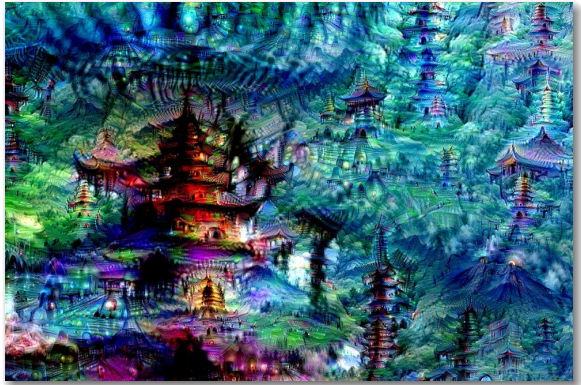


psychedelic

ψυχη (“mind, soul”) + δηλοσ (“manifest, reveal”)

1. (*noun*) Any psychoactive substance (such as LSD or psilocybin) which, when consumed, causes perceptual changes (sometimes erratic and uncontrollable), visual hallucination, and altered awareness of the body and mind.
2. (*hippie slang*) awesome, cool, groovy.


















The Wiktionary




















ALTERED STATES OF CONSCIOUSNESS

- ▶ Defined with respect to a “*normal*” state of consciousness.
- ▶ Complex, multi-faceted changes in experience.

Pharmacological

-  Amanita Muscaria
-  Anadenanthera peregrina
-  Scopolamine & Angel's trumpet
-  Belladonna
-  Betel
-  Bolivian torch cactus
-  Caffeine
-  Cannabis
-  Coca
-  DMT & Ayahuasca
-  Henbane
-  Ibogain
-  Kava
-  Ketamine
-  Khat
-  LSD
-  MDMA

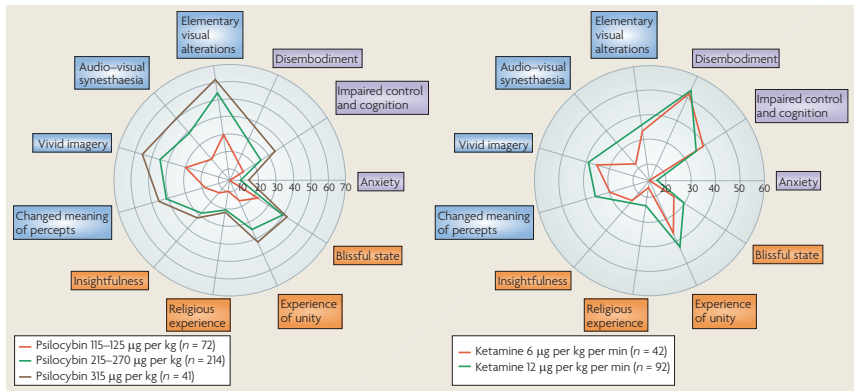
Non-pharmacological

-  Autogenic Training
-  Binaural beats
-  Flotation Tank
-  Ganzfeld
-  Holotropic Breathwork
-  Hypnosis
-  Loving Kindness Meditation
-  Mantra/Tantric Mantra
-  Mind Machine
-  Mindfulness Meditation
-  Om Mantra Meditation
-  Runner's high
-  Self-hypnosis
-  Sweat Lodge Ceremony
-  Tibetan Buddhist Meditation
-  Trance (Shamanic)
-  Transcendental Meditation

(Jagannathan *et al.*, 2016)

ALTERED STATES OF CONSCIOUSNESS

QUANTITATIVE PHENOMENOLOGY

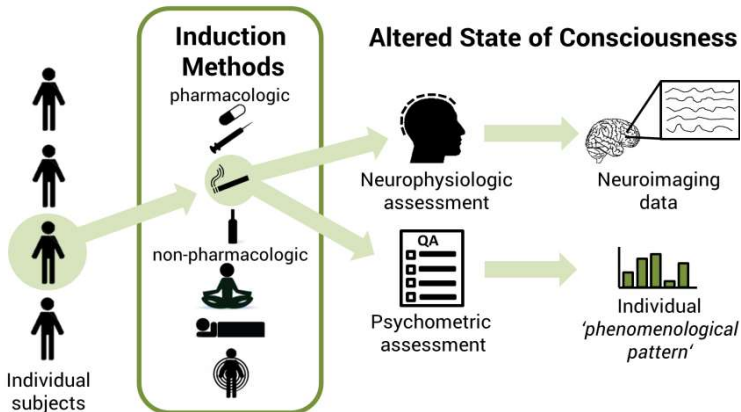


(Vollenweider & Kometer, 2010)

ALTERED STATES OF CONSCIOUSNESS

GOAL

Physiology \longleftrightarrow Phenomenology



(Schmidt, 2018)

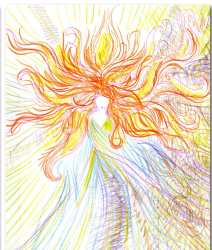
ALTERED STATES OF CONSCIOUSNESS

THIS TALK

MUSICAL IMPROVISATION



PSYCHEDELICS

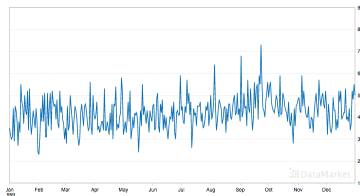
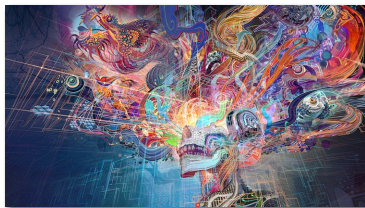




THE ENTROPIC BRAIN



THE ENTROPIC BRAIN



Richness of
experience



Signal
diversity

frontiers in
HUMAN NEUROSCIENCE

HYPOTHESIS AND THEORY ARTICLE

published: 03 February 2014

doi: 10.3389/fnhum.2014.00020



The entropic brain: a theory of conscious states informed
by neuroimaging research with psychedelic drugs

Robin L. Carhart-Harris^{1}, Robert Leech², Peter J. Hellyer², Murray Shanahan³, Amanda Feilding⁴, Enzo Tagliazucchi⁵, Dante R. Chialvo⁶ and David Nutt¹*

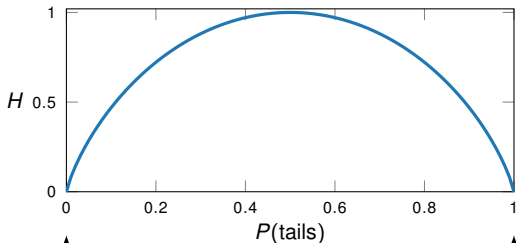
WHAT IS ENTROPY?

- ▶ Entropy == maximal information content of a signal.

$$H(X) = - \sum_x p_x \log p_x$$



Claude
Shannon



↑
Always
heads



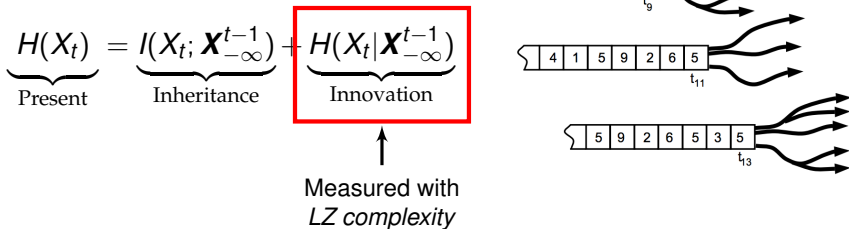
↑
Always
tails

ENTROPY VS ENTROPY RATE

- ▶ Problem: highly entropic signals can be very boring:

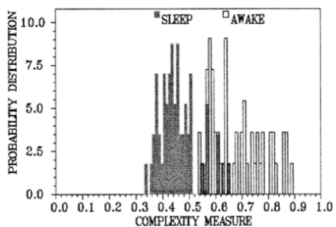
$$0101010101010101 \rightarrow H(X_t) = 1$$

- ▶ **Entropy rate:** entropy of the future given the past.

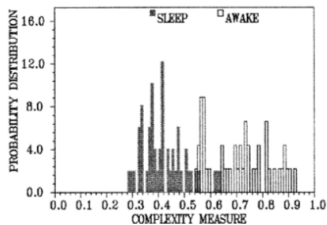


EXPERIMENTAL FINDINGS

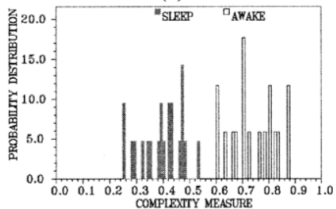
ANAESTHESIA



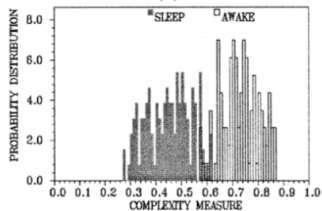
(A)



(B)



(C)

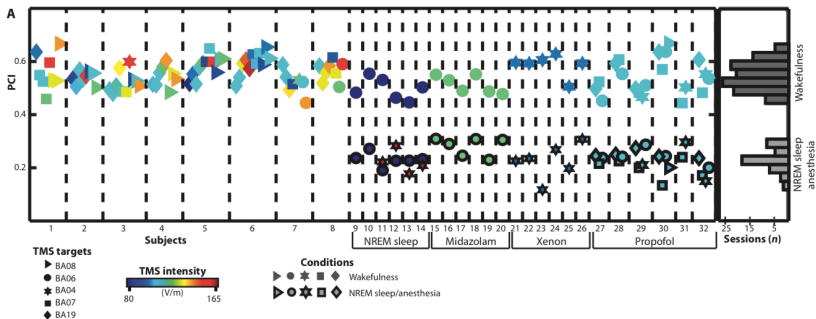


(D)

(Zhang *et al.*, 2001)

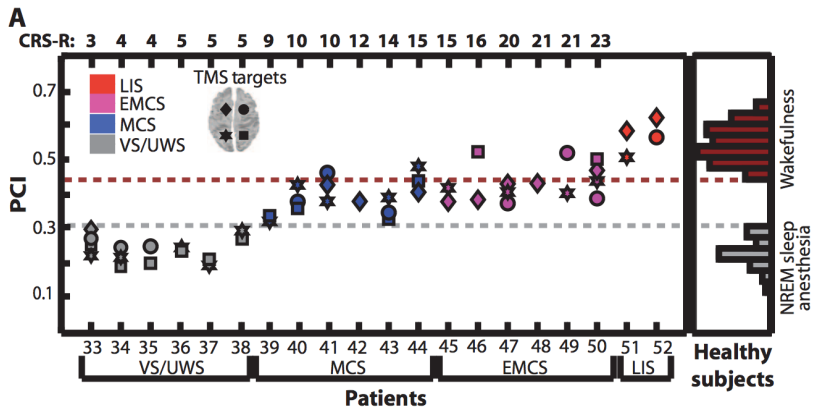
EXPERIMENTAL FINDINGS

SLEEP

(Casali *et al.*, 2013)

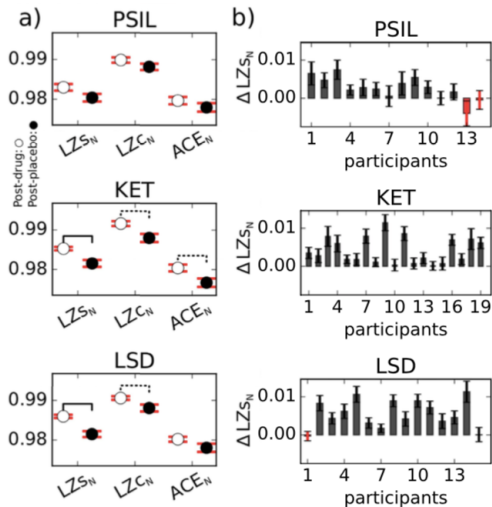
EXPERIMENTAL FINDINGS

DISORDERS OF CONSCIOUSNESS

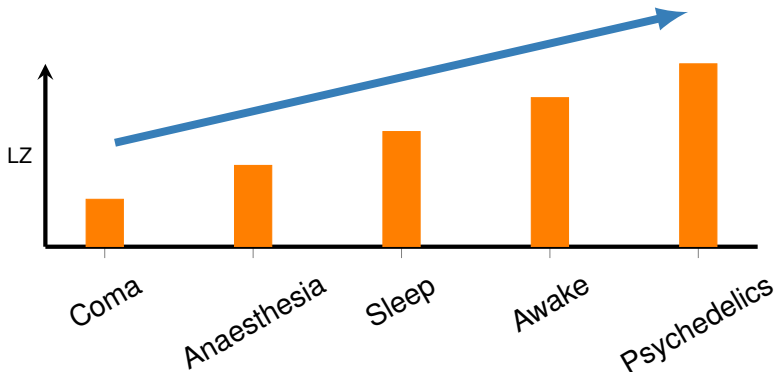
(Casali *et al.*, 2013)

EXPERIMENTAL FINDINGS

PSYCHEDELICS

(Schartner *et al.*, 2017)

THE ENTROPY SPECTRUM



MUSICAL IMPROVISATION

CORTÁZAR'S THE PURSUER

(EL PERSEGUIDOR)

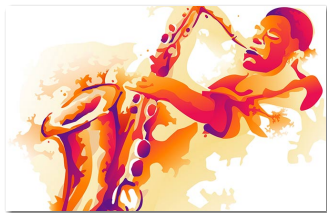
*Hell no, I don't get lost when I'm playing. Only the place changes. It's like in an elevator, you're in an elevator talking with people, you don't feel anything strange, meanwhile you've passed the first floor, the tenth, the twenty-first, and the city's down there below you, and you're finishing the sentence you began when you stepped into it, and between the first words and the last ones, there're fifty-two floors. **I realized that when I started playing I was stepping into an elevator, but the elevator was time, if I can put it that way.***

Julio Cortázar, 1959

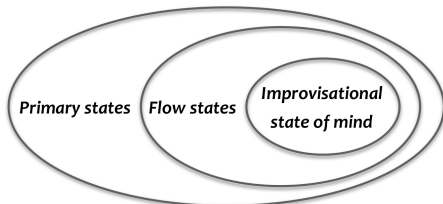


DRIVING HYPOTHESIS

An improvisational
state of mind



- ▶ **Flow** (Csikszentmihalyi, 1975)
 - *“The holistic sensation that people feel when they act with total involvement.”*
- ▶ **Primary state** (Carhart-Harris, 2014)
 - *“Relinquishing of the ego’s usual hold on reality”*



MUSICAL IMPROVISATION



VS.



Bach, Mozart, Beethoven, *et al* were great improvisers!

THE EXPERIMENT

- ▶ We organised a chamber music trio concert.
- ▶ Pieces were played twice, in **strict** and **let-go** conditions.



(Dolan *et al.*, 2018)



TRY IT YOURSELF!

SUBJECTIVE REPORTS



▶ In the **strict** performance:

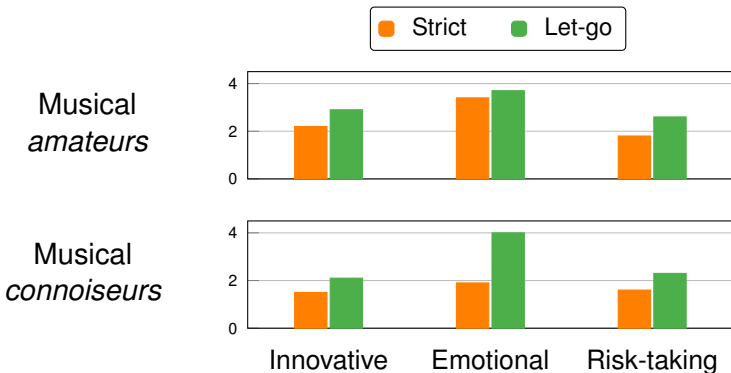
- ...*very little sense of connection between the performers...*
- ...*increased performance anxiety and internal critical chatter...*

▶ In the **let-go** performance:

- ...*greater sense of connection...*
- ...*Trust in my own musical instincts and capability...*
- ...*the freedom of the 'let go' mindset allowed me to create a wider range of colors and dynamics...*

POST-PERFORMANCE QUESTIONNAIRE

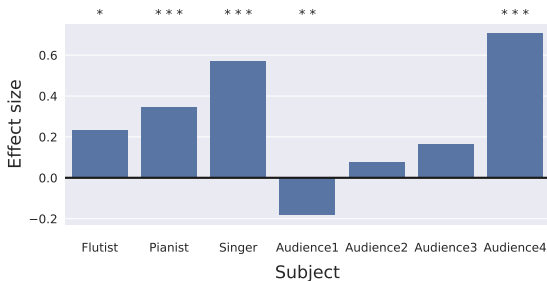
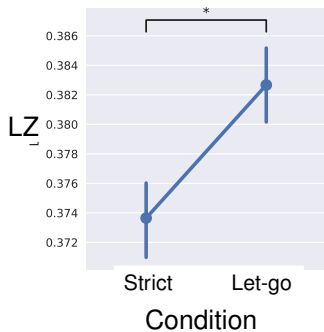
- Audience rated performance as more innovative, more emotional and more musical.



NEUROIMAGING RESULTS I



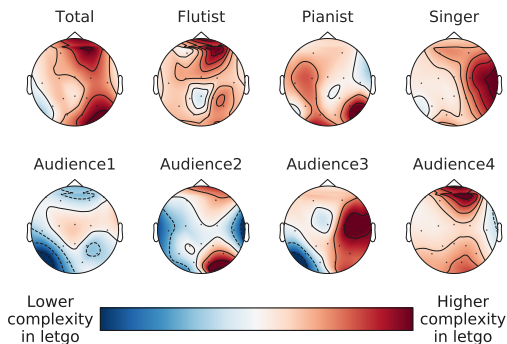
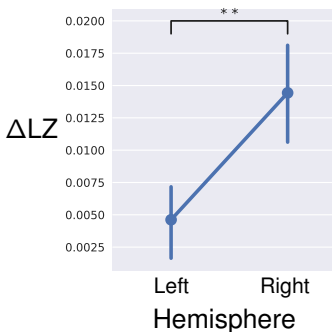
Improvisation consistently increases brain entropy.



NEUROIMAGING RESULTS II



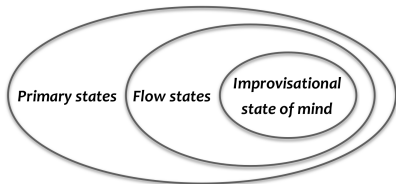
Entropy increase is located in the right hemisphere.



CONCLUSIONS

MUSICAL IMPROVISATION

- ✓ Improvisation is not exclusive of jazz, also plays a major role in classical music.
- ✓ Data supports the existence of an *improvisational state of mind*, which is a state of flow and a primary state.





PSYCHEDELIC STATE



PSYCHEDELIC PHENOMENOLOGY



PSYCHEDELIC PHENOMENOLOGY

- ▶ Onset of audiovisual hallucinations.
 - *“With eyes closed, I saw geometric patterns.”*

- ▶ Distortion of self models.
 - *“I experienced a disintegration of my ‘self’.”*

- ▶ Increased cognitive flexibility.
 - *“My thoughts wandered freely.”*

Disclaimer:

We have no idea of what we're doing

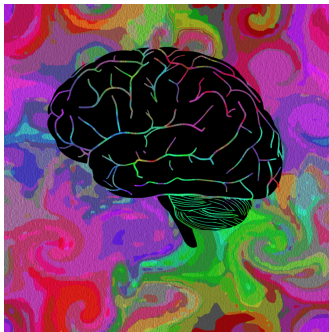
PSYCHEDELIC NEUROSCIENCE IS A MESS

PSYCHEDELIC NEUROSCIENCE IS A MESS

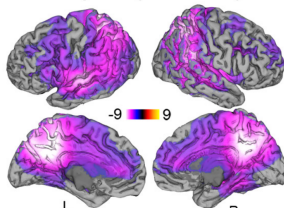
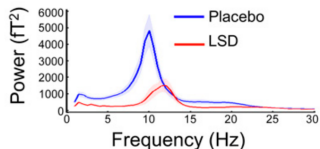
PART I: NEURONS DON'T WORK



Intense experience,
faster *stream of consciousness*



Radically *decreased* activity
throughout the brain



(Muthukumaraswamy *et al.*, 2013)

(Carhart-Harris *et al.*, 2016)

PSYCHEDELIC NEUROSCIENCE IS A MESS

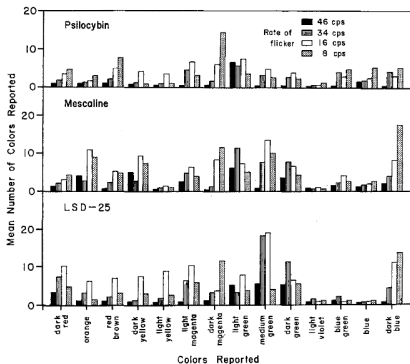
PART II: PERCEPTION DOESN'T WORK



Increase in *intense, raw*
perceptual content



You *report* seeing more colours,
but you *actually* see less



(Hartman & Hollister, 1963)

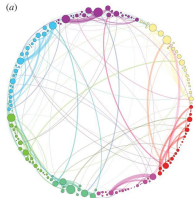
PSYCHEDELIC NEUROSCIENCE IS A MESS

PART III: NETWORKS DON'T WORK

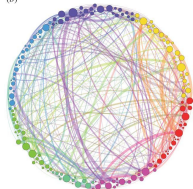


New connections formed
between brain regions

(a)



(b)



Widespread inter-region
communication breakdown



↑ Correlation



↓ Information transfer

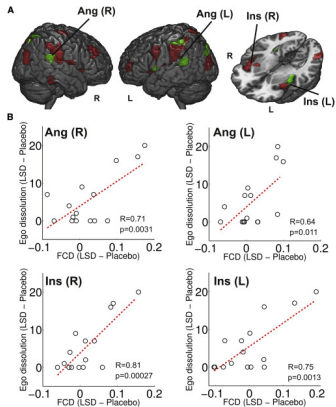
(Petri *et al.*, 2014)
(Barnett *et al.*, 2019)

PSYCHEDELIC NEUROSCIENCE IS A MESS

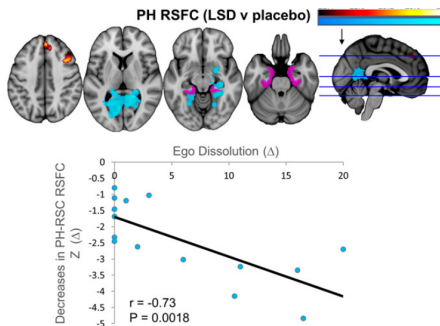
PART III: NETWORKS DON'T WORK



Ego dissolution
correlates with FC



Ego dissolution
anti-correlates with FC



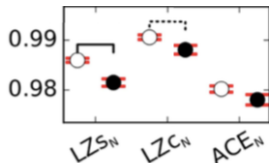
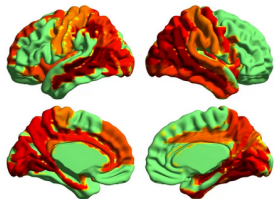
(Tagliazucchi *et al.*, 2016)
(Carhart-Harris *et al.*, 2016)

PSYCHEDELIC NEUROSCIENCE IS A MESS

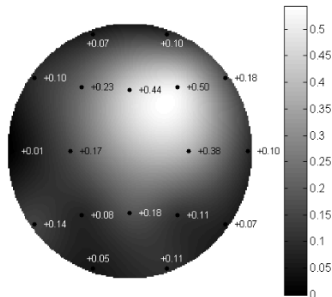
PART IV: ENTROPY DOESN'T WORK



Increased entropy
promotes *flexibility*



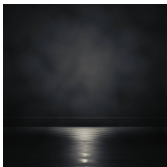
Increased entropy
in *depression* patients



(Schartner *et al.*, 2017)
(Bachmann *et al.*, 2015)

THE EXPERIMENT

- ▶ 16 subjects, 4 conditions with different stimuli.



eyes closed/no music



eyes closed/music



eyes open/no video

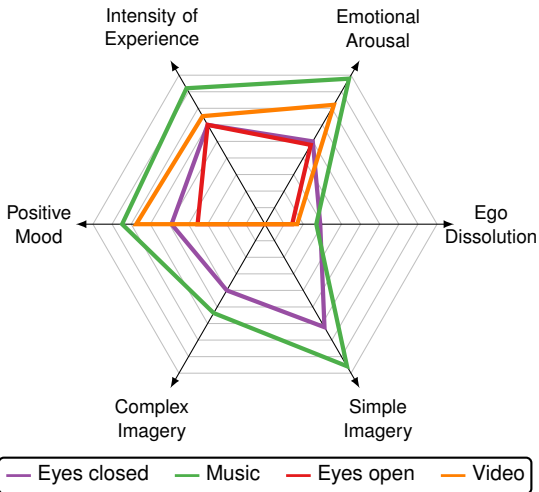


eyes open/video

SUBJECTIVE REPORTS

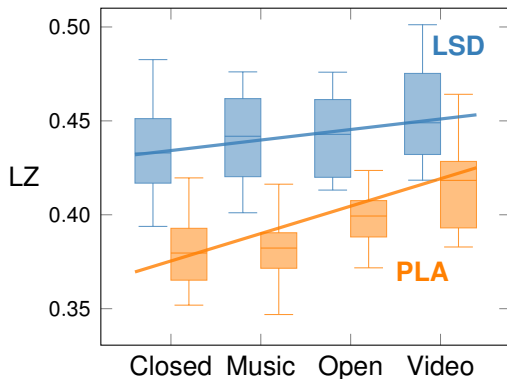


Music boosts subjective phenomenological ratings.



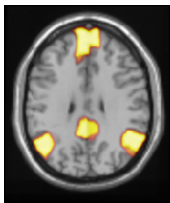
NEUROIMAGING RESULTS

- ▶ Entropy increases with external stimulation.
- ▶ Effect of LSD *decreases* with external stimulation.

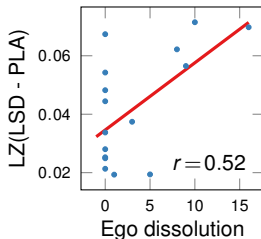


NEUROIMAGING RESULTS

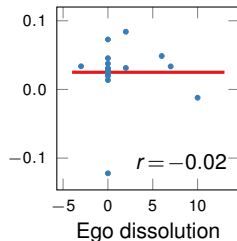
DEFAULT
MODE
NETWORK



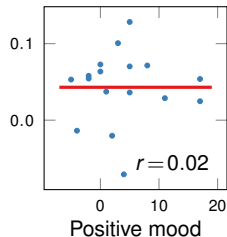
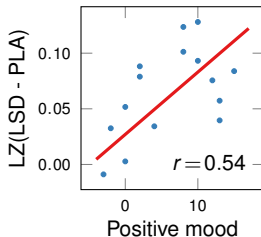
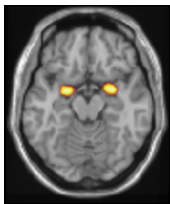
EYES CLOSED



VIDEO



AMYGDALA

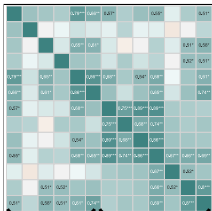
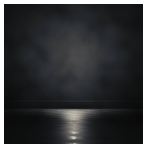


NEUROIMAGING RESULTS

- Brain entropy predicts subjective reports.

▶ Except when watching a video!

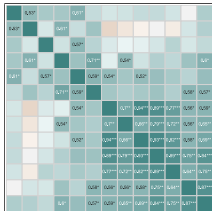
eyes closed/no music



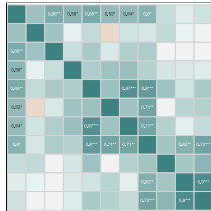
Mind

Brain

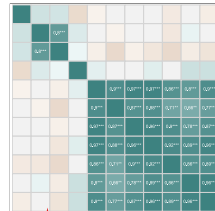
eyes closed/music



eyes open/no video



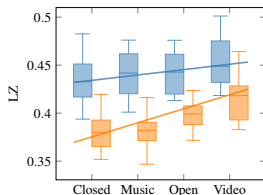
eyes open/video



CONCLUSIONS

PSYCHEDELIC STATE

- ✓ Both personal expectations and external environment have measurable effects on the brain – *set and setting*.
- ✓ Stronger effects in more inward-focused states:
 - *Tripping is easy with eyes closed.*



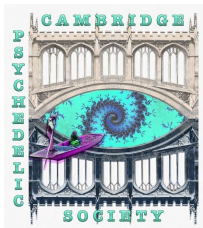
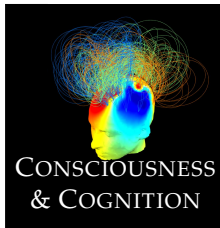


WRAP-UP



WRAP-UP

- ✓ The scientific study of altered states of consciousness allows us to tap into how the brain generates experience.
- ✓ The Entropic Brain Hypothesis is remarkably simple, yet remarkably powerful.
- ? We still don't have a clue.



plogp@pm.me

Thank you for listening!