Neural Basis of Moral Emotions, Rewards and Altruism

From Scanners to the Real World

Reunião Magna – ABC

Museu do Amanhã, 2017

SESSÃO CIENTÍFICA: "CÉREBRO, ENVELHECIMENTO E CAPACIDADE COGNITIVA"

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INSTITUTO D'OR PESQUISA E ENSINO

REUNIÃO MAGNA 2017 | ABC
PROJETO DE CIÊNCIA PARA O BRASIL

ACADEMIA BRASILEIRA DE CIÊNCIAS

No conflicts of interest

Outline

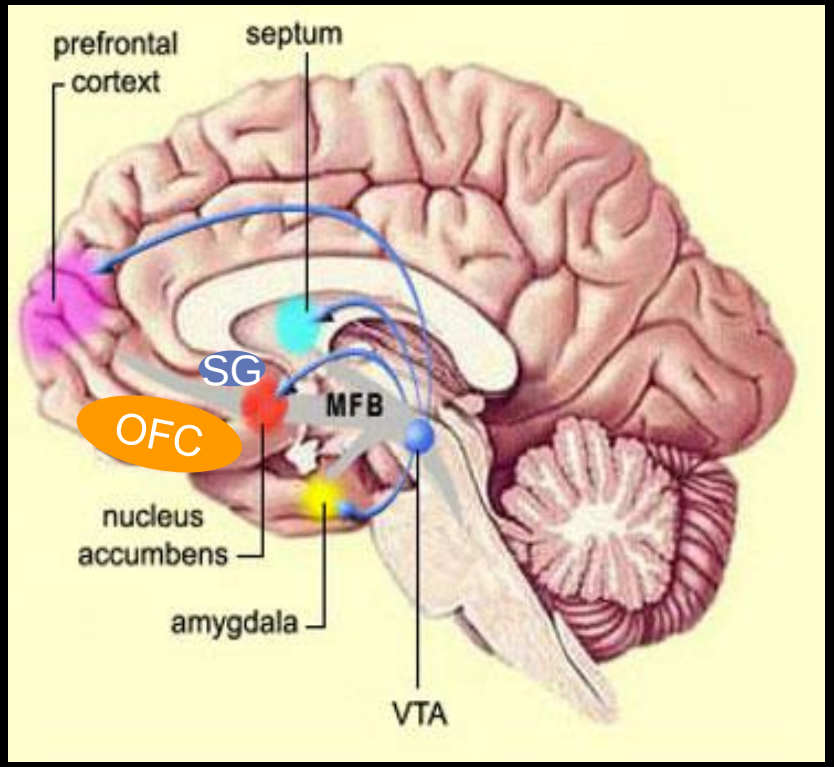
- Neuroscience of emotions, rewards and moral cognition
- Functional imaging of moral emotions and impairments in neuropsychiatry
- Real-time neurofeedback of moral emotions using functional MRI
- Emerging clinical applications
- Perspectives

Rewards and immediate self-interest

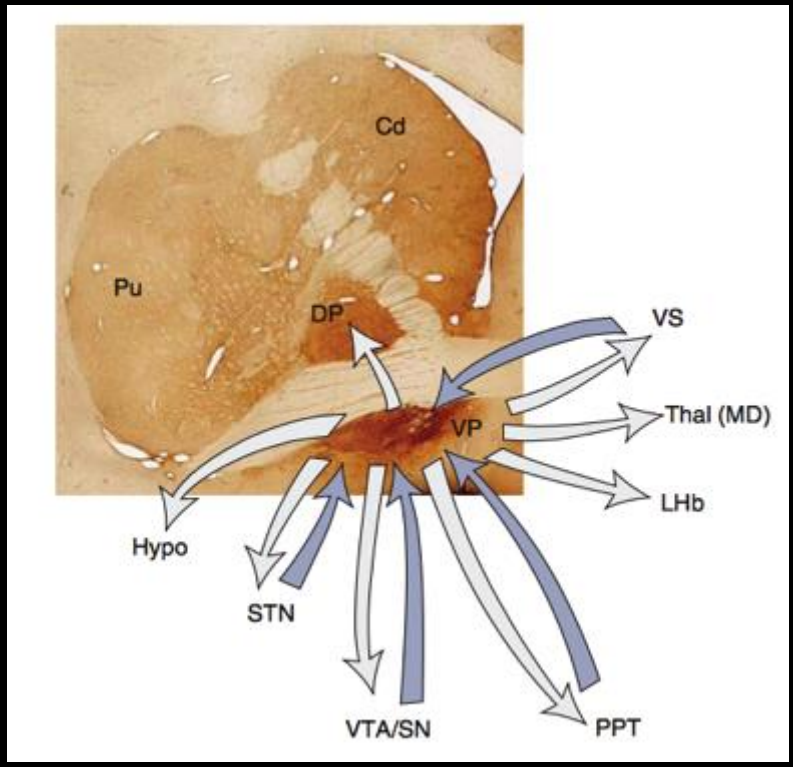
Reward system (“valuation”)

Associated higher-level cognitive mechanisms

→ *Goal, prediction, comparison, ambiguity, prospective evaluation*

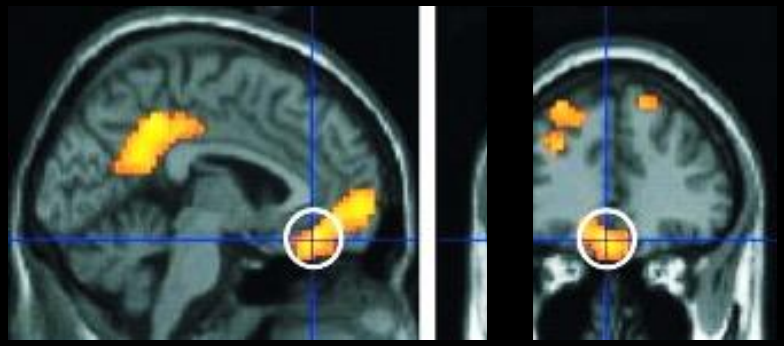


Schultz W. NRN, 2000

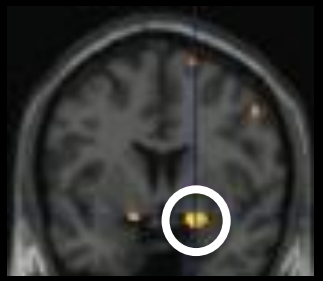


Haber & Knutson, NPP2010

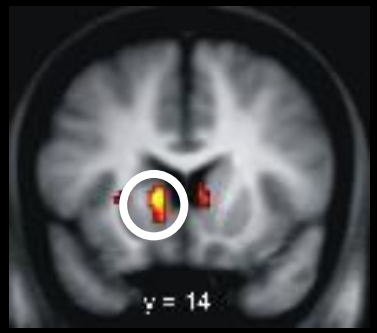
Brain imaging and economic value



Medial orbitofrontal cortex



Amygdala



Striatum

Insula

Kim et al., 2010; Knutson et al., 2001; Levy & Glimcher, 2012

Moral emotions and social values

MORALITY

SETS OF CUSTOMS AND VALUES ADOPTED BY INDIVIDUALS AND SOCIETIES TO GUIDE SOCIAL BEHAVIOR

MORAL MOTIVATION

THE ABILITY TO BE MOTIVATED BY SOCIO-CULTURAL NORMS OR OTHER PEOPLE'S NEEDS

→ Moral behavior requires (1) the knowledge about the needs of others (SOCIAL KNOWLEDGE) and about specific sociocultural norms and (2) the motivation to behave in such ways

What motivates us to behave morally?

"Moral sentiments"

Adam Smith & David Hume: 18th century Scottish Enlightenment

Modern psychology (Tangney, 2007, Eisenberg, 2000): "Moral emotions", e.g. guilt, compassion, pride, gratitude, contempt

Moral motivations tied to

social action in specific context of sequence of events

abstract moral value

"Your mother calls you one night telling you she was not feeling well. You did not take her seriously, and the next day she died"

→ Guilt

in 80% of Brazilian sample (Moll et al., 2007)

"You act dishonestly towards your best friend"

→ Guilt

in 73% of US sample (Zahn et al., 2009)

Functional MRI of implicit moral sentiments

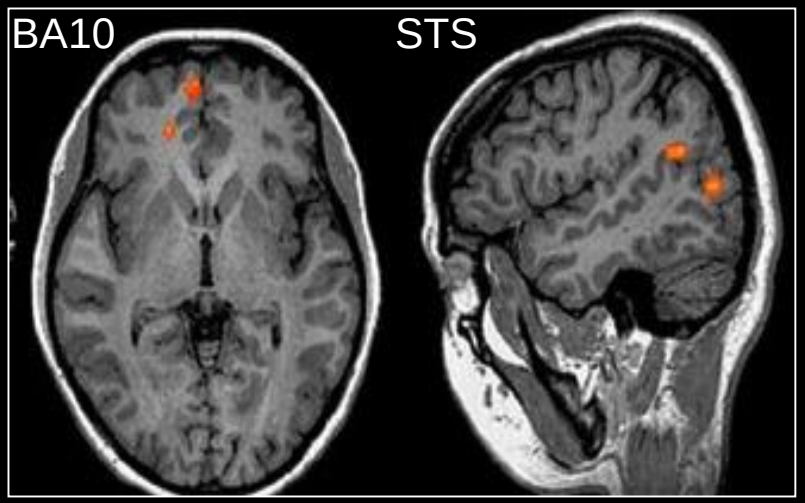
Indignation

Compassion

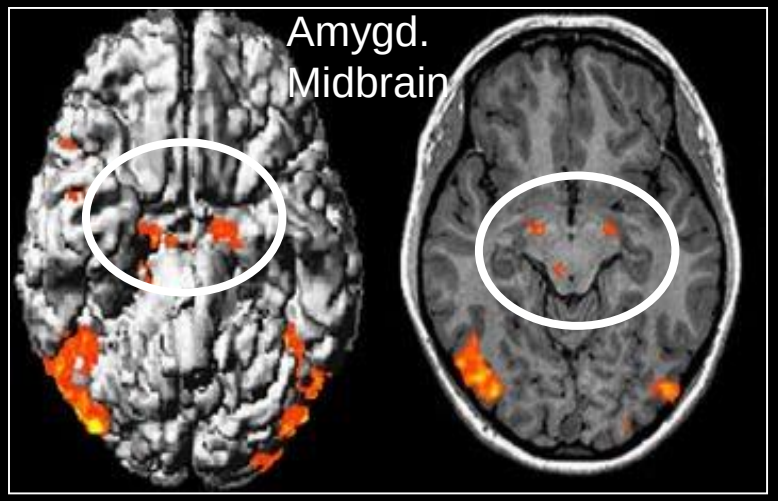
Fear

Disgust

Moral unpl. vs. Unpleasant



Moral unpl. ∩ Unpleasant

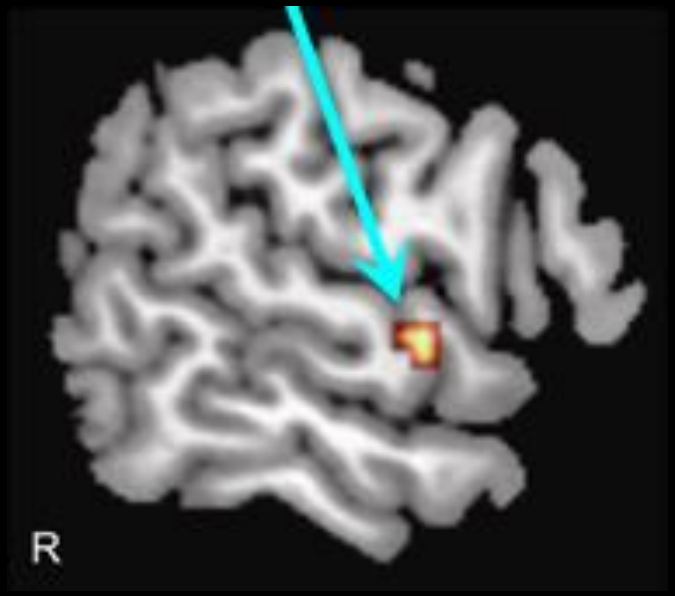


Moll, de Oliveira-Souza, Eslinger et al. J Neurosci, 2002

The right ATL & social knowledge

Contextualized social concepts (values) → moral sentiments

e.g. [YOU] acted [stingily or generously] towards [BEST FRIEND]



Right Anterior Temporal Lobe

→ *across all condition*

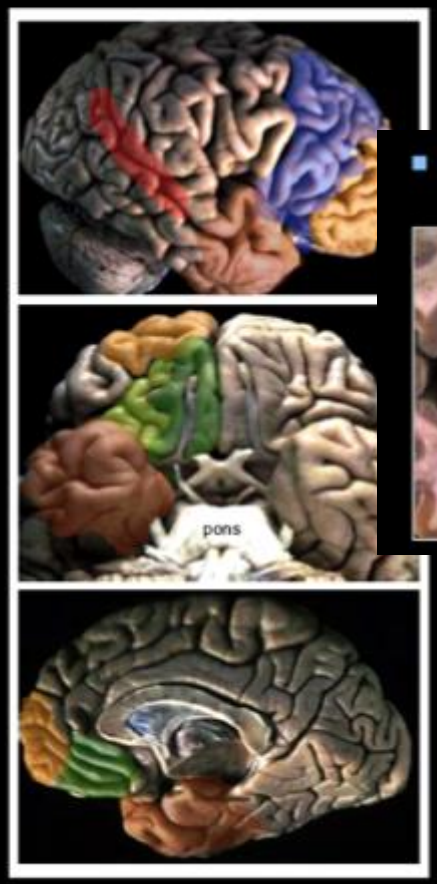
Other fronto-subcortical areas

→ *different moral sentiments*

Zahn R, Moll J, Paiva M, Garrido G, Krueger F, Huey E, Grafman J.
Cerebral Cortex, 2009

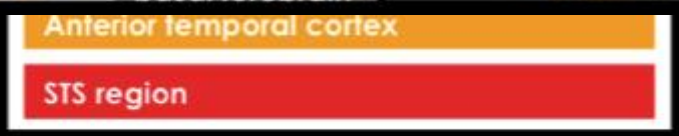
Brain regions consistently involved in moral cognition, emotion and behavior: lesion & fMRI

- *Cortical (event and action knowledge, planning, abstract concepts)*



- *Subcortical-limbic (motivational-emotional)*

- *Subcortical-limbic (motivational-emotional)*



Moll J, Zahn R, Oliveira-Souza R, Krueger F, Grafman J. The neural basis of human moral cognition. *Nature Rev Neurosc, 2005*

SOCIAL ATTACHMENT

- Establishment of strong social bonds
- Promotion of cooperation and altruism
- Social cohesion

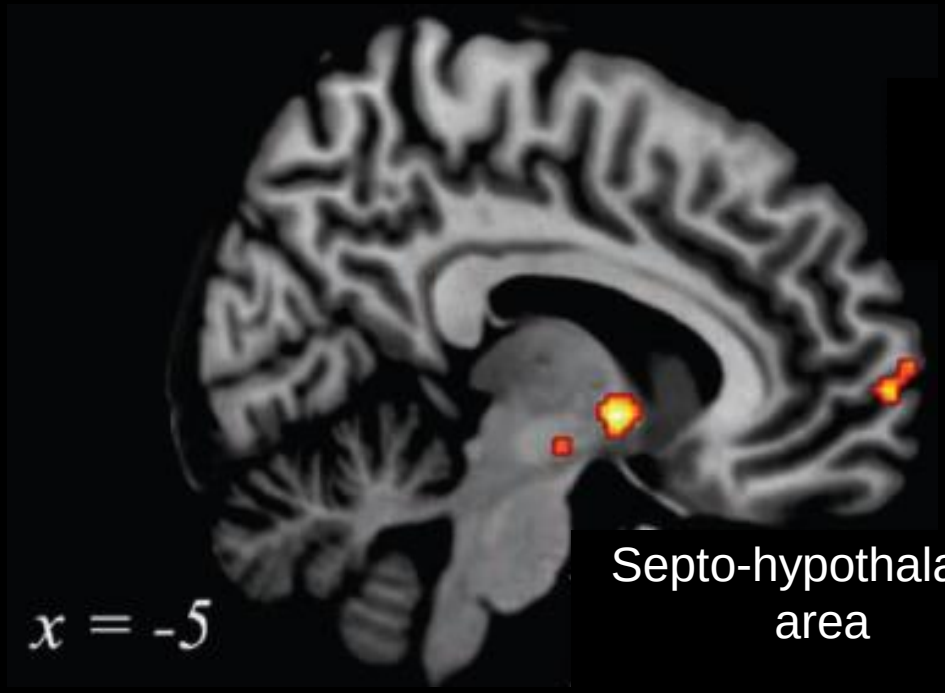
Social affiliation → tender/affectionate feelings

Insel and Young, 2001; Depue and Morrone-Strupinsky, 2005; Moll & Schulkin, 2009

Guilt and compassion: affiliative (“social attachment”) system

“Your mother calls you one night telling she was not feeling well. You did not take her seriously, and the next day she died.” (guilt)

“You went with a friend to a restaurant. When you passed by the kitchen, you saw rats crawling all over the place.” (indignation)



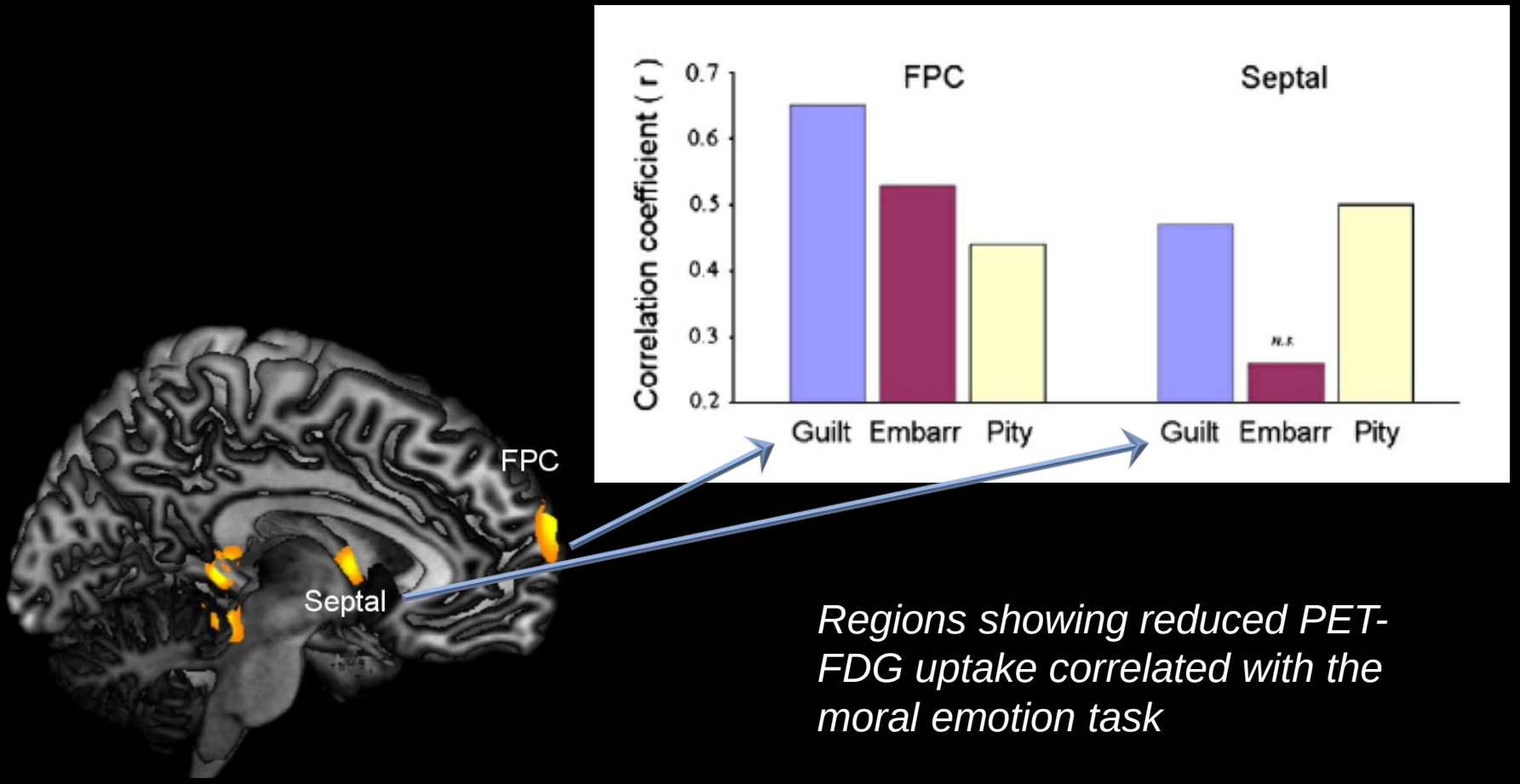
Frontopolar cortex

GUILT & COMPASSION

Septo-hypothalamic area

Moll et al. Soc Neurosci, 2007

Impaired prosocial sentiments in behavioral variant frontotemporal dementia



Regions showing reduced PET-FDG uptake correlated with the moral emotion task

Specific impairments of prosocial sentiments in patients with Fronto-Temporal Dementia

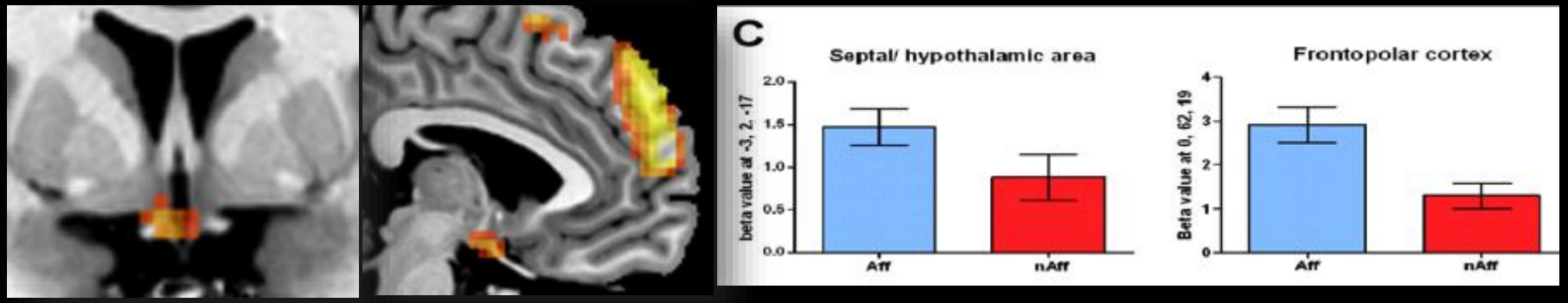
Moll J, Zahn R, de Oliveira-Souza R, et al. NeuroImage, 2011

Neural signature of affiliative emotions (tenderness/affection)

AFFILIATIVE vs NON-AFFILIATIVE

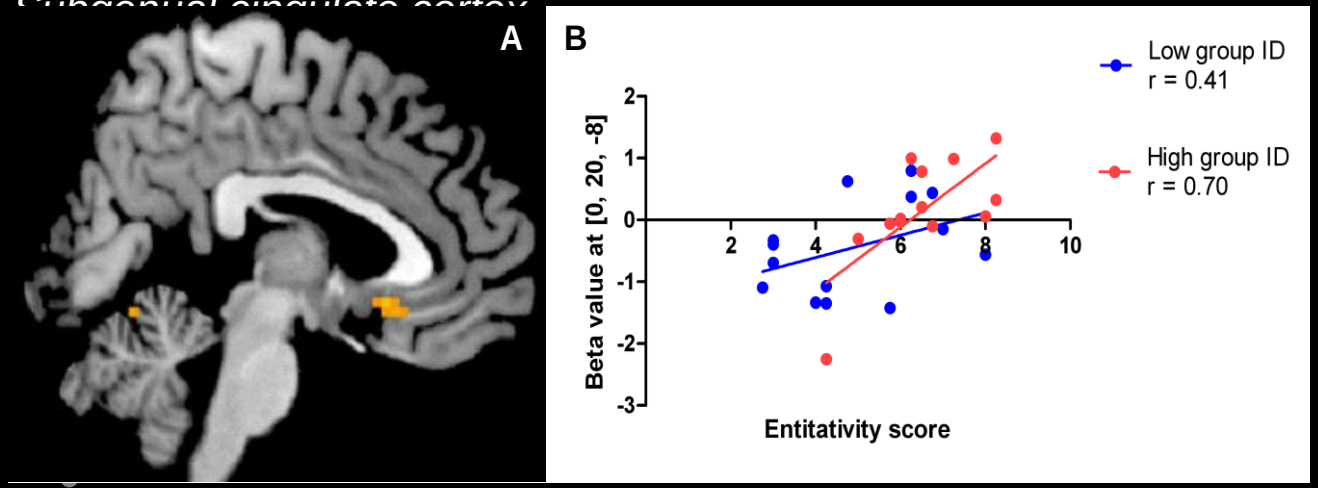
Septal-medial preoptic hypothalamus & Frontopolar cortex

Moll et al., J Neurosci 2012



PERCEIVING FAMILY AS A COHESE SOCIAL GROUP

Subgenual cingulate cortex

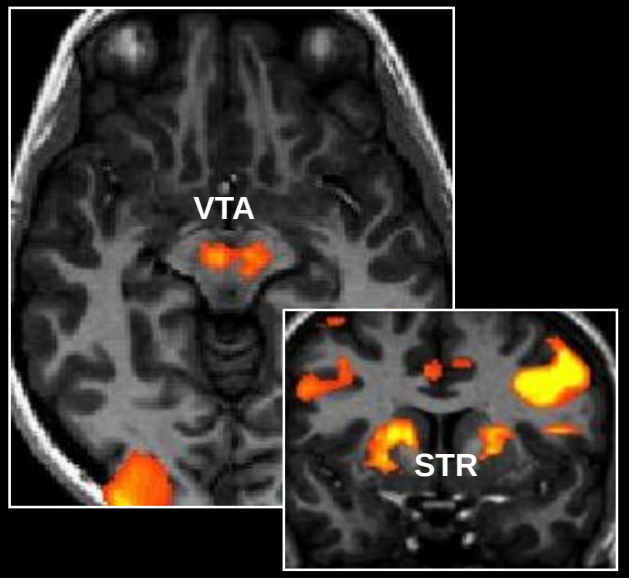


Rusch et al., Soc Neurosci, 2014

Charitable donations – fMRI study

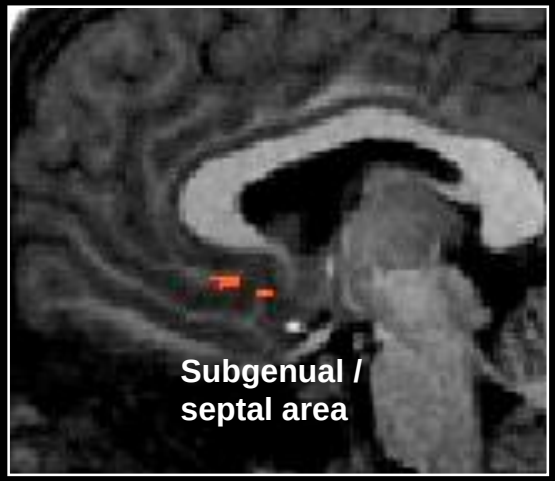
Pure $ reward and donation vs baseline

Mesolimbic reward system:
self reward



Costly and non-costly donation *vs.*
pure $ reward

Subgenual cortex / septal region:
attachment to societal causes



Moll J, Krueger F, Zahn R, et al. PNAS, 2006

Neurofeedback: self-regulation of brain activity when provided with feedback information about one's own physiological responses

Are humans able to modulate their own neural responses arising from moral emotions?

Philip K. Dick: *"Do Androids Dream of Electric Sheep?"(1968)*

Ridley Scott: *Blade Runner* (1982)

The Penfield Mood Organ:"dialing"moods

Brain decoding and neurofeedback

Pattern recognition methods in neuroimaging
Inferring cognitive / psychological states
Neurofeedback applications

Characterizing neural signatures and promoting adaptive neural/psychological states

Development of a real-time functional MRI and neurofeedback system:

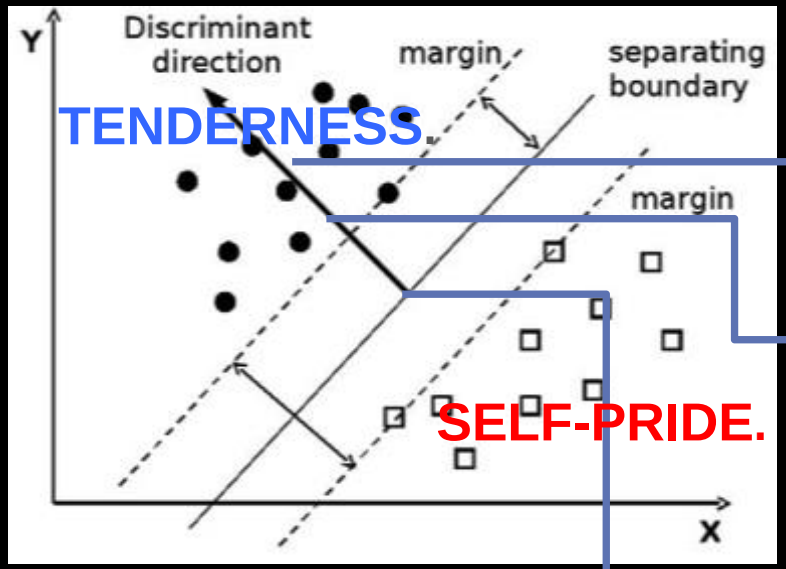
FRIEND: Functional Real-time Interactive Endogenous Neuromodulation and Decoding. Free for non-commercial use.

FRIEND - FUNCTIONAL REAL-TIME INTERACTIVE ENDOGENOUS NEUROMODULATION AND DECODING de D'OR INSTITUTE OF RESEARCH AND EDUCATION é licenciado sob uma Licença Creative Commons

Sato et al., Plos One, 2013
Basilio et al., Front in Behav Neurosc, 2014

Discrimination between TENDERNESS and SELF-PRIDE associated with autobiographical memories (baseline = emotionally “NEUTRAL”)

24 participants, randomized to a NFB or control group



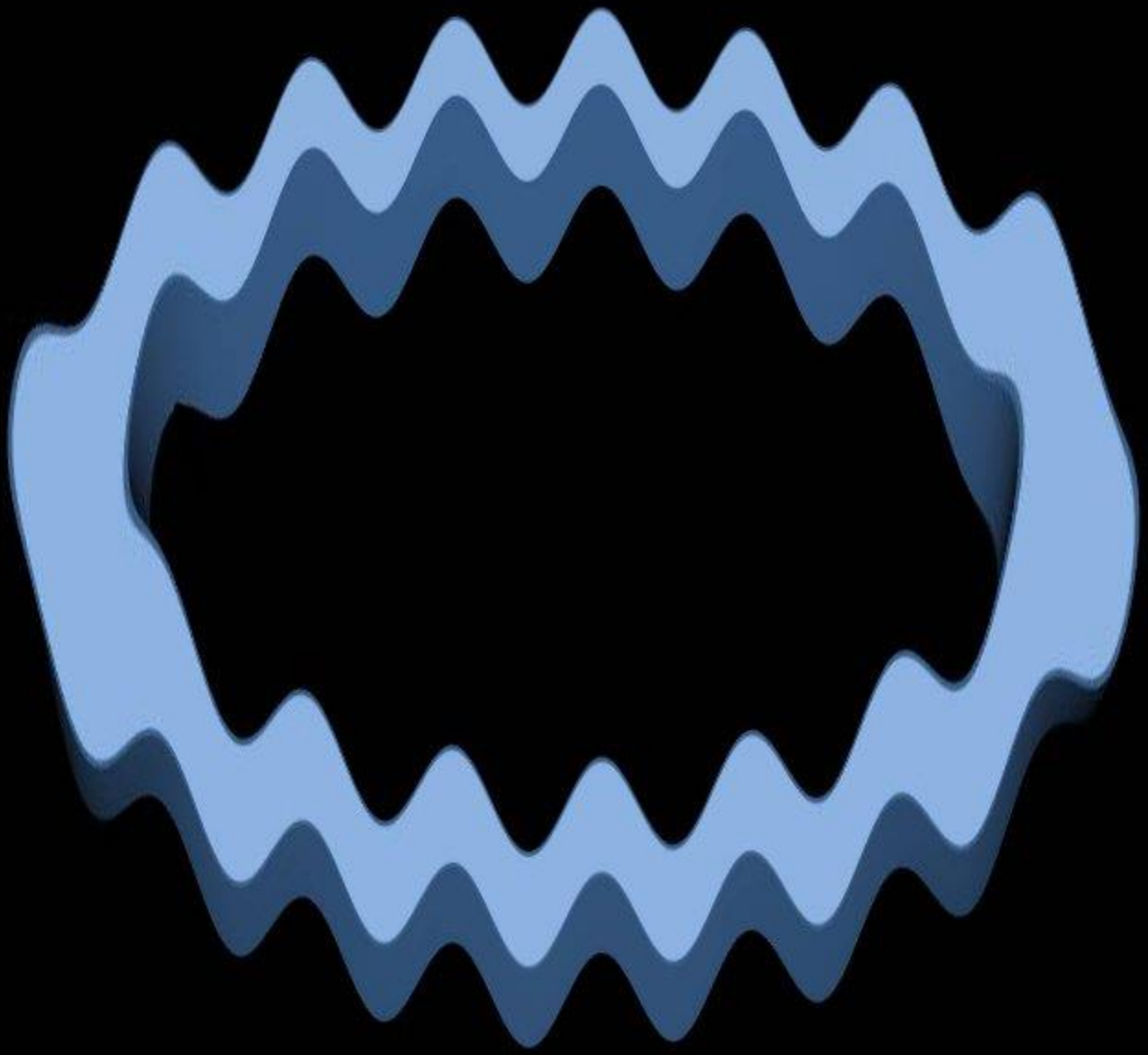
SUPPORT VECTOR MACHINE FOR PATTERN DECODING

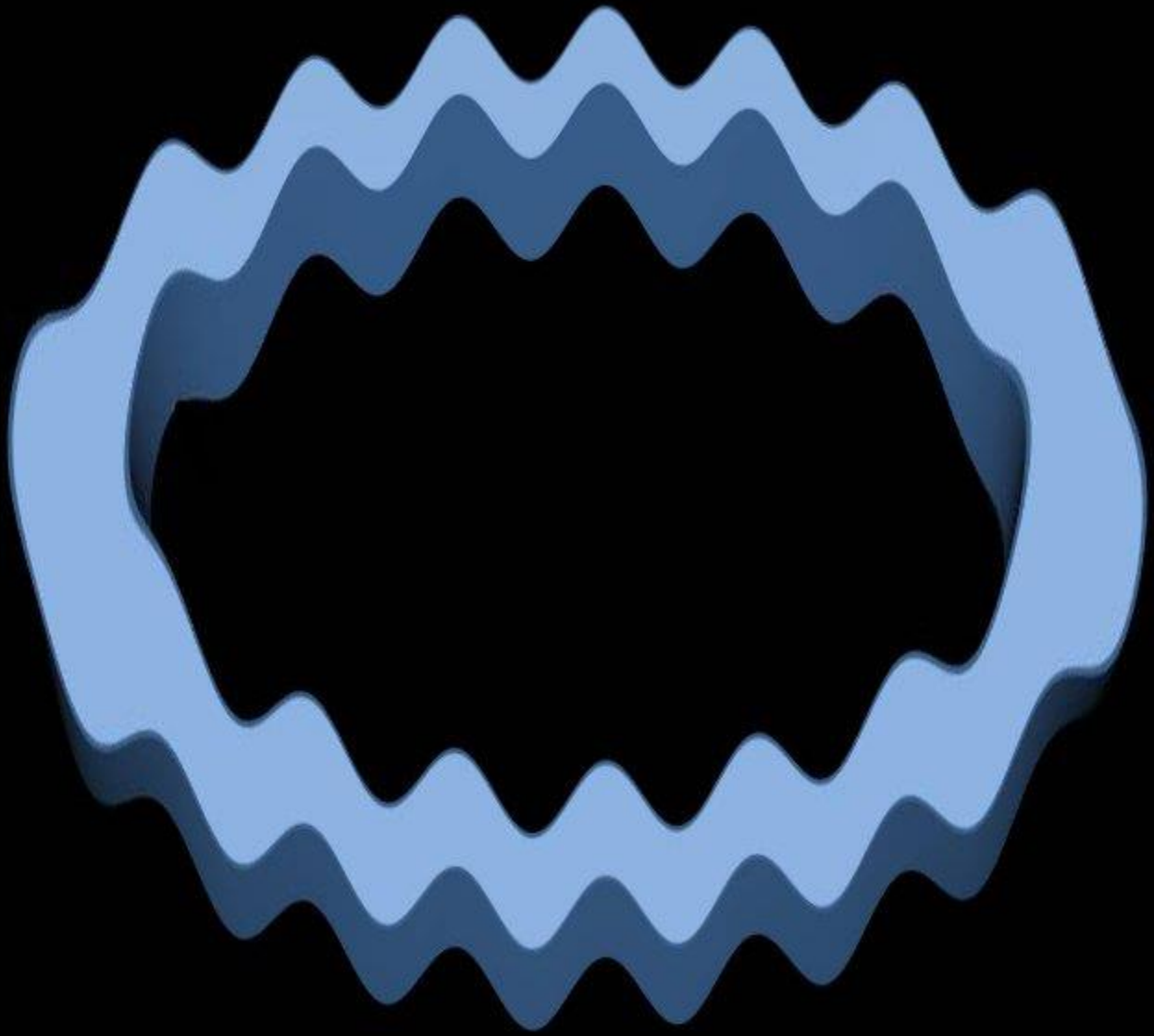
A hit with highest SVM projection

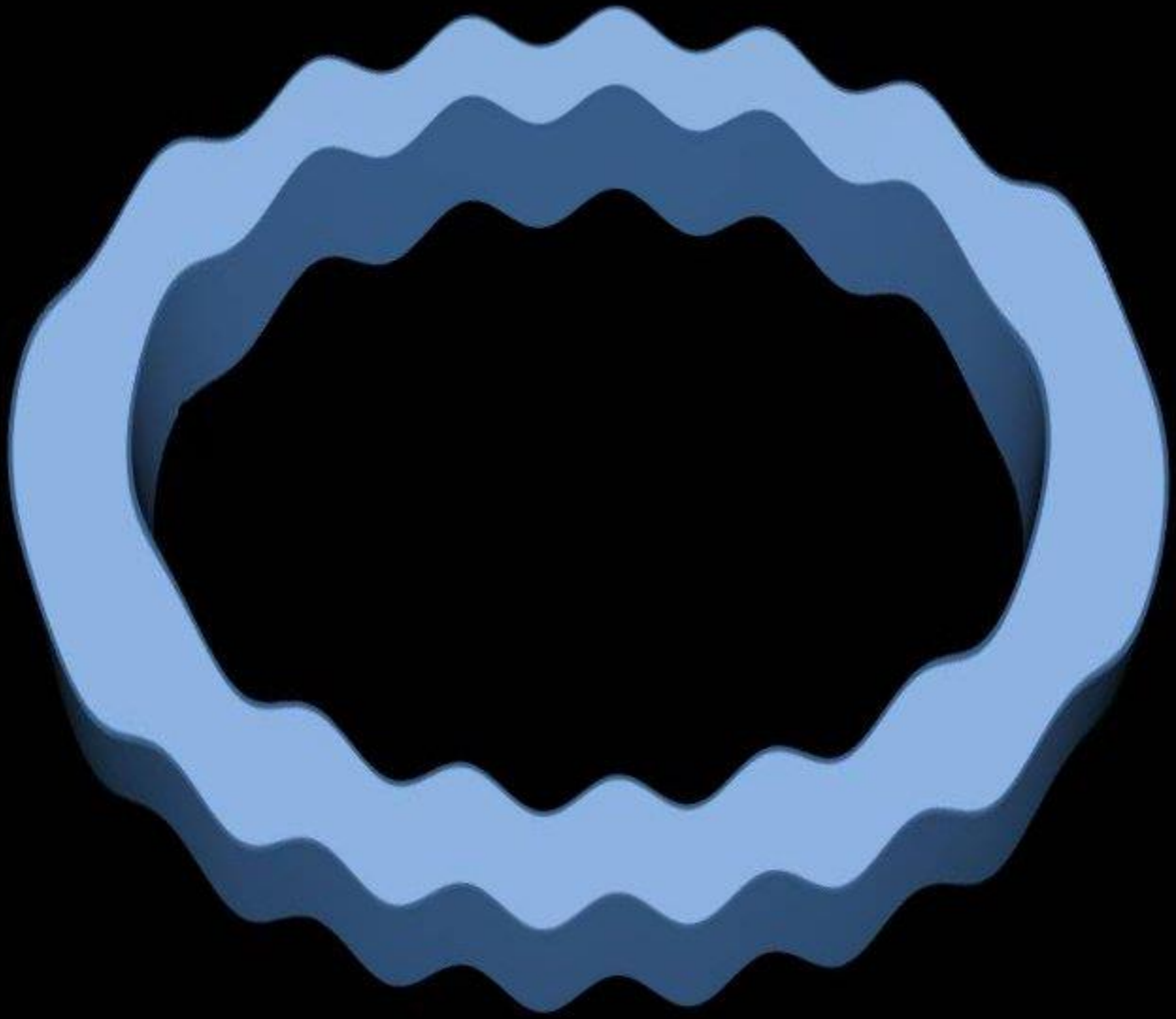
Distance from hyperplane

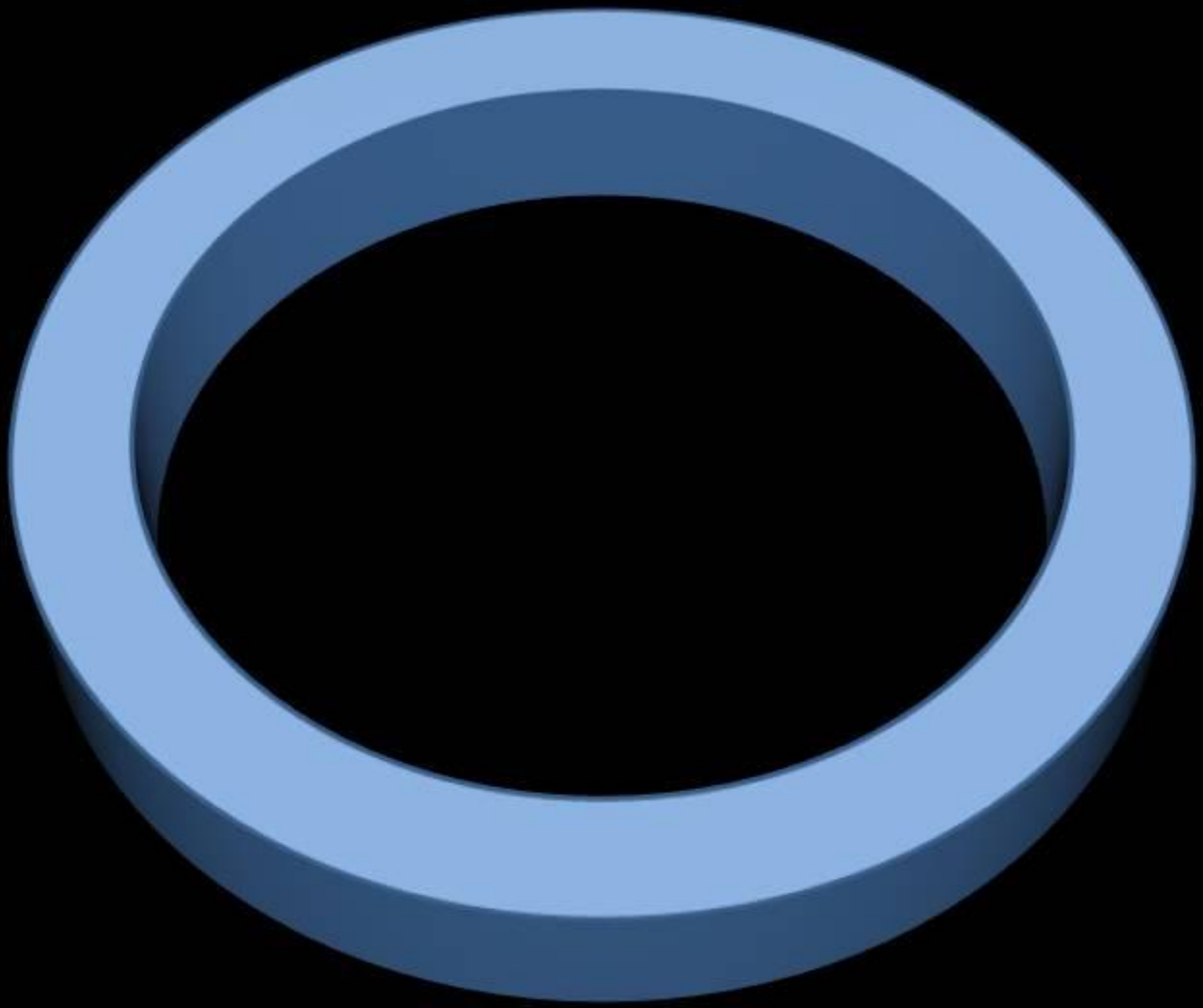
A hit with mid-range SVM projection

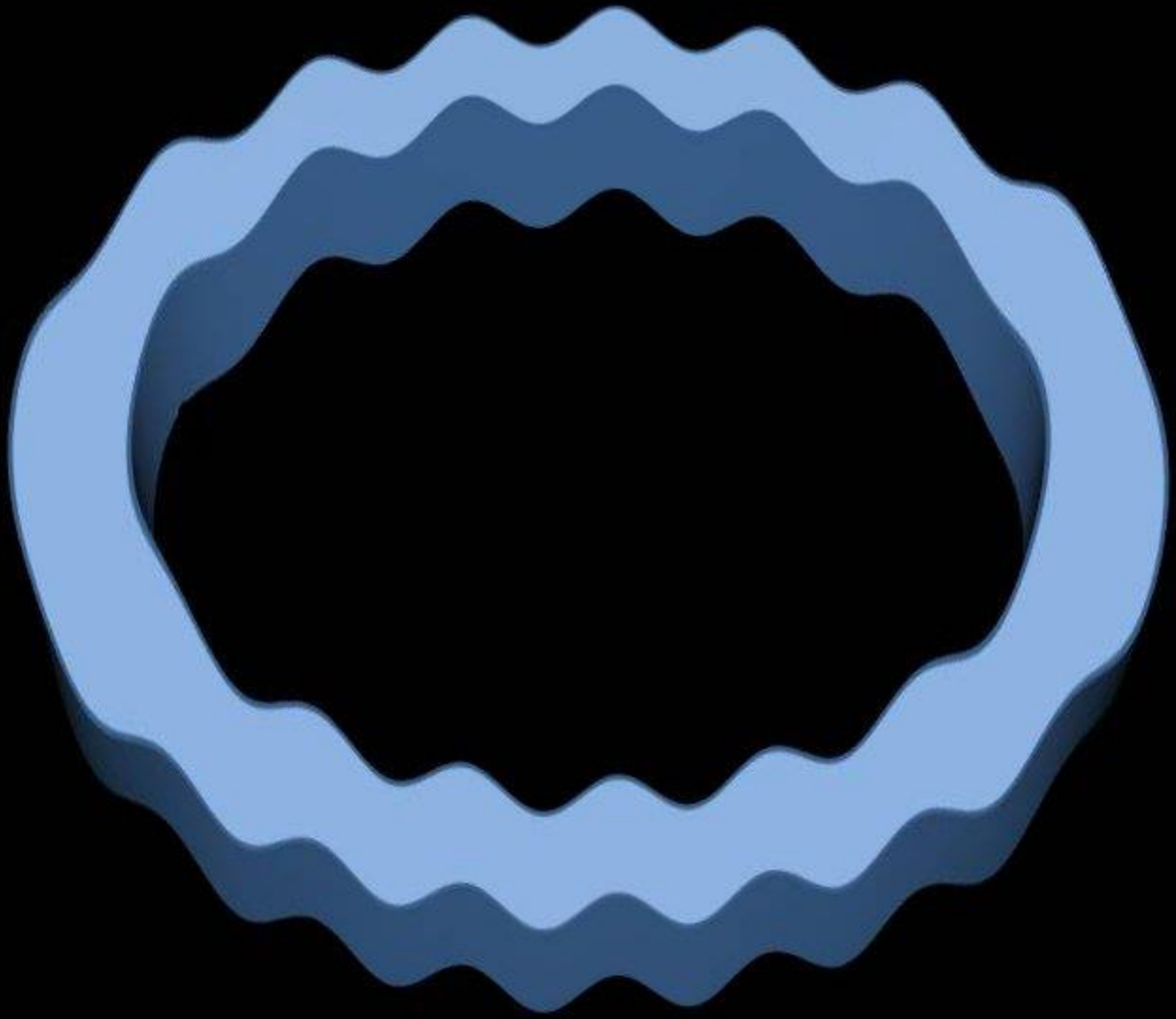
Either error in classification or a hit with low SVM projections

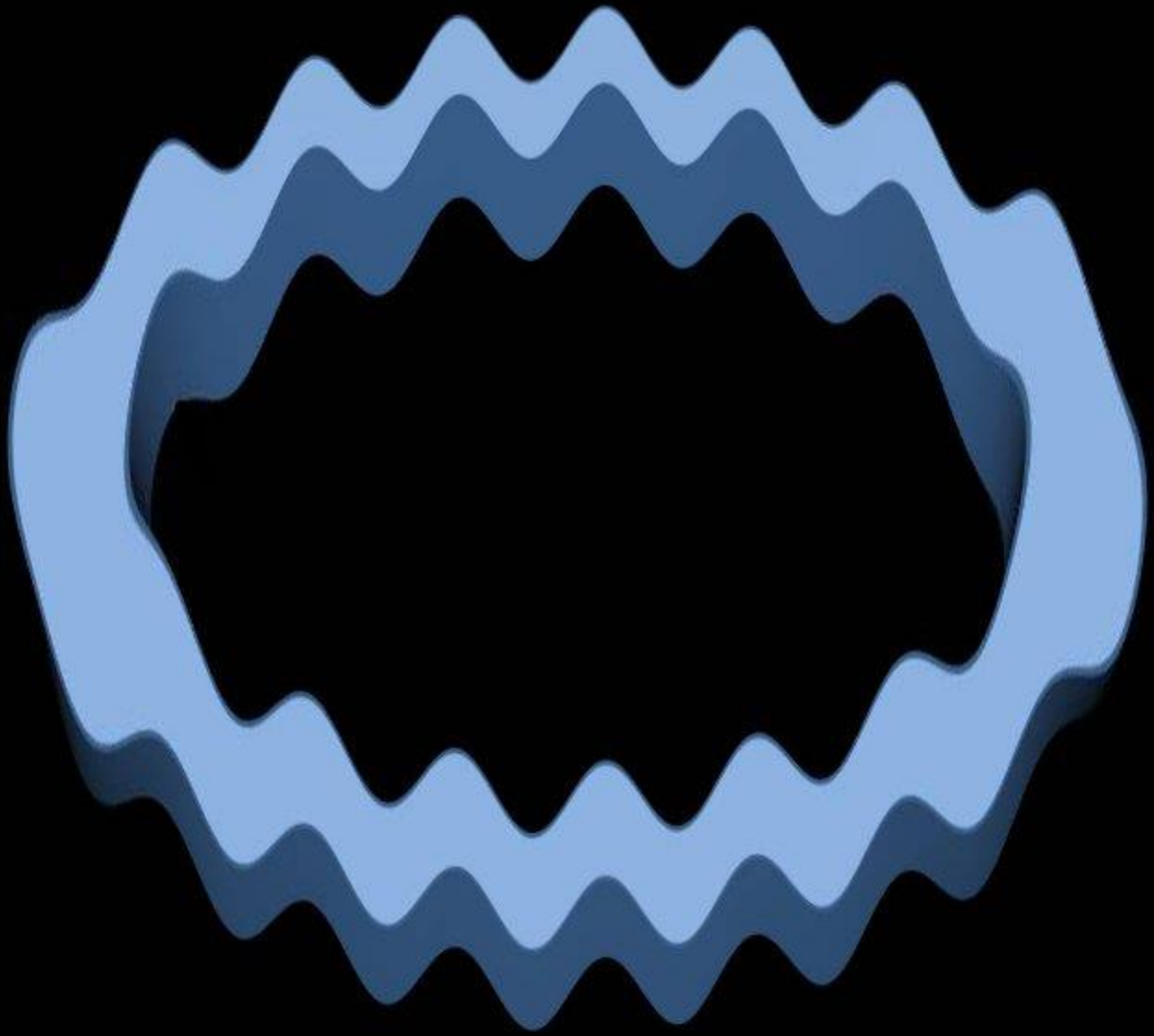


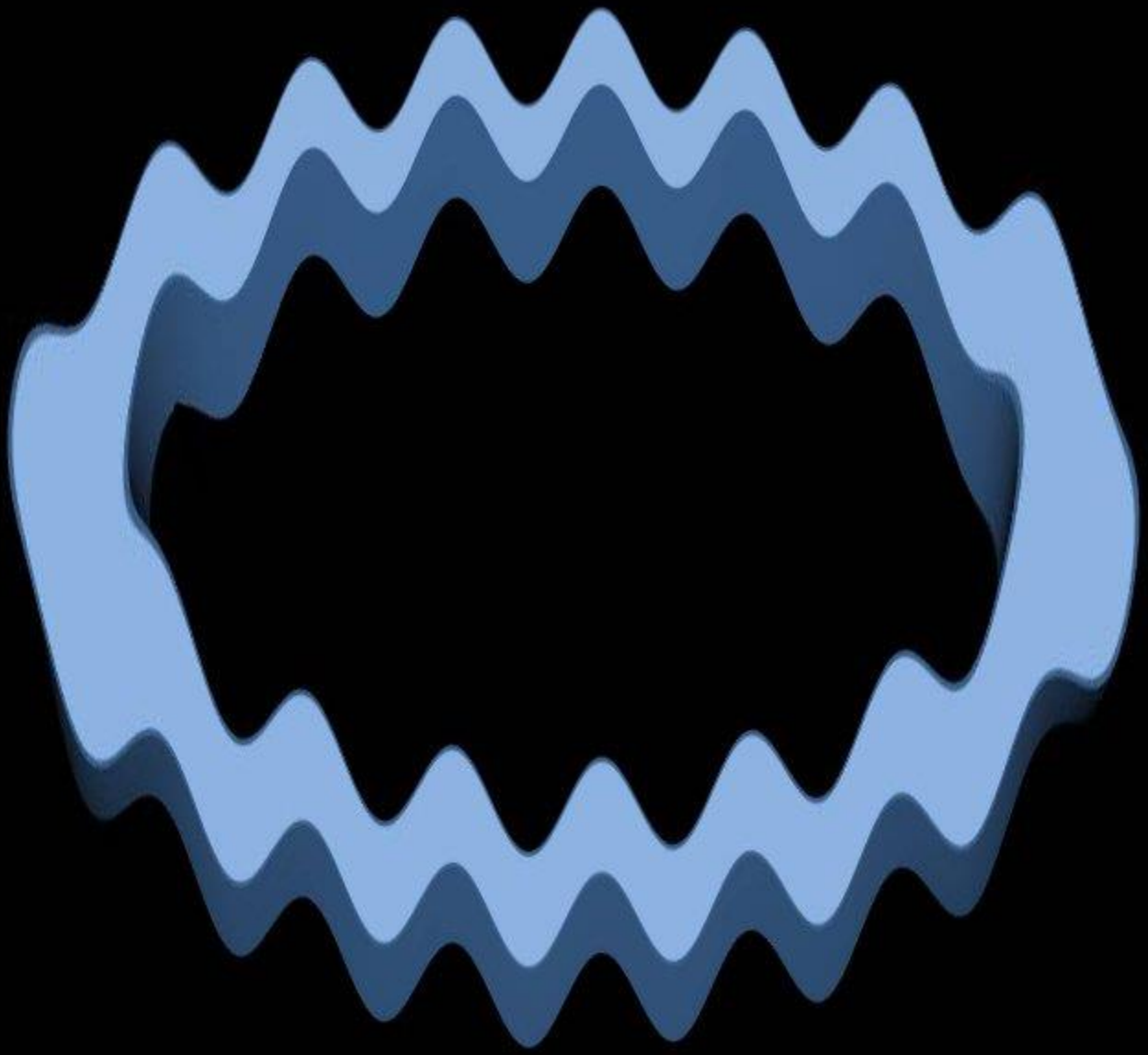


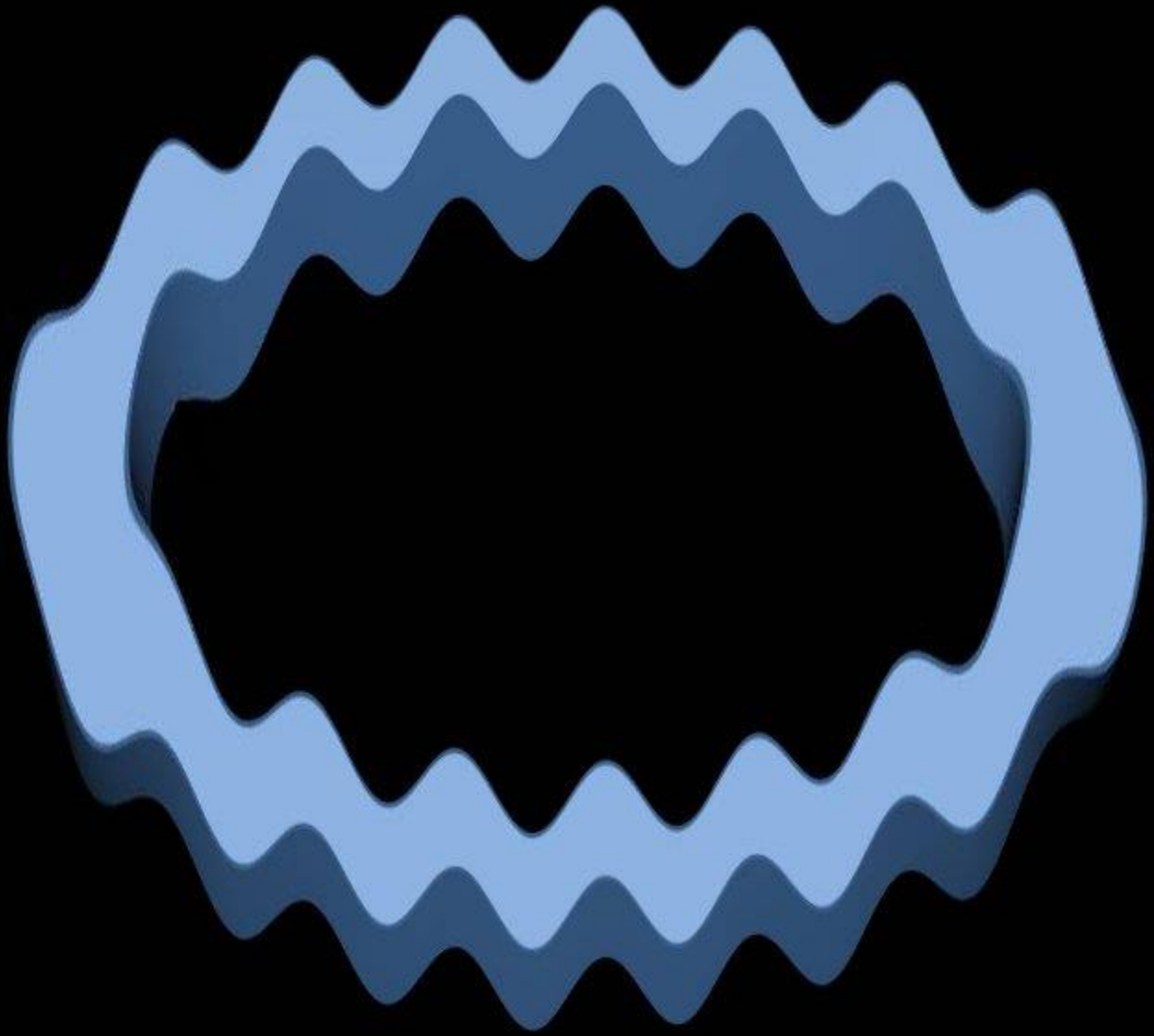


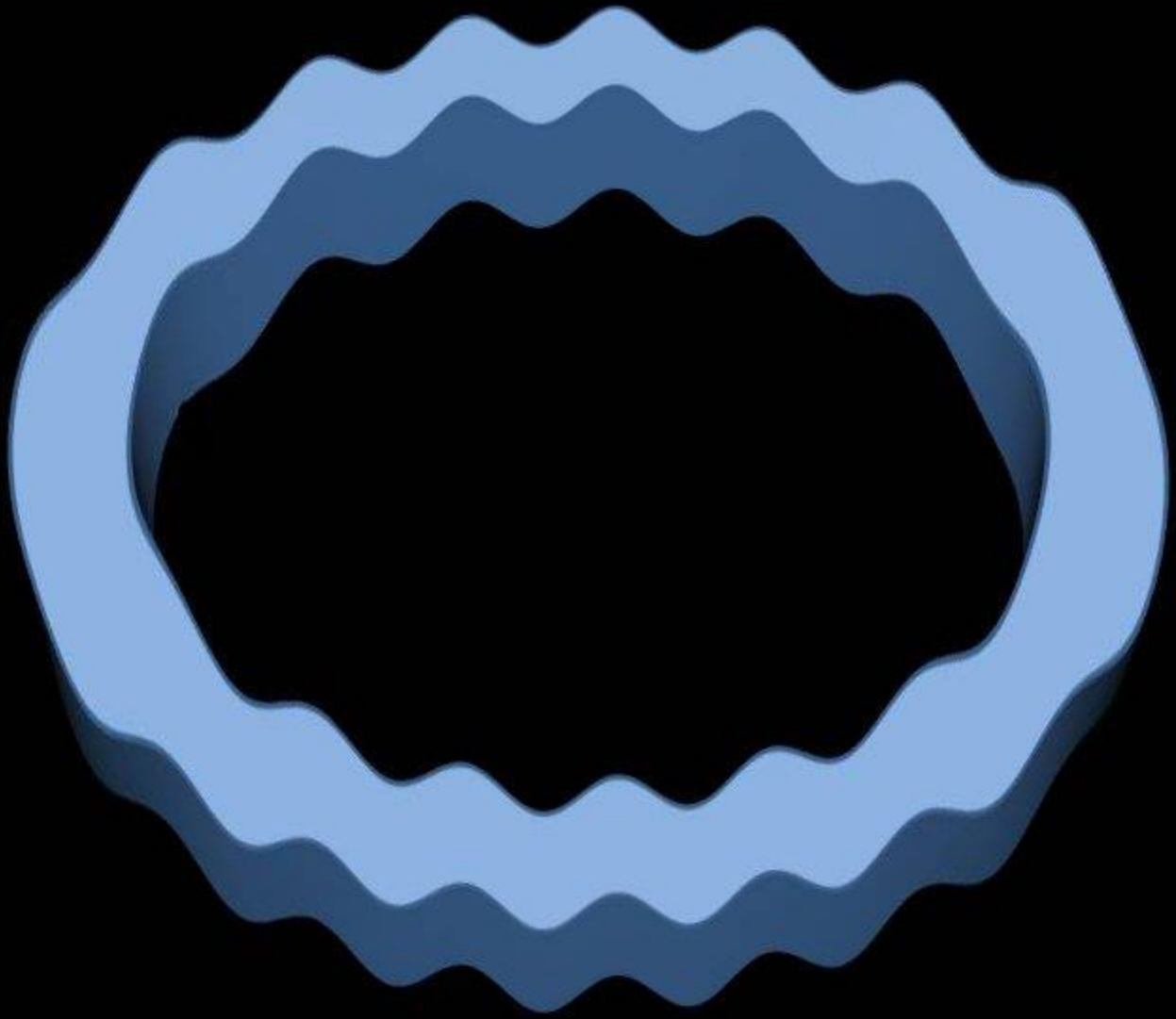


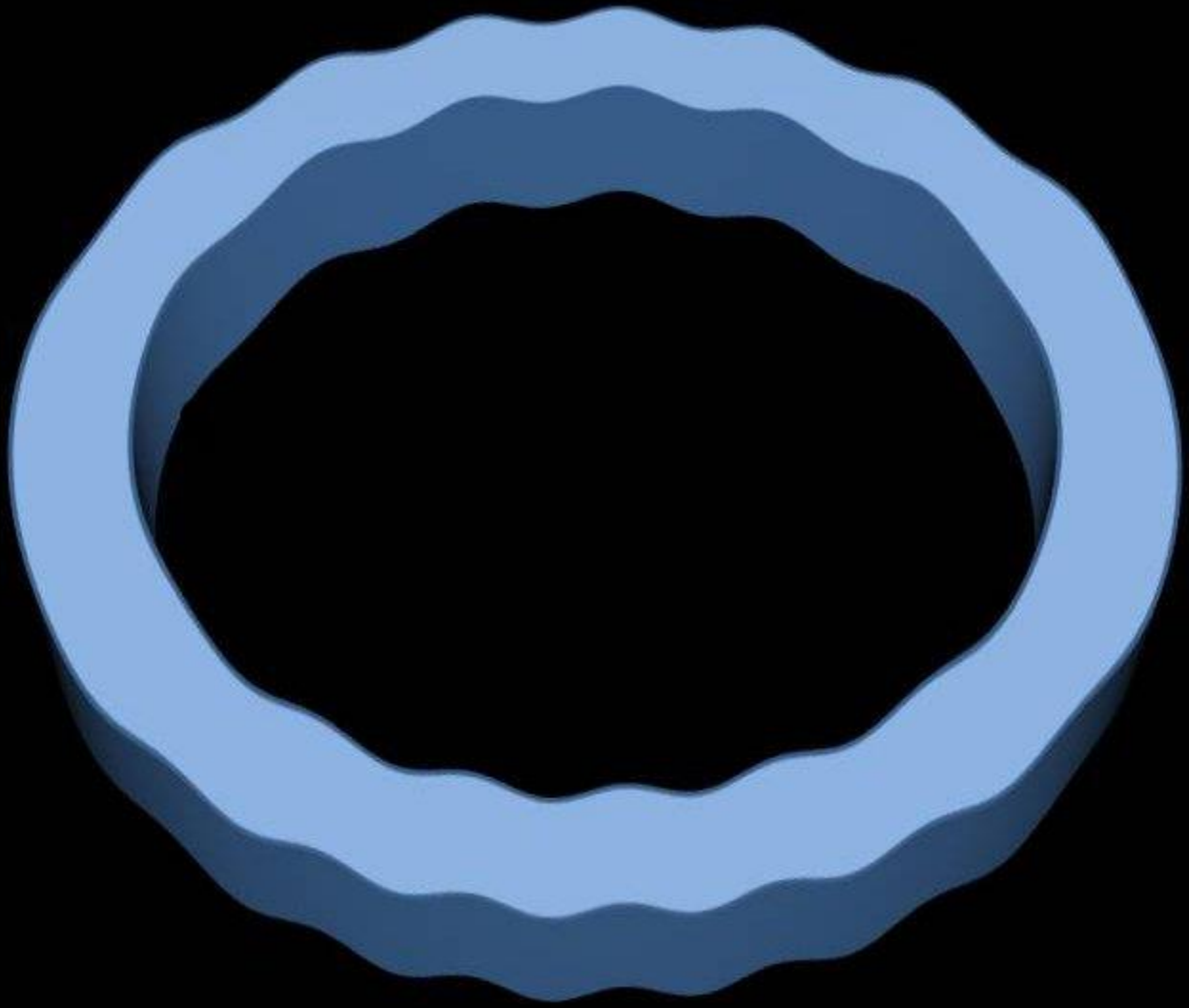


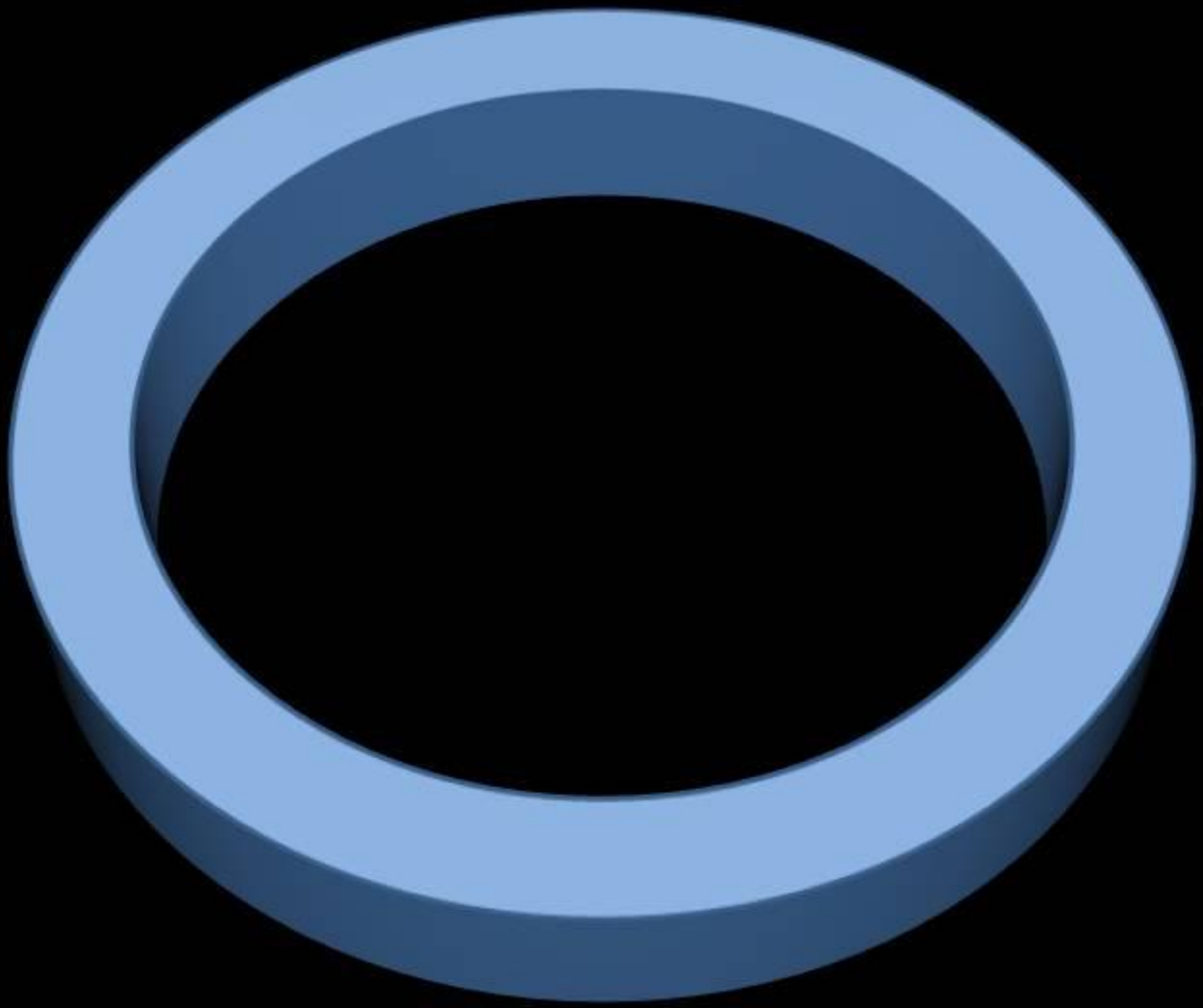




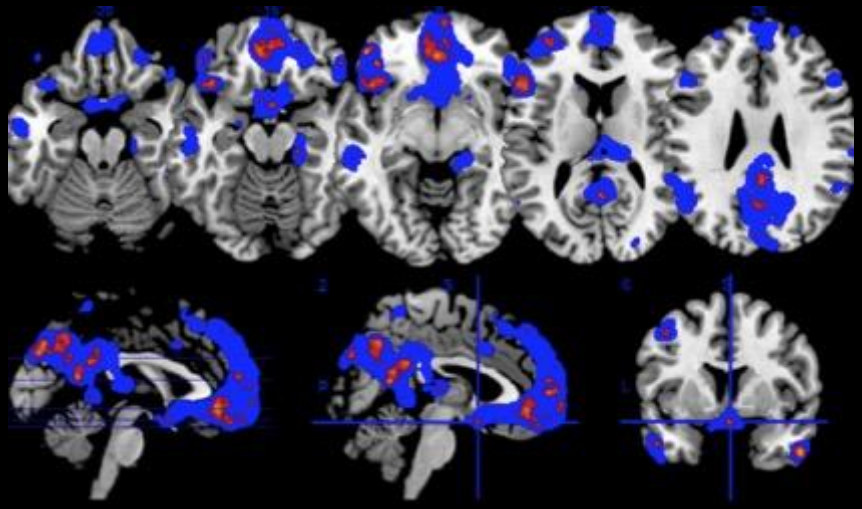




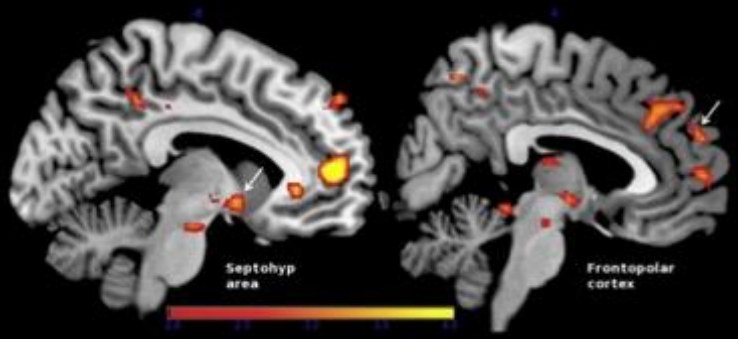




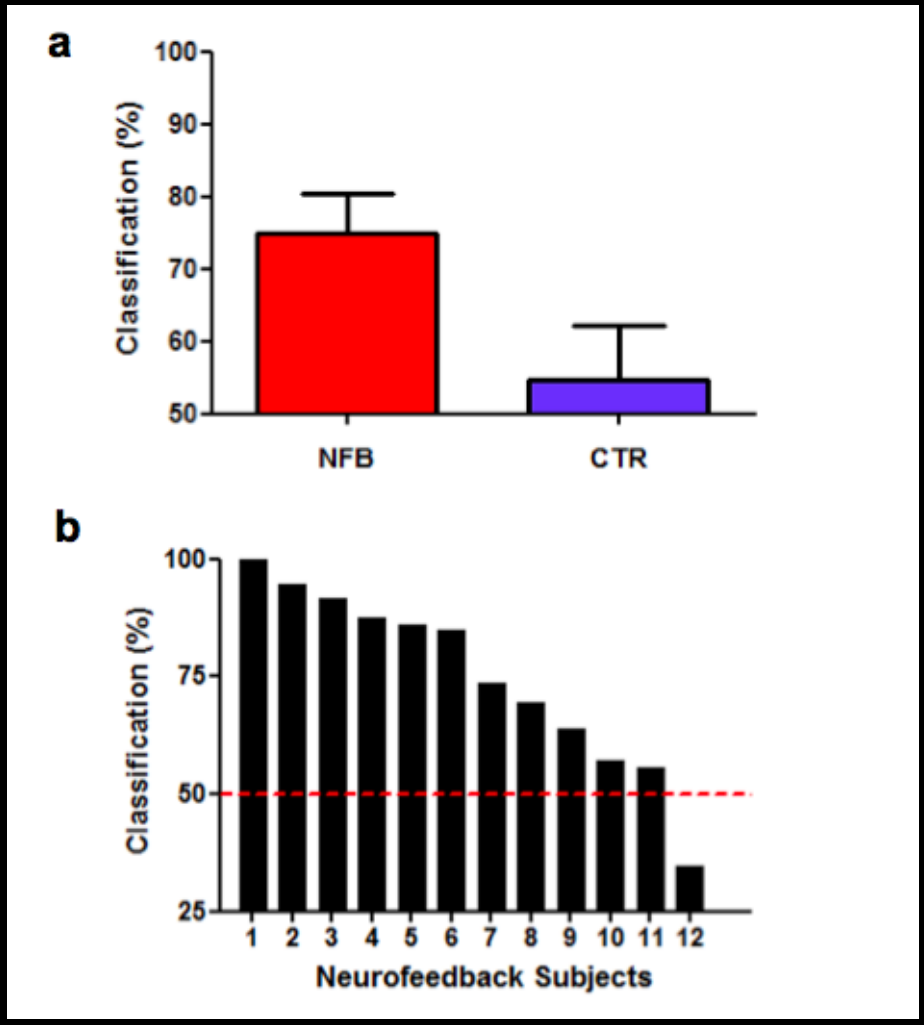
Neurofeedback and control groups: tenderness vs. pride (24ss)



Support Vector Machine (SVM) discriminant maps



BOLD increases associated with increased decoding across NFB sessions



Moll et al., Voluntary enhancement of neural signatures of affiliative emotion using FMRI neurofeedback. Plos One, 2014

ANGUISH / DISTRESS

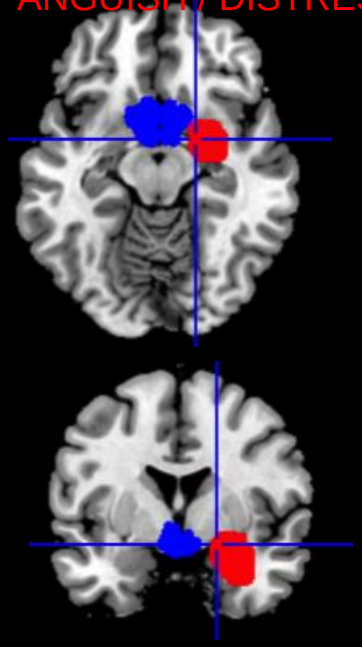
EMOTIONALLY NEUTRAL STATE

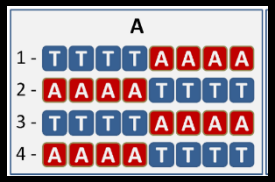
AFFECTION / AFFILIATIVE

Virtual-reality based neurofeedback for emotional regulation

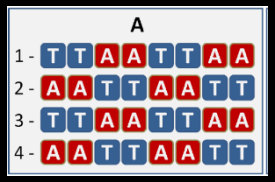
Regions of Interest (ROIs) or SVM for:

AFFECTION / AFFILIATIVE STATES
ANGUISH / DISTRESS STATES





ROI



SVM

Septal / medial preoptic hypothalamic area

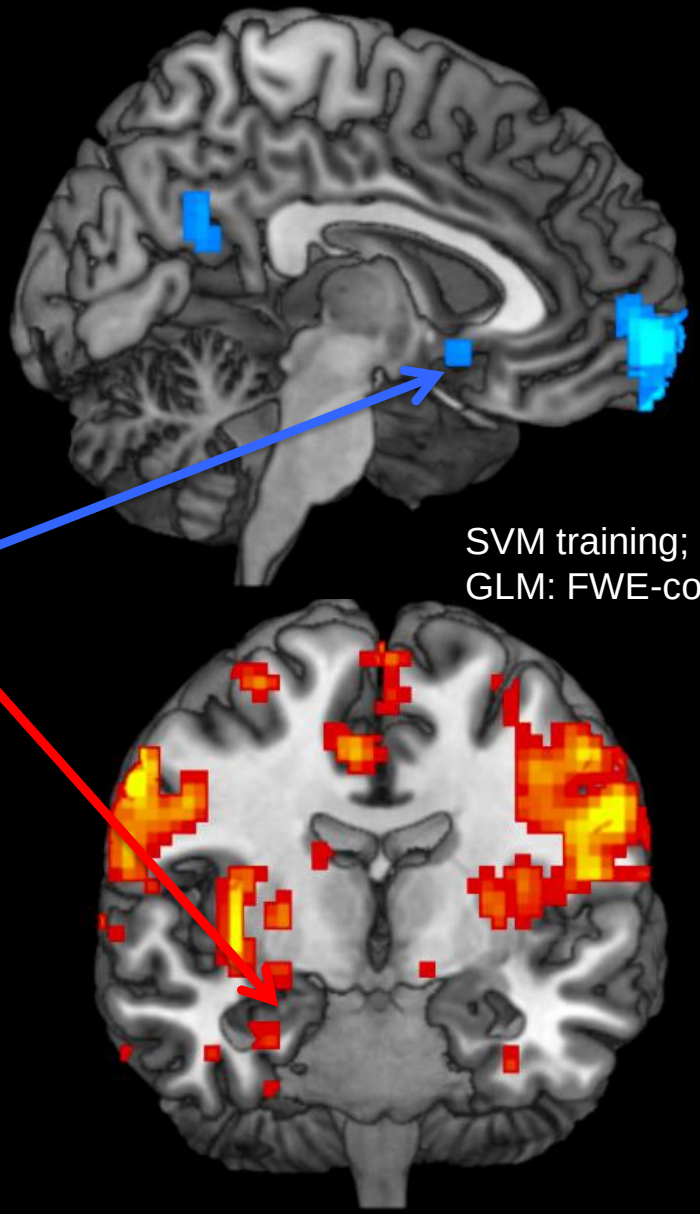
Right amygdala

+

Associated networks comprising the:

mOFC, PCC

Insula, lOFC, DLPFC



SVM training;
GLM: FWE-corr

MONASH University

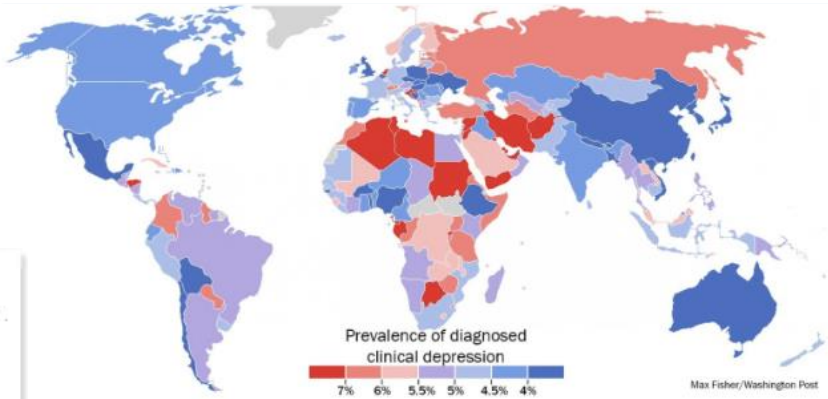
Rio-Melbourne pilot study (with Murat Yucel & Valentina Lorenzetti)

Need for new therapeutic options in psychiatry

WorldViews

A stunning map of depression rates around the world

The Washington Post



edder countries have higher depression rates. Bluer countries have lower depression rates. (Max sher/The Washington Post)

he Middle East and North Africa suffer the world's highest depression rates, cording to a new study by researchers at Australia's University of ueensland -- and it's costing people in the region years off their lives.

he study, published this week in the journal PLOS Medicine, used data on e prevalence, incidence and duration of depression to determine the social and public health burden of the disorder around the world. Globally, they found, depression is the second-leading cause of disability, with slightly more than 4 percent of the world's population diagnosed with it. The map at the top

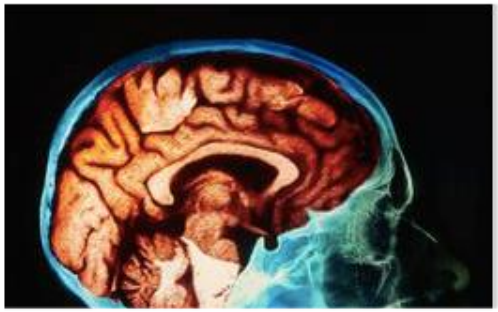
nature

Psychopharmacology in crisis

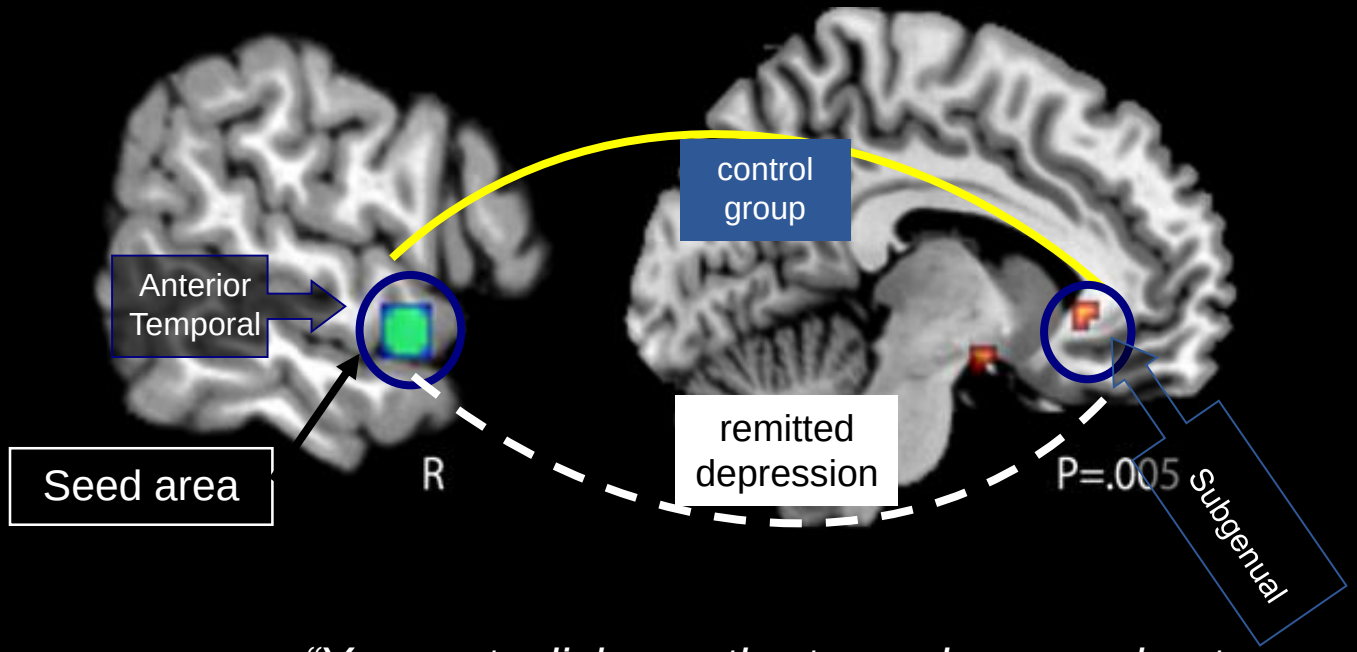
Researchers warn of 'withdrawal of hope' as funding shrivels.

Daniel Cressey

Many people affected by mental illness are facing a bleak future as drug companies abandon research into the area and other funding providers fail to take up the slack, according to a new report.



Searching for an fMRI signature of depression vulnerability: Guilt-selective functional decoupling in remitted major depression



"You act dishonestly towards your best friend"

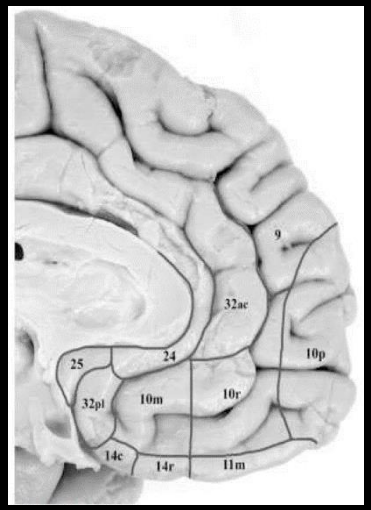
Remitted depression: lower coupling during self-blame (guilt) versus other-blame (indignation)

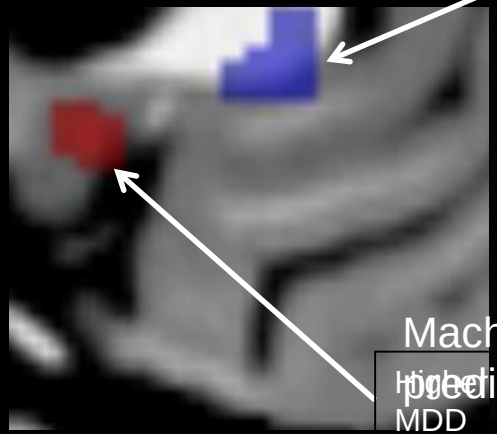
S. Green, M. Lambon Ralph, J. Moll, J.W. Deakin, R. Zahn. *Arch. Gen. Psychiatry, 2012*

Self-blame-selective functional connectivity in remitted MDD

Does subgenual-ATL connectivty predict recurrence?

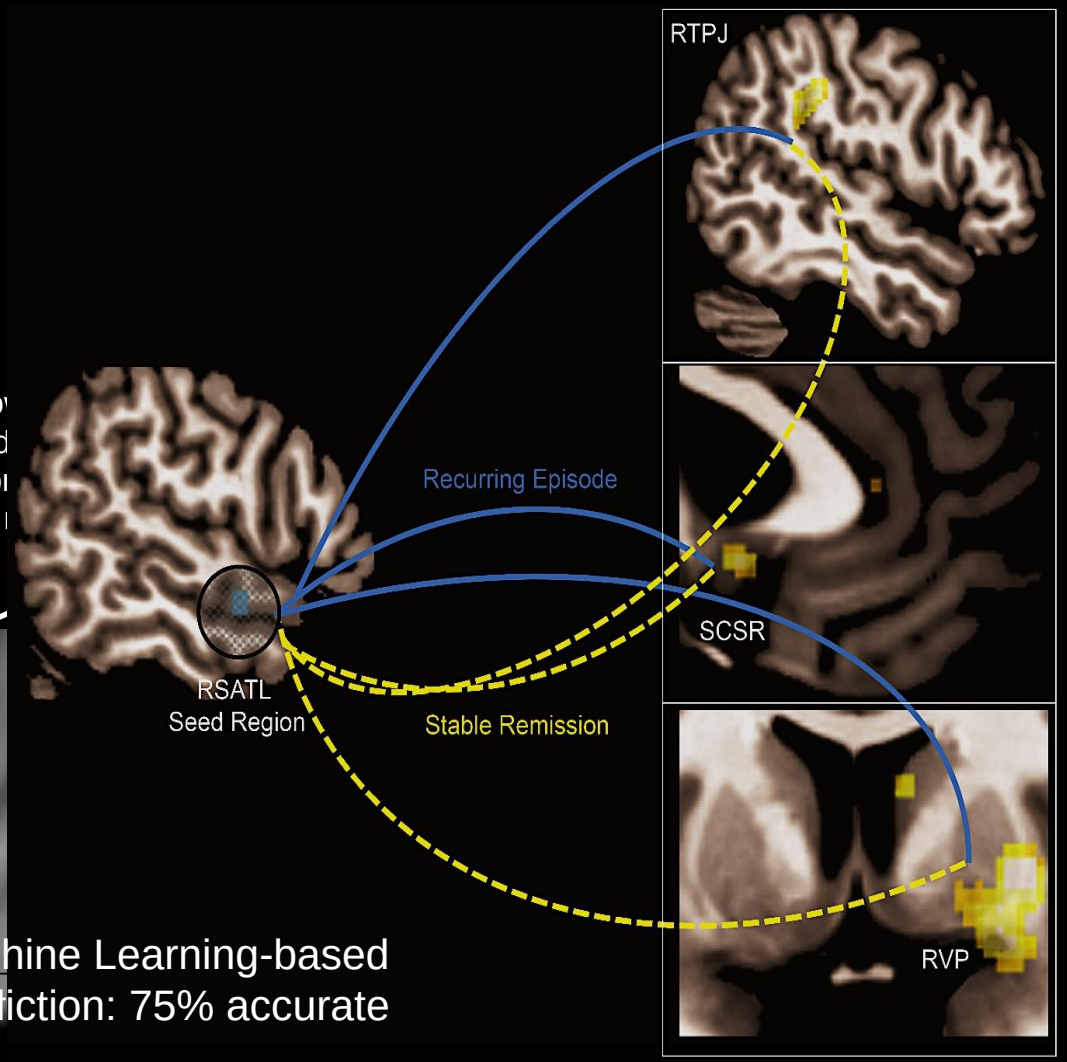
Ongur et al., 2003





Machine Learning-based prediction: 75% accurate

Higher in MDD

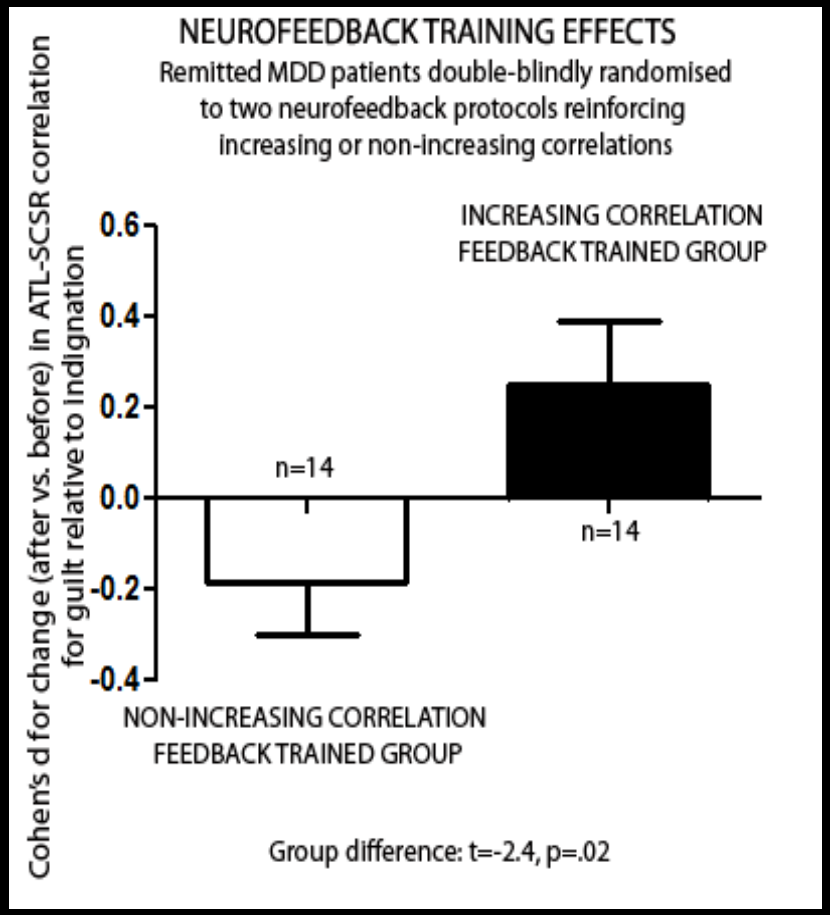


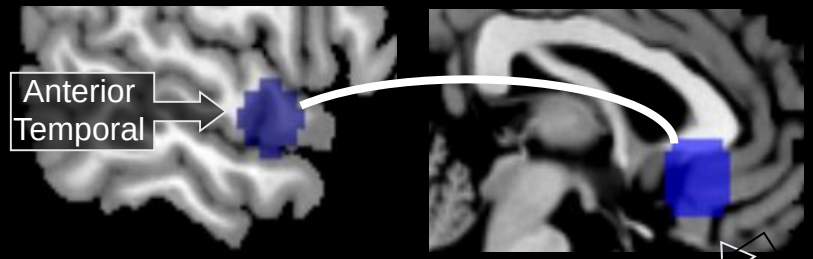
Self-blaming vs. Other-blaming emotions
all patients medication-free (FWE-corr, P<.05, a priori SGC)

Lythe K., Moll J., Gethin J., Workman C., Green S., Lambon Ralph, M., Deakin J., Zahn R. JAMA Psychiatry (2015)

Blame rebalance neurofeedback: proof-of-concept trial

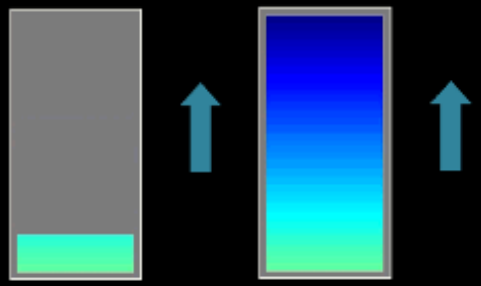
Controlled, double-blind, technical proof-of-concept trial in major depressive disorder





Correlations between 10% most highly activated voxels in each region using sliding time window and controlling for signal drift and motion

Visual thermometer scale feedback



Zahn & Moll: http://clinicaltrials.gov/ct2/show/NCT01920490

Undergoing RCT in remitted MDD patients
(PI: Roland Zahn, PhD project: Tanja Jaeckle)

Institute of Psychiatry at The Maudsley — King's College London

Instituto D'Or Pesquisa e Ensino

Prospects

Combining technologies – digital / mobile, portable EEG and near-infrared spectroscopy – to study social behavior in ecological settings

Use of virtual / augmented reality and games to boost ecological validity of the moral motivation approach in experimental and clinical studies

Refined neural models of human moral emotion, cognition and motivation: trait and state biomarkers / predictive models of behavior, symptoms, disease status and treatment response

Explore the full potential of neurofeedback using more powerful techniques (parallel fMRI acquisition, connectivity, hi-res) + computational models

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