Evidências sobre as bases neurais dos sentimentos morais, comportamento pró-social e anti-social

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INNT – Instituto Nacional de Neurociencia Translacional

OUTLINE

The moral brain: neuroscience of moral behavior
- *Introduction*
- *Evolution and the social brain*
- *Morality from a scientific perspective*
- *Functional architecture of moral judgment and emotion*

Altruism, decision-making and antisocial behavior
- *Moral sentiments and values*
- *Altruistic and economic decision-making*
- *Psychopathy and fronto-temporal dementia*

Brain decoding and the moral brain
- *Classifying psychological states and disorders*
- *Neurofeedback: self-modulation of subjective states*

Final remarks

Emergence of human morality

Cooperation in non-human primates

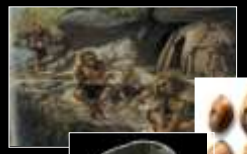
- *Coalition forming*
- *Food sharing*
- *Reciprocity*

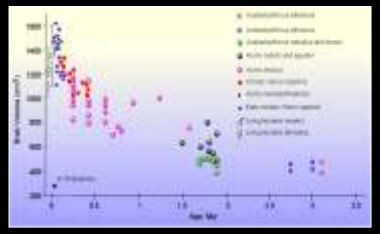
Grooming and coalition-forming in non-human primates

Emergence of human morality

Modern humans: the cultural explosion (Upper Paleolithic period)

- *Symbolic thinking*
- *Division of labor*
- *Economical exchanges*
- *Cultural norms*





Rewards and immediate self-interest

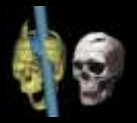
Complex social / moral feelings

Morality from a scientific perspective

- *Sets of customs and values that are embraced by a cultural group to guide social conduct*
- *Philosophy: universal principles that should guide human conduct*
- *Science: documentation of changes in moral behavior in patients with brain dysfunction and from functional imaging studies*
- *Inferences on the major dimensions of moral cognition and behavior*
- *Moral cognitive neuroscience: better understanding and treatment of neuropsychiatric conditions*

Casebeer W. NRN, 2003

Frontal lobe damage *(e.g., Eslinger, 1992; Anderson, 1999)*



- *Poor planning, lack of foresight, impulsivity, loss of flexibility, poor social judgment*

Temporal lobe damage *(e.g., Miller, 1997; Mendez, 2000)*

- *Impaired social perception (STS: face emotion, gaze), severe changes in social conduct, loss of empathy (anterior temporal lobe, mainly right)*

Subcortical-limbic damage *(e.g., Weissenberger, 2001)*

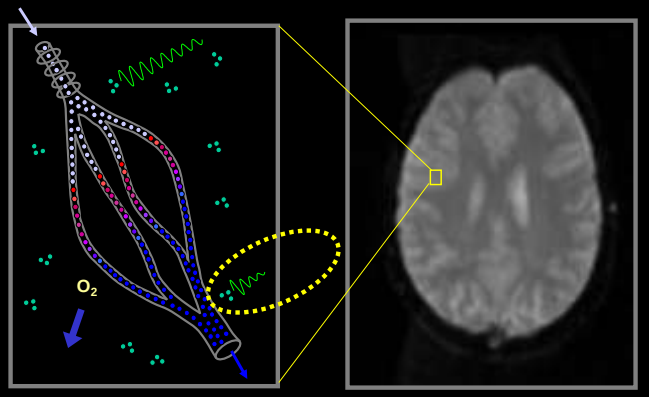
- *Often, death or coma; extreme violence, sexual and eating perversions*

Evidence from functional neuroimaging

A few words on the methods….

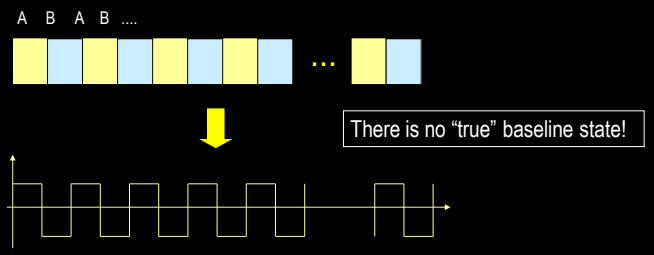
- *Tremendous technical and methodological advance since fMRI (functional magnetic resonance imaging) was introduced (1990's)*
- *Non-invasive studies in vivo*
- *Allows for multiple experimental conditions*
- *Increasingly sophisticated study designs*

Effect of oxy- vs. deoxy-hemoglobin and brain activation

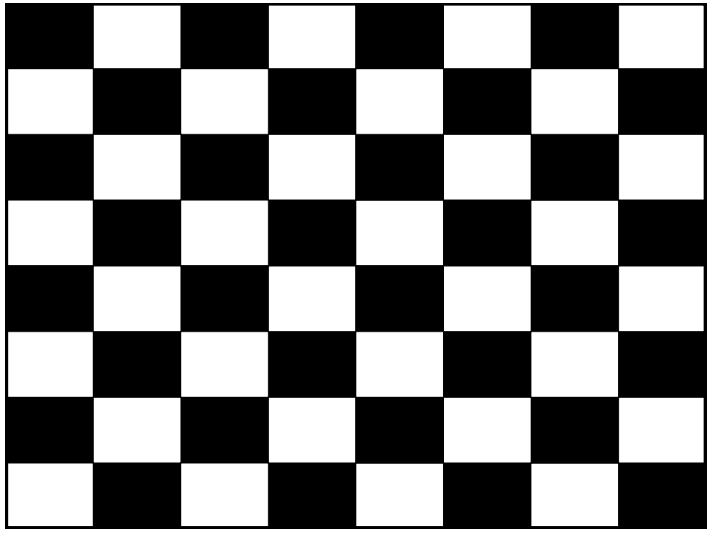


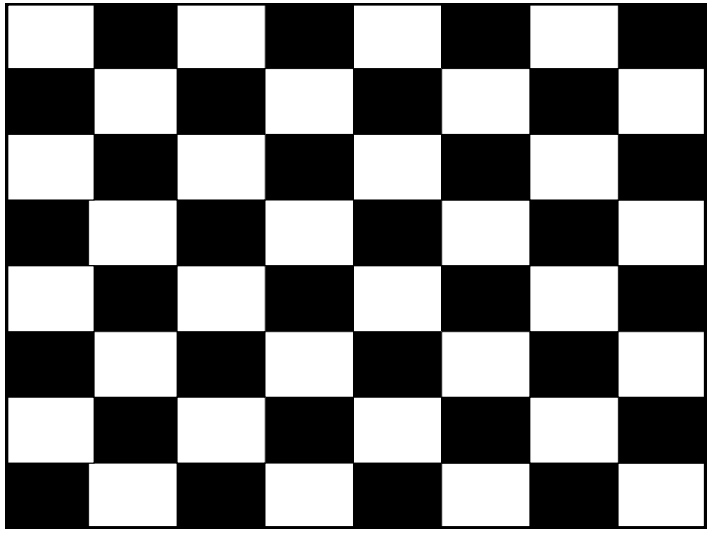
Functional MRI: the basics

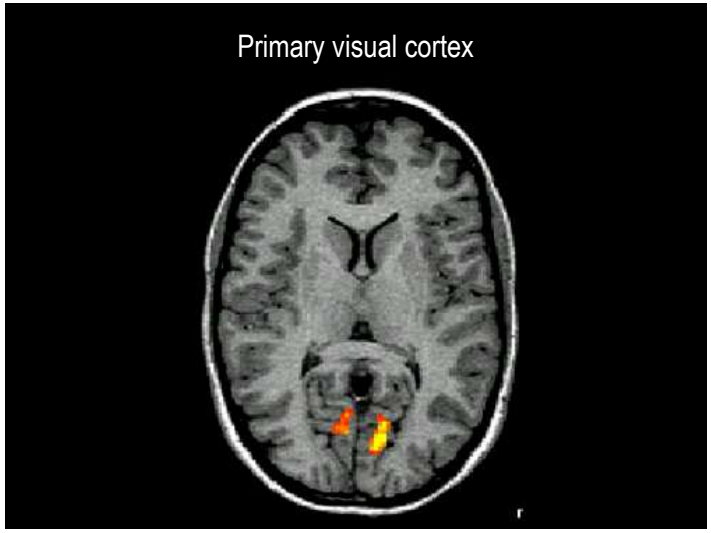
Alternating conditions: baseline vs. condition of interest



E.g. A = resting condition (darkness)
B = visual stimulation







Functional MRI: moral judgment

Hypothesis: moral judgments, will activate regions associated with impaired moral behavior

Moral judgments operationally defined as judgments of values, rights, or responsibilities (Colby et al., 1990)

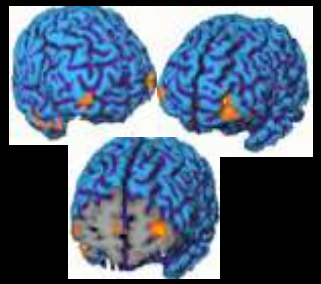
'Right' or 'Wrong'

Factual
Telephones never ring.

Moral
They hung an innocent man.

Functional MRI: moral judgment

Moral *vs.* factual judgments



Frontopolar cortex (BA 10)

Superior Temporal Sulcus (STS)

Temporo-polar cortex

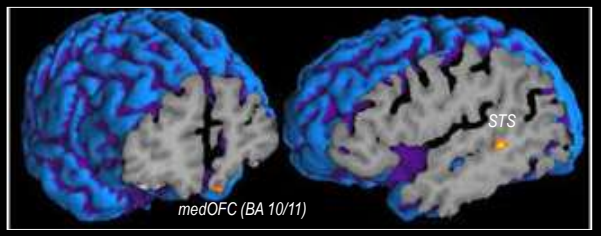
	Moral	Factual
Moral content	⇑	⇓
Emotional valence	⇑	⇓
Difficulty of judgment	≈	≈
Social scenario	yes	no

Oliveira-Souza and Moll, Neurology (Suppl.), 2000

Moll J, Oliveira-Souza R, Eslinger J, Arq Neuropsiq, 2001

Functional MRI: moral judgment

Controlling for emotional valence, social scenario and judgment difficulty



Moll et al., Neuroimage, 2002

Functional MRI: moral sentiments

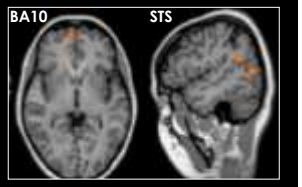
***Hypotheses**: passive* presentation of basic and moral emotion-evocative stimuli will engage the same neural network

"*Just pay attention to the pictures*"

Pictures: neutral, moral-emotional, non-moral-emotional

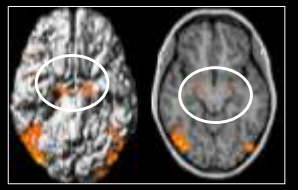
Moral sentiments (compassion, indignation) vs. basic (disgust, fear)

Frontopolar cortex (FPC) and superior temporal sucus (STS) activation



Basic *and* moral sentiments (conjunction) vs. neutral

Subcortical and limbic regions (thalamus, amygdala, midbrain)



Moll, de Oliveira-Souza, Eslinger, Bramati, Mourao-Miranda, Andreiuolo, Pessoa. J Neurosci, 2002

Summary: fMRI in moral cognition

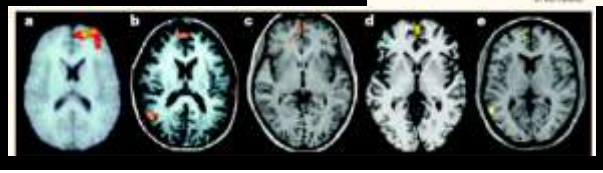
Functional MRI studies of moral judgment and moral sentiments

Medial orbitofrontal and frontopolar cortex (BA 10/11), superior temporal sulcus (STS), anterior temporal (aTC) and subcortical regions

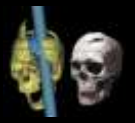
Remarkably stabe despite the use of :
Pictures, simple moral judgments, difficult moral dilemmas, etc.

→ *MORAL SENSITIVITY hypothesis*

Moll et al., 2001, 2002a,b, 2007; Heekeren et al., 2003,2005; Greene et al., 2001, 2004; Takahashi et al., 2004



Frontal lobe damage *(e.g., Eslinger, 1992; Anderson, 1999)*



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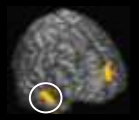


- *Impaired social perception (STS: face emotion, gaze), severe changes in social conduct, loss of empathy (anterior temporal lobe, mainly right)*

Subcortical-limbic damage *(e.g., Weissenberger, 2001)*

- *Often, death or coma; extreme violence, sexual and eating perversions*

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

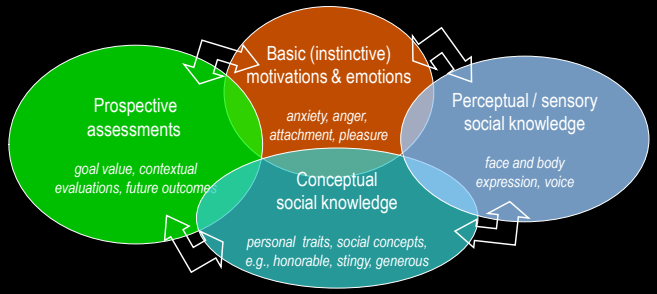
- *Cortical (event and action knowledge, planning, abstract concepts)*

- *Subcortical-limbic (motivational-emotional)*

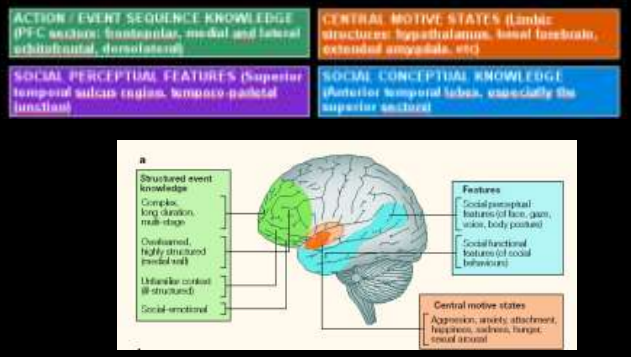
- Frontopolar cortex
- Dorsolateral PFC (*right*)
- Medial OFC
- Lateral OFC
- Anterior temporal cortex
- STS region

Brain regions not constistently involved in moral cognition and impaired moral behavior

Main cognitive-affective domains and emergent moral values and sentiments



The "Event-Feature-Emotion complex (EFEC) model



Moll J, Zahn R, Oliveira-Souza R, Krueger F, Grafman J.
Nature Reviews Neuroscience, 2005

Implications of these lines of evidence to our understanding of human moral cognition

An improvement over hierachical models proposing top-down control of emotion by reason or bottom-up viscero-emotional biases)?

The classical hierarchical view: reason vs. emotion

This hierarchical, top-down archetype has pervaded philosophical and neuroscientific views

The 'layered' brain:

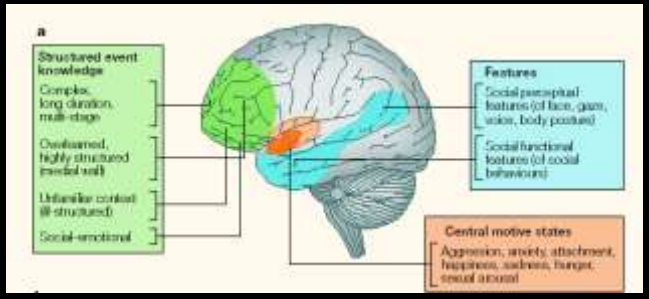
High reason (cortex) controls and suppresses instincts and emotions

→ limbic system, brain stem

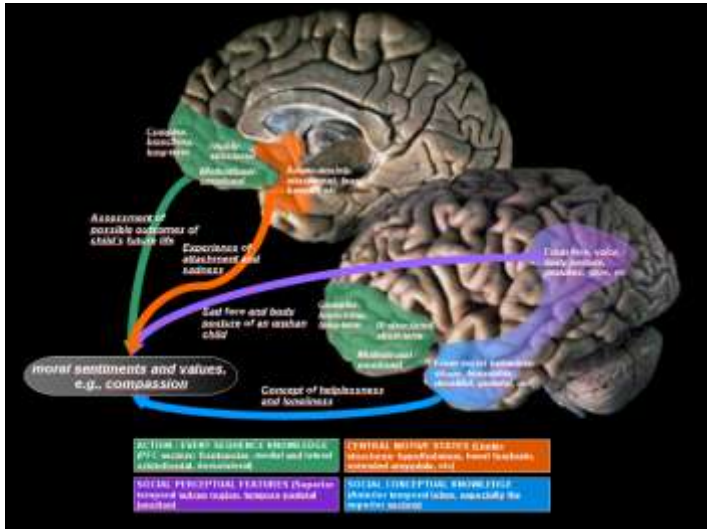
McLean, 1970/1990

Integration of cognitive components and emotion in human moral cognition: *the Event-Feature-Emotion complex (EFEC) model*

Functional integration instead of top-down control (Wolf Singer: temporal binding model of visual perception, shape + motion)



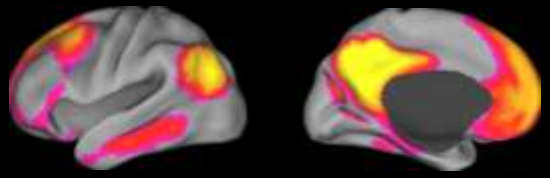
Moll J, Zahn R, Oliveira-Souza R, Krueger F, Grafman J. Nature Rev Neurosci, 2005



The "moral-emotional brain" & the "resting brain"

Regions comprising the "default mode network" *(Raichle et al., PNAS, 2001)*

"The concept of a default mode of brain function arose out of a focused need to explain the appearance of activity decreases in functional neuroimaging data when the control state was passive visual fixation or eyes closed resting (…) activity decreases were remarkably consistent across a wide variety of task conditions." *(Raichle & Snyder, Neuroimage 2007)*



For a moment, think of:

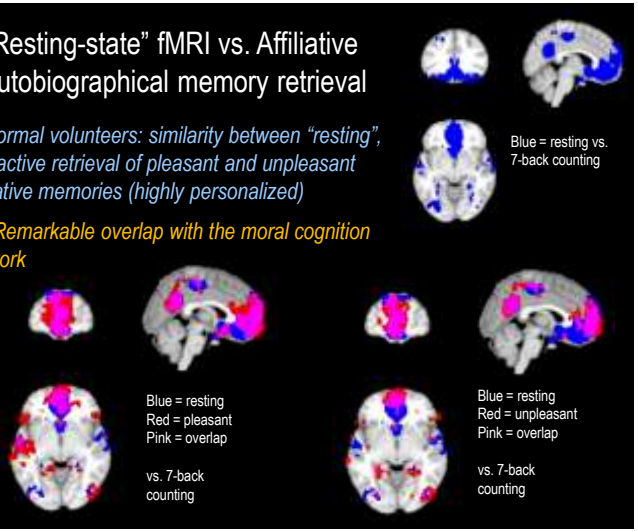
One of the best, happiest moments in your life

One of the worst, most sad episodes in your life

"Resting-state" fMRI vs. Affiliative autobiographical memory retrieval

15 normal volunteers: similarity between "resting", and active retrieval of pleasant and unpleasant affiliative memories (highly personalized)

→ *Remarkable overlap with the moral cognition network*



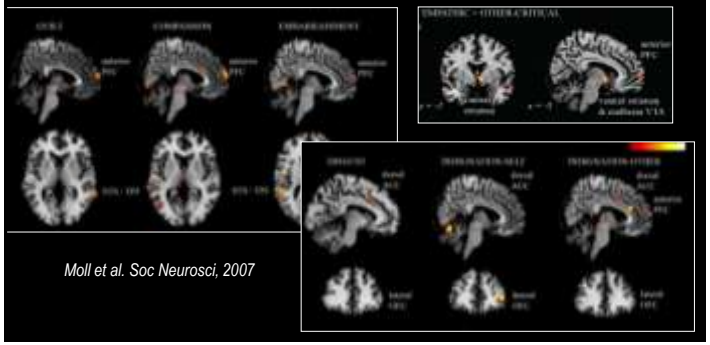
Neural bases of altruistic decisions, moral sentiments and their impairments

- *Fractionating moral sentiments and evidence for moral sentiment impairments in FTD*
- *From social concepts to social values*
- *Altruistic and trusting decisions*
- *Structural brain changes in psychopathy*

Neural bases of distinct moral sentiments

"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)



Moll et al. Soc Neurosci, 2007

Social conceptual knowledge: ant. sup. temporal cortex

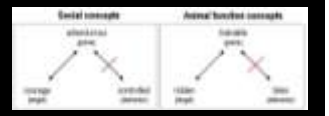
Social functional concepts (semantic)

Stingy, Generous, Coward, Brave

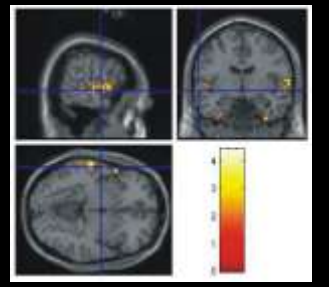
Non-social (animal) functional concepts (semantic)

Useful, Nutritious, Dangerous, Poisonous

Zahn R, Moll J, Krueger F, Huey E, Grafman J. PNAS, 2007



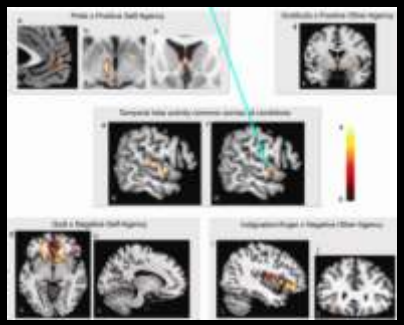
Social vs. non-social concepts



The neural bases of human social values

Contextualized social concepts (values) elicit moral sentiments

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



Anterior sup. temporal cortex

→*across all condition*

Distinct fronto-subcortical areas

→ *different moral sentiments*

Zahn R, Moll J, Paiva M, Garrido G, Krueger F, Huey E, Grafman J. Cerebral Cortex, 2008

The charitable donation study

Self monetary reward vs. altruistic charitable donations

X

or

∩

monetary gain

altruistic helping

The charitable donation study

Monetary reinforcement vs. prosocial feelings

→ *Decisions: monetary gains, donating or opposing to causes (NGOs)*

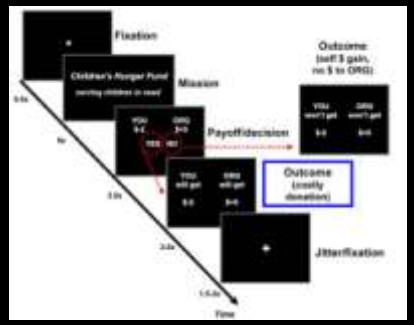
→ *Abortion, euthanasia, gender equality, civil rights, war, nuclear energy, biotech, animal rights, etc*

Maximum endowment = $128 (if purely self-interested)

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

The charitable donation study

Anonymous decisions to donate or oppose to non-profit ORGs (19ss)



Main decision outcomes

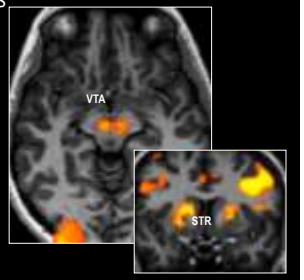
- Costly oppose
- Non-costly oppose
- Costly donate
- Non-costly donate
- Pure $ reward

fMRI results: charitable donations

Pure $ reward and donation (conjunction) vs baseline

Midbrain ventral tegmental area (VTA) and striatum: brain's "reward / pleasure centers"

Mesolimbic reward system: experience and anticipation of reward



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

fMRI results: charitable donations

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

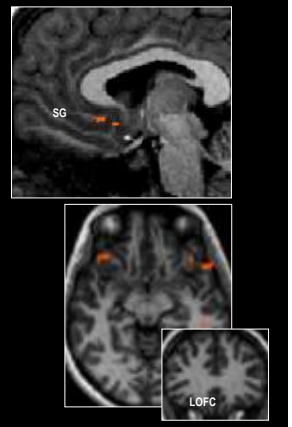
Subgenual cortex (SG; BA25) and septal region: social attachment (and depression)

Attachment to (or self-identification with) societal causes and principles

Costly and non-costly opposition

Lateral OFC / anterior insula: aversion

Culturally-mediated social aversion



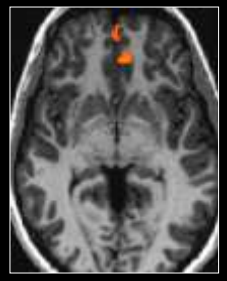
fMRI results: charitable donations

Costly (altruistic) decisions to donate to or oppose ORGs

Anterior PFC (frontopolar cortex) and anterior OFC (FPC; BA10/11/32)

Integrating costs and benefits of decisions

Guilt avoidance (protecting self-identity, e.g., being a generous and not stingy person)?

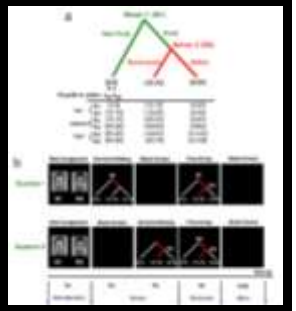


Moll et al., PNAS, 2006

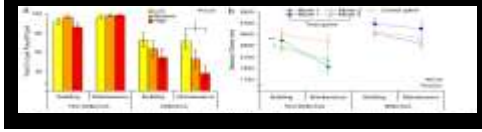
fMRI and economic cooperation: trust game

Pairs adopt strategies during simultaneous fMRI scanning

Conditional cooperation
vs.
Unconditional cooperation (trust)

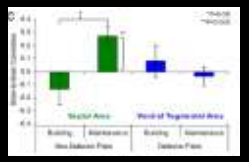


Krueger, McCabe, Moll, et al. PNAS, 2007



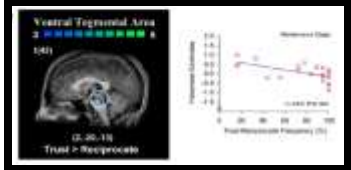
fMRI results: trust game

Conditional cooperation (strategic, mutual benefits) vs. *unconditional cooperation (trust)*

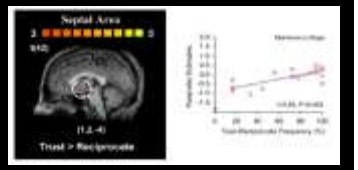


Brain-to-brain functional correlation among participant dyads:

VTA: strategic cooperation



Septal region: trust



Evidence for impaired moral sentiments in FTD

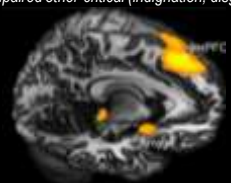
21 patients *(CNS, NINDS)* with behavioral variant Fronto-Temporal Dementia

FTD vs. NC: FDG-PET

Moral Sentiment Task impairment and reduced of FDG metabolism

Impaired prosocial (guilt, embarrassment, pity)

Impaired other-critical (indignation, disgust)



Specific impairments of prosocial sentiments in patients with Fronto-Temporal Dementia
Moll J, Zahn R, de Oliveira-Souza R, et al. NeuroImage, 2011

Psychopathy

Severe and persistent anti-social behavior
(Cleckley, 1941; Hare, 1980; Blair, 2004)

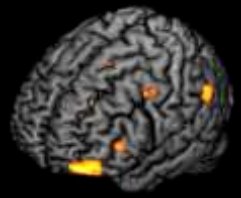
Lack of empathy and remorse, manipulativeness, instrumental aggression: *difficult to explain solely on the basis of PFC dysfunction*

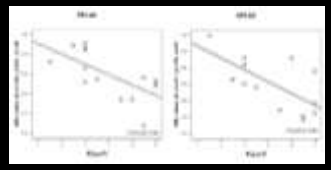
Several MRI volumetric studies have implicated the frontal cortex; less consistently, other regions (hipoccampus; amygdala)

Structural cortical changes in Psychopathy

15 individuals with psychopathy vs. 15 normal controls

Distributed grey matter reductions in regions implicated in moral cognition and behavior; correlations with Factor 1 (callousness)



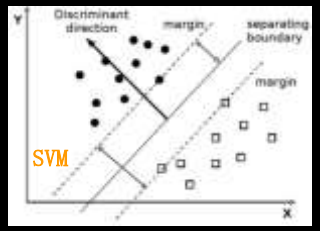


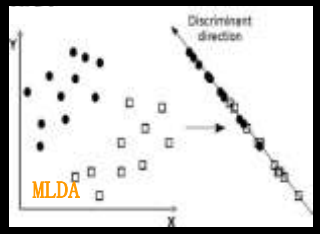
Psychopathy as a disorder of the moral brain: fronto-temporo-limbic grey matter reductions demonstrated by voxel-based morphometry.
de Oliveira-Souza, Hare, Bramati, Garrido, Ignacio, Tovar-Moll & Moll. NeuroImage, 2008

Neuroinformatics: brain decoding

- *Pattern recognition methods in functional and structural neuroimaging studies*
- *Classify patients with brain disorders*
- *Infer cognitive / psychological states*
- *Neurofeedback applications*

- *Spatial distribution of voxels containing discriminative information*
- *Support Vector Machine (SVM) and Maximum uncertainty Linear Discrimination Analysis (MLDA)*





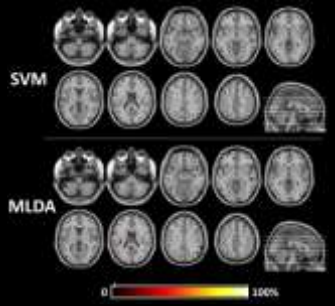
- Discriminative information, providing a multivariate tool for brain mapping *(groundbreaking work of Just & Mitchell, Sitaram, Weiskopf and Birbaumer, Brammer, deCharms, Laconte, Posse, Haynes & Rees)*

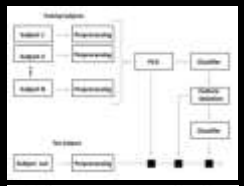
- Machine learning and pattern recognition: powerful tools mainly for classification and prediction of mental states and brain decoding (Mitchell et al., 2004; Haynes and Rees, 2006; Sato et al., 2009)

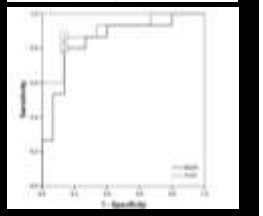
Sato JR et al., NeuroImage, 2009

Multivariate pattern classification of VBM data (15 psychopaths, 15 controls)

Sensitivity and specificity = 86.7% for SVM



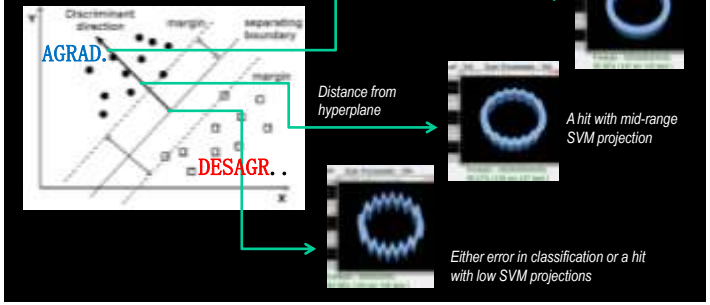




Identification of psychopathic individuals using pattern classification of MRI images.
João R. Sato, Ricardo de Oliveira-Souza, Carlos E. Thomaz, Rodrigo Basílio, Ivanei E. Bramati, Edson Amaro Jr, Fernanda Tovar Moll, Robert D. Hare, Jorge Moll, Soc Neurosc 2011

Implementation of a real-time functional MRI and neurofeedback system: imagery task

Discrimination between pleasant ("AGRADÁVEL") vs. unpleasant ("DESAGRADÁVEL") autobiographical affiliative memories (baseline = emotionally "NEUTRAL")



Conclusions (I)

Human moral cognition & the brain

Stable network of neural components engaged in moral sentiments, concepts and decisions despite wide variations of task and stimuli

Integration of cortico-subcortical networks
- *beyond cognition-emotion dualism, towards better understanding of human motivations and emotions*

Overlapping networks representing distinct moral sentiments, values and altruistic decisions, and their impairments
- *septal region, frontopolar cortex and subgenual cortex*

Conclusions (II)

Pattern recognition methods and neurofeedback

- *Predicting patient category (psychopathy vs. controls)*
- *A window into subjective emotion states (now in "real-time")*
- *Neurofeedback: Endogenously boost adaptive motivational states (e.g., gratitude, determination, tolerance) and tune down maladaptive ones (e.g., hatred, abnormal guilt and anxiety)?*

Conclusions (III)

Growing ability to predict behavior: implications for diagnosis, treatment neuropsychiatric disorders and for criminal justice

→ deep ethical implications

Tailoring better behavioral, pharmachological and surgical interventions based on improved neurocognitive frameworks

Applications to cognitive enhancement and well-being (e.g., aiding training programs for organizations, teams, couples, …. politicians ?!?) based on objective markers of subjective motivational-emotional states

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Thank You !