# Come presentare una proposta di successo in ambito ERC: Panel LS - Life Sciences


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# ERC 2014: HUMO Project

**What is everybody doing? Prediction, categorization, and monitoring in the prefrontal cortex.**

Aldo Genovesio

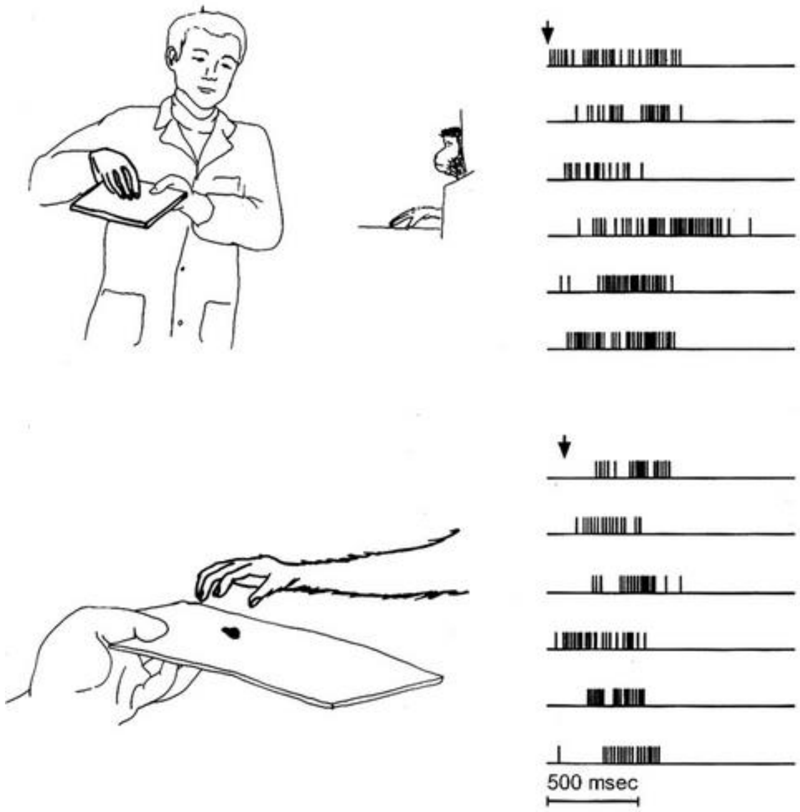
# Machiavelli intelligent hypothesis

Nicholas Humphrey's "The Social Function of Intellect" (1976)

*Machiavellian Intelligence* (Byrne and Whiten 1988)

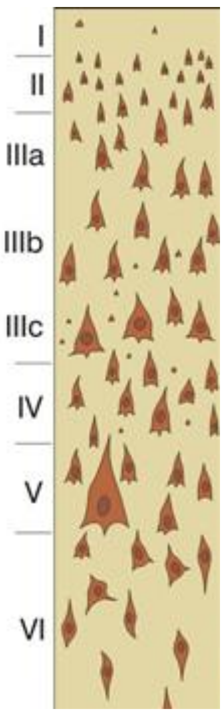
# Mirror neurons

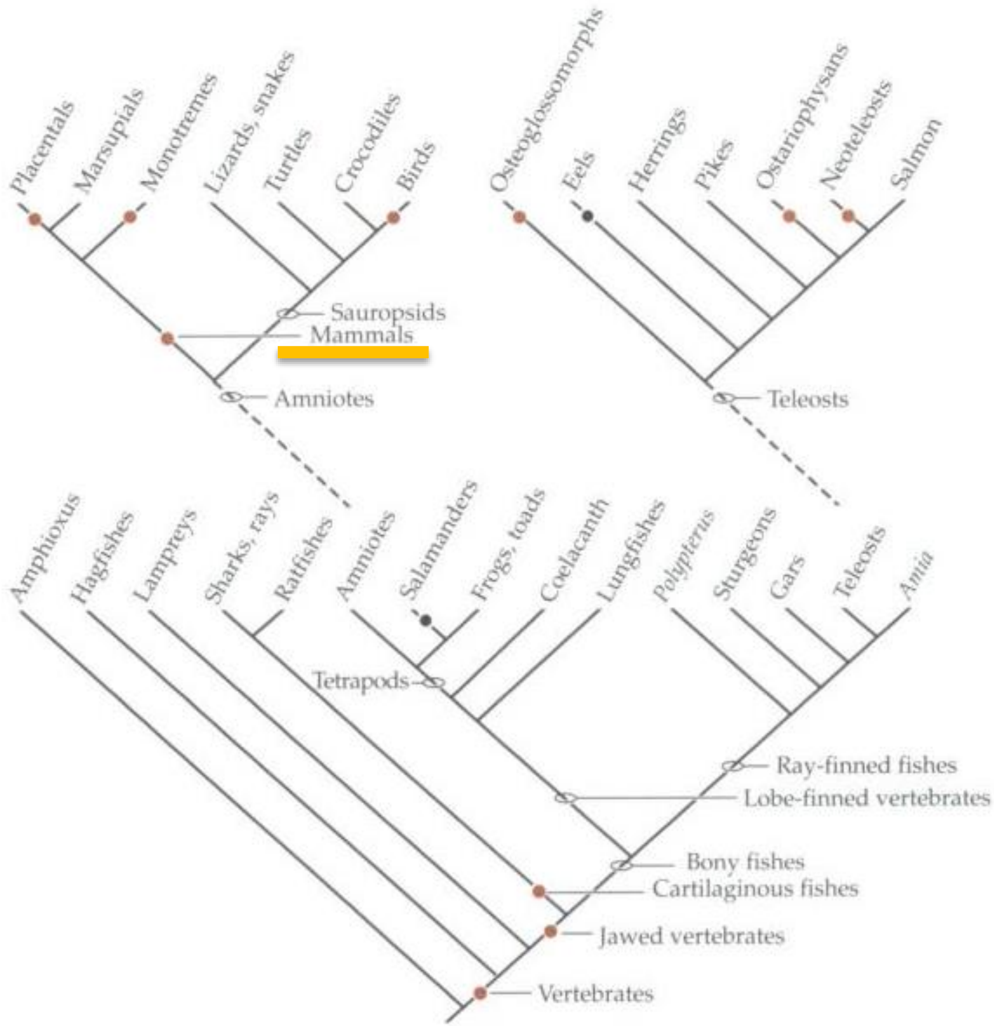
Sharing the representation of action



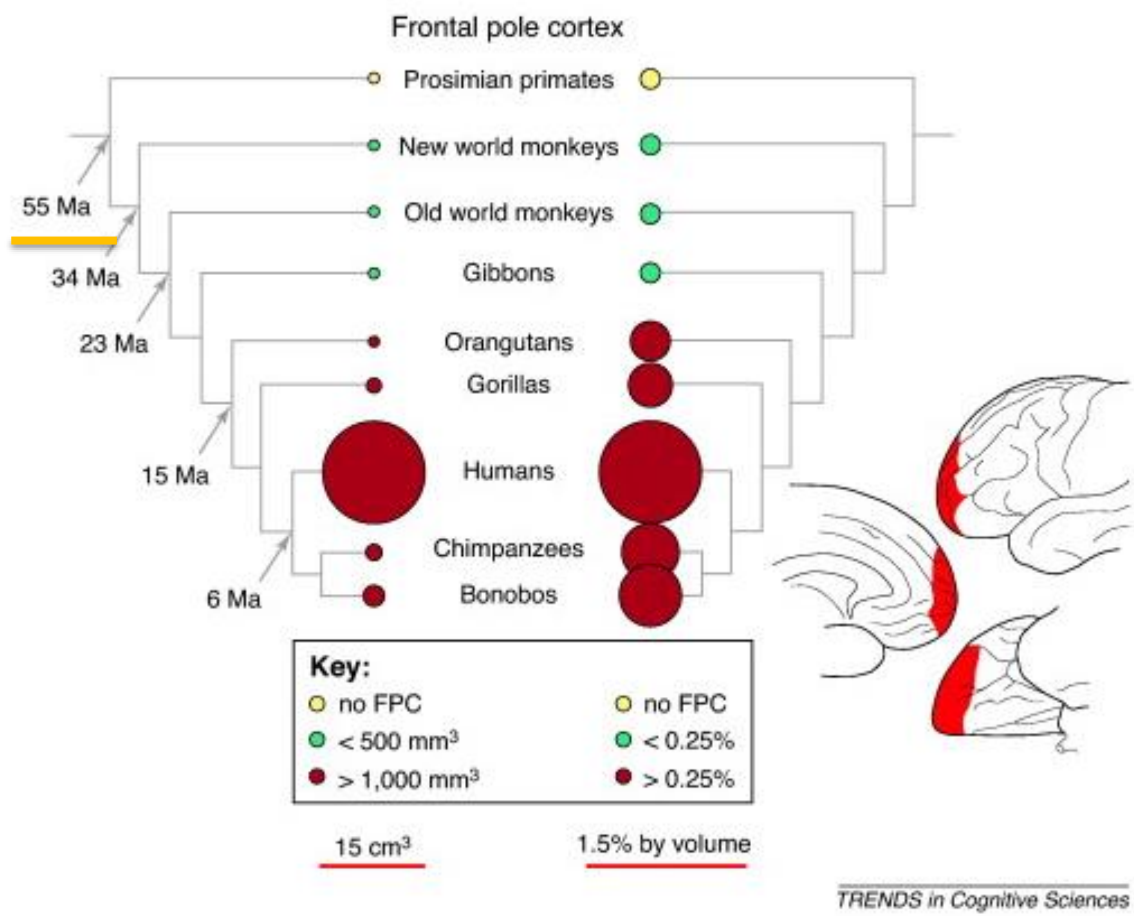
# Mammals Innovation

**165 million of  years ago**
**Neocortex**



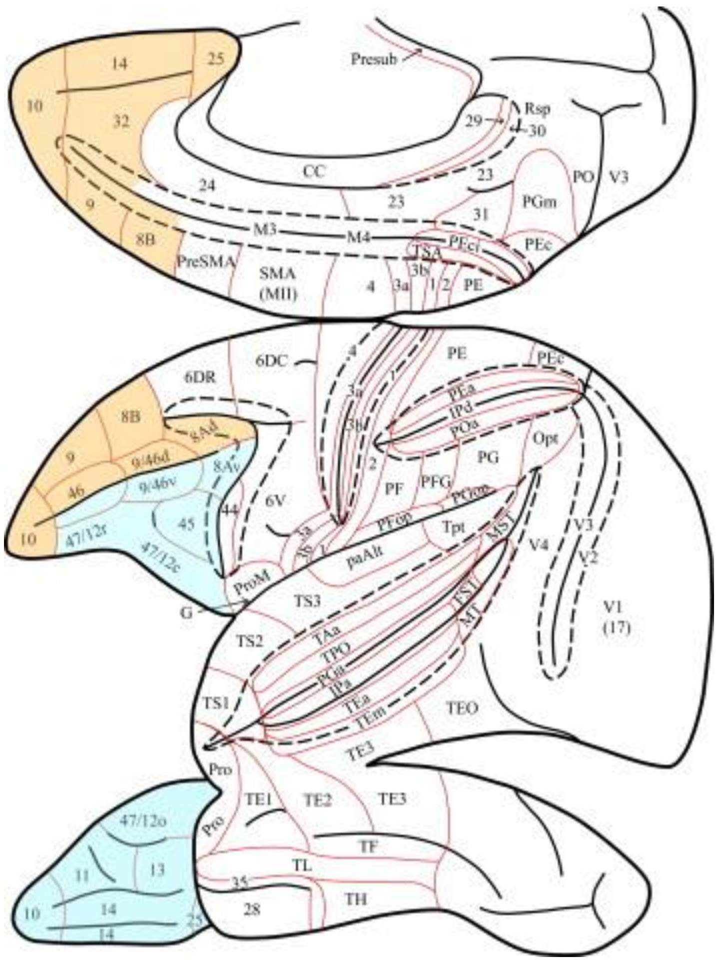



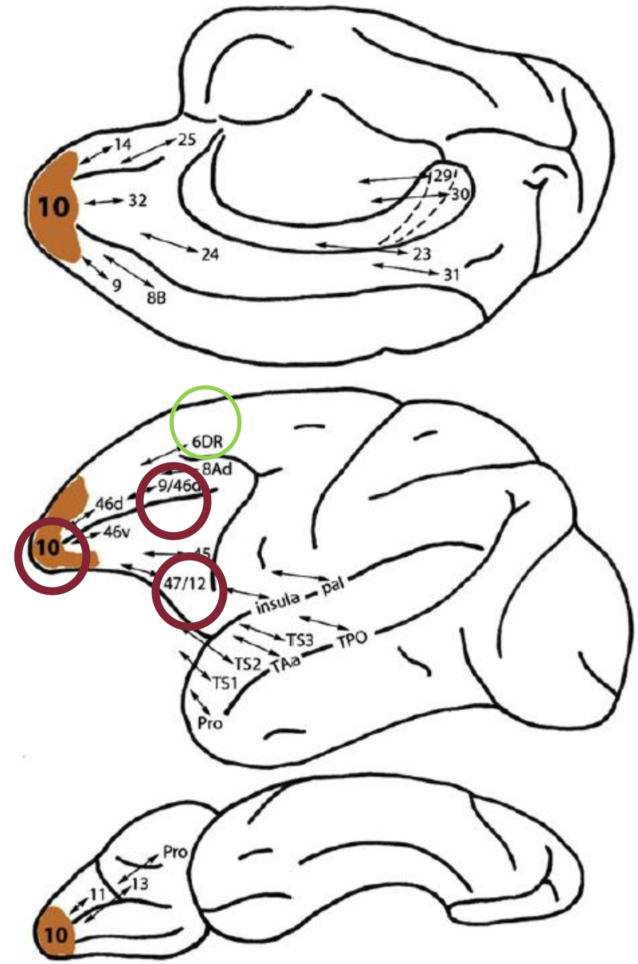
# Primates Innovation




**55 million of years ago Frontal Pole**

# Frontal Pole Connectivity




Special issue: Review

CORTEX 48 (2012) 58–81

**The cortical connectivity of the prefrontal cortex in the monkey brain**

*Edward H. Yeterian [a,b,c,*], Deepak N. Pandya [b,c,d], Francesco Tomaiuolo [e] and Michael Petrides [f]*

# Monitoring of goal achievement in the Frontal Pole cortex



Jonathan D Wallis

**The frontal pole cortex is thought to be the most complex of all frontal cortex areas. Overcoming technical obstacles to direct recordings, a study in this issue finds that neurons in this area have unexpectedly simple response properties.**

The polar explorer Ernest Shackleton said "Difficulties are just things to overcome, after all." The last decade has seen rapid progress in our understanding of the functional organization of the frontal lobe. Much of our knowledge of this organization has come from studies recording the electrical activity of single neurons in awake, behaving monkeys. One area, however, has resisted exploration. The frontal pole (Brodmann area 10) is the most anterior region of the frontal cortex (Fig. 1). Until now, no one has been able to record neuronal activity from this area because it lies underneath a bony air sinus. In this issue, Tsujimoto *et al.*[1] treated this difficulty as just an obstacle to overcome and their intrepid exploring has produced some surprising results.


ARTICLES

nature neuroscience

## Evaluating self-generated decisions in frontal pole cortex of monkeys

Satoshi Tsujimoto[1,2], Aldo Genovesio[1,3] & Steven P Wise[1]

# H-M paradigm

OPEN ACCESS Freely available online

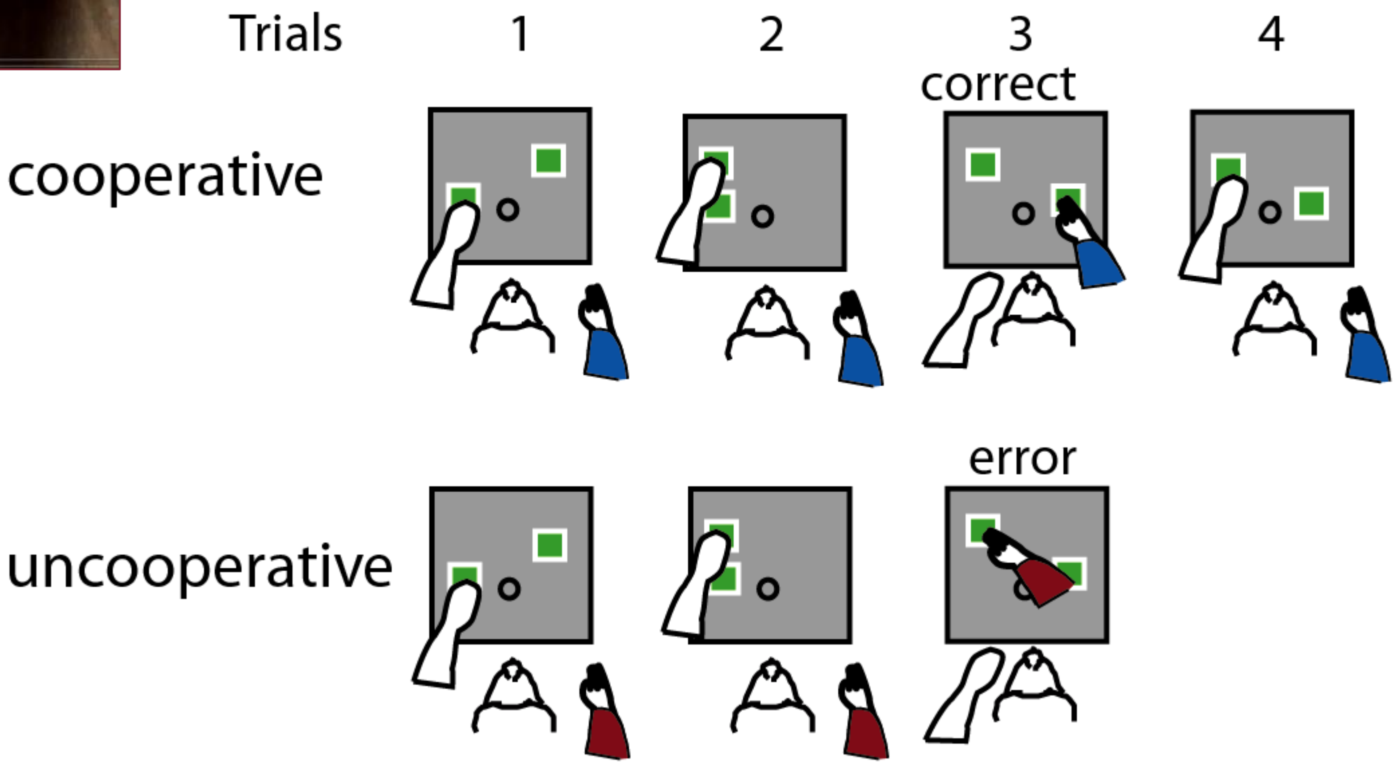
PLoS one

## Monkeys Monitor Human Goals in a Nonmatch-to-Goal Interactive Task

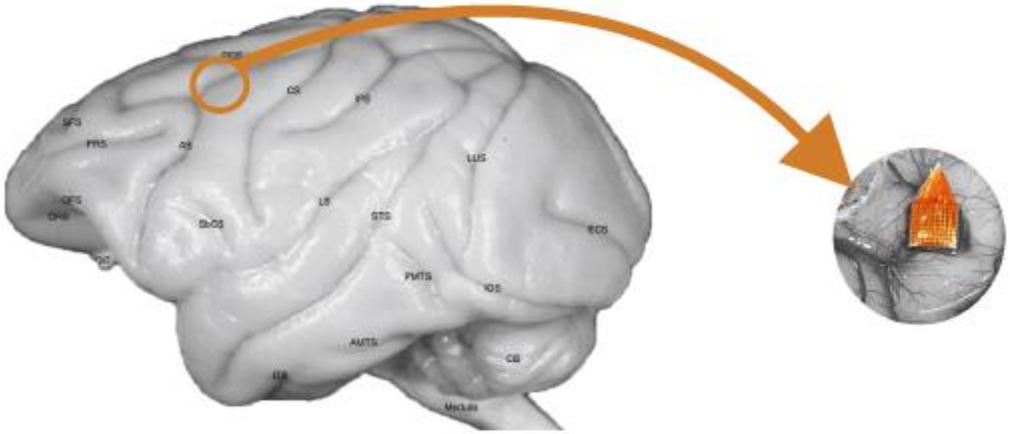
**Rossella Falcone, Emiliano Brunamonti, Stefano Ferraina, Aldo Genovesio***

Department of Physiology and Pharmacology, Sapienza University of Rome, Rome, Italy

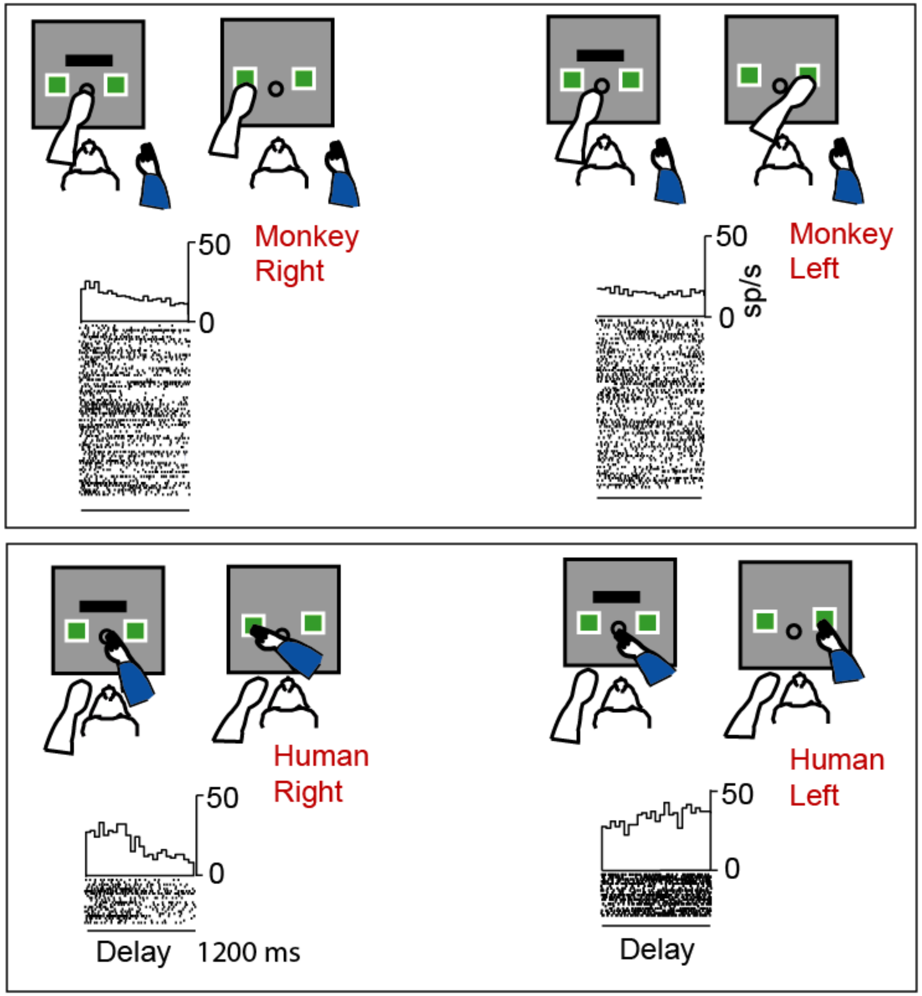
# H-M paradigm

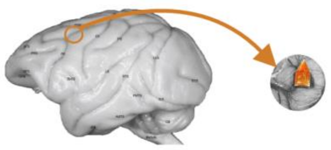


# Multi-array recordings, array in premotor cortex

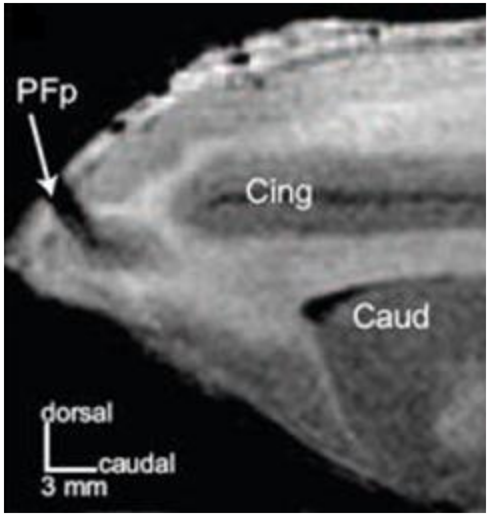


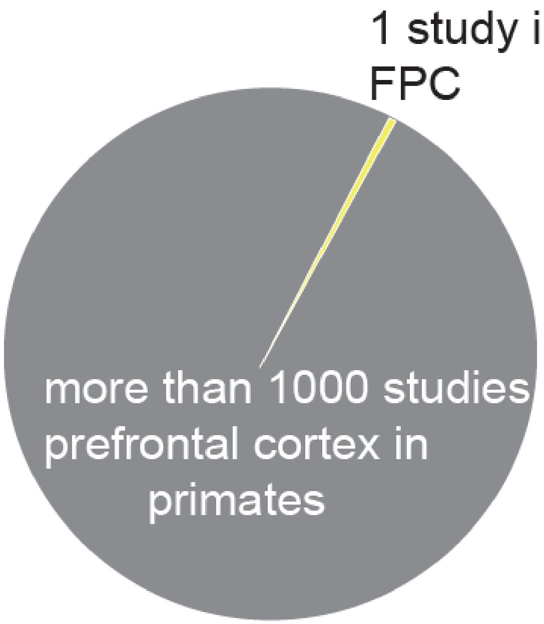

# Preliminary data with H-M paradigm in Premotor cortex



# Only one study




Evaluating self-generated decisions in frontal pole cortex of monkeys.

Why do we study the frontal pole cortex in Monkeys?

Why do we study social behavior in Monkeys?

Why should be my lab to address this question?

# Several years to answer many questions

**Frontal Pole**

- Does it monitor the choices of other agents?
- Does it represent the confidence with which a goal is accomplished?
- Is it involved in learning from single events (object-in-scene learning task)?
- Does it have a function in observation learning?

**Dorsolateral Prefrontal cortex**

- Does it predict what the others will do next?
- Does it predict the behaviour of others based on their category (cooperative and
- uncoperative agents)
- Does it mantein in memory the previous choices of others?
- Does it distinguish self from others?
- Does it track the history of who acted before?
- Does it show a neural bias in the condition of free choice?

**Orbitofrontal**

- Does it monitor the past action of other agents and the outcome?

# People in the Department of Physiology

## Faculty

Stefano Ferraina

Alexandra
Battaglia-Mayer

Roberto Caminiti

## The Lab

## Collaborators

Paul Verschure
Robotic

Paolo Mazzone
Neurosurgery

Giovanni Pezzullo
Modelling

# Additional Slides

Social group size and Frontal Pole

Frontal Pole and Theory of Mind

Frontal Pole and Autism

Oxytocin

Object-in-place task

Insula, TPO, orbitofrontal

Observation learning

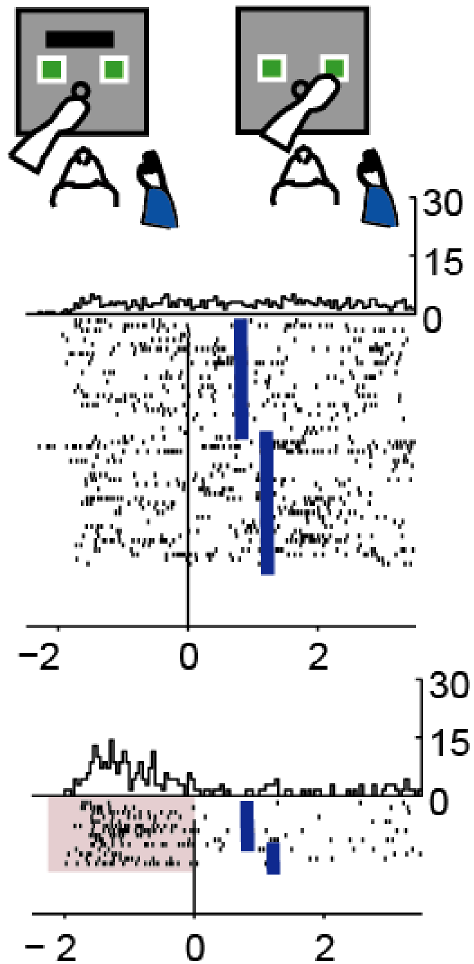
Spatial and Object tasks

# Time table

A  Monkeys 1,2,3); NMTG task
B (Monkeys 3, 4):  Object-in-place scene learning task

| Months | Month 1-18 | Month 19-36 | Month 37-54 | Month 55-60 | Total (M1-60) |
|---|---|---|---|---|---|
| TRAINING | A-B | | | | |
| RECORDING | A-B | A | | | |
| DATA ANALIYSIS | A | A1-B | A-B | A | A |
| PUBLICATION | | | A | A-B | A-B |

# Preliminary data on H-M paradigm in premotor cortex



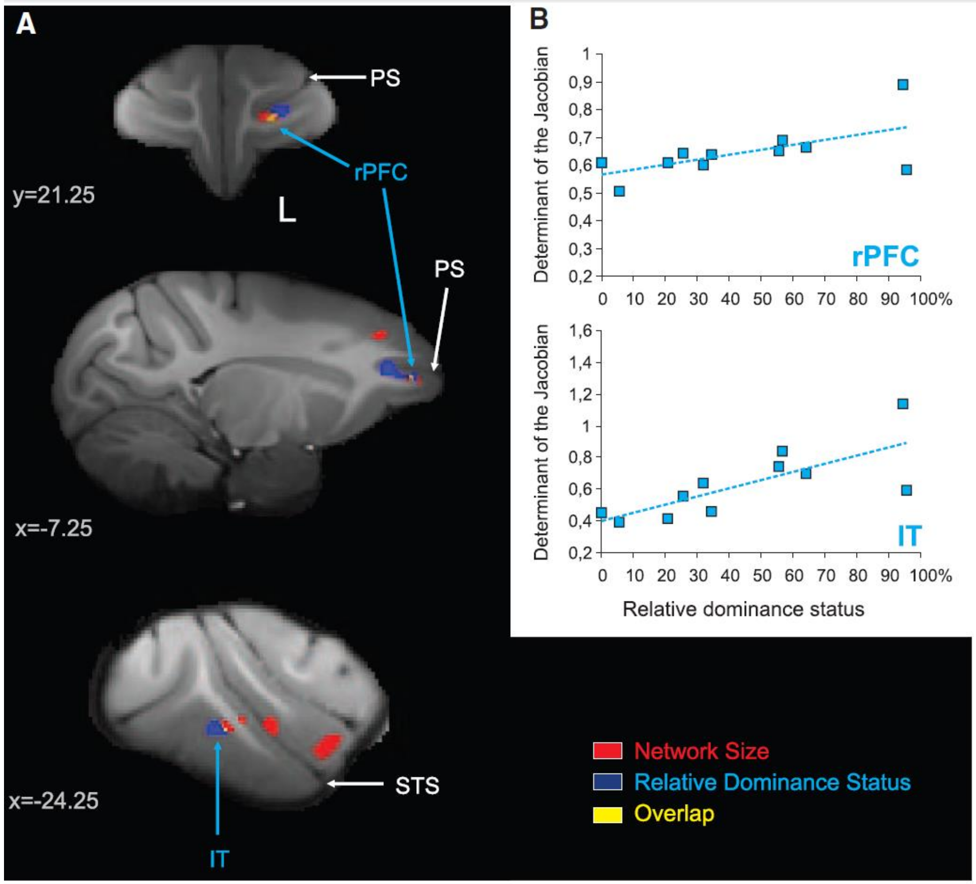

Previous trial performed by monkey

Previous trial performed by human

# Social group dimensions affects Frontal pole

## Social Network Size Affects Neural Circuits in Macaques

J. Sallet,[1,2*†] R. B. Mars,[1,2*] M. P. Noonan,[1,2*] J. L. Andersson,[2] J. X. O'Reilly,[2] S. Jbabdi,[2] P. L. Croxson,[1,3] M. Jenkinson,[2] K. L. Miller,[2] M. F. S. Rushworth[1,2]




rupt emotional responsiveness in both humans and macaques (*13*, *14*). Bickart and colleagues (*2*) have reported a similar correlation in human subjects but, unlike here, they were unable to determine whether differences in amygdala size were the consequence of differences in experienced social network size.

Our initial analysis also identified clusters in rPFC, in the rostral principal sulcus, at the border between dorsolateral prefrontal cortex (area 46) and the frontal pole (area 10) (Fig. 1, A and B, and table S3). In human subjects, an rPFC area rostral to the paracingulate sulcus, together with the STS, is active when predictions are made and updated about the intentions of others (*15*, *16*). Such predictions will have to be made about more individuals, and combinations of individuals, as social network size increases. It is possible that the rPFC region that we have identified in the macaques in the present study is similar to the human rPFC area (*17*, *18*). In humans, rPFC, together with STS and TPJ, is associated with "theory of mind" and prediction of another individual's overt behavior as well as their intentions (*15*, *16*). It is not clear if macaques have a theory of mind and are able to represent others' intentions (*15*, *16*), but they can make decisions based on inferences about what others can see (*19*), which might be a precursor of such an ability. There is also evidence that the activ-

# Theory of mind and Frontal pole

## Neuronal correlates of theory of mind and empathy: A functional magnetic resonance imaging study in a nonverbal task

Birgit A. Völlm[a], Alexander N.W. Taylor[a], Paul Richardson[a], Rhiannon Corcoran[b], John Stirling[c], Shane McKie[a], John F.W. Deakin[a], Rebecca Elliott[a]

Show more

doi:10.1016/j.neuroimage.2005.07.022



### Abstract

Theory of Mind (ToM), the ability to attribute mental states to others, and empathy, the ability to infer emotional experiences, are important processes in social cognition. Brain imaging studies in healthy subjects have described a brain system involving medial prefrontal cortex, superior temporal sulcus and temporal pole in ToM processing. Studies investigating networks associated with empathic responding also suggest involvement of temporal and frontal lobe regions. In this fMRI study, we used a cartoon task derived from Sarfati et al. (1997) [Sarfati, Y., Hardy-Bayle, M.C., Besche, C., Widlocher, D. 1997. Attribution of intentions to others in people with schizophrenia: a non-verbal exploration with comic strips. Schizophrenia Research 25, 199-209.]with both ToM and empathy stimuli in order to allow comparison of brain activations in these two processes. Results of 13 right-handed, healthy, male volunteers were included. Functional images were acquired using a 1.5 T Phillips Gyroscan. Our results confirmed that ToM and empathy stimuli are associated with overlapping but distinct neuronal networks. Common areas of activation included the medial prefrontal cortex, temporoparietal junction and temporal poles. Compared to the empathy condition, ToM stimuli revealed increased activations in lateral orbitofrontal cortex, middle frontal gyrus, cuneus and superior temporal gyrus. Empathy, on the other hand, was associated with enhanced activations of paracingulate, anterior and posterior cingulate and amygdala. We therefore suggest that ToM and empathy both rely on networks associated with making inferences about mental states of others. However, empathic responding requires the additional recruitment of networks involved in emotional processing. These results have implications for our understanding of disorders characterized by impairments of social cognition, such as autism and psychopathy.

# Patients with area 10 lesions have theory of mind deficits

## The role of Area 10 (BA10) in human multitasking and in social cognition: A lesion study

María Roca[a, b, c], Teresa Torralva[a, b], Ezequiel Gleichgerrcht[a, b], Alexandra Woolgar[d], Russell Thompson[d], John Duncan[d], Facundo Manes[a, b]

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doi:10.1016/j.neuropsychologia.2011.09.003

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### Abstract

A role for rostral prefrontal cortex (BA10) has been proposed in multitasking, in particular, the selection and maintenance of higher order internal goals while other sub-goals are being performed. BA10 has also been implicated in the ability to infer someone else's feelings and thoughts, often referred to as theory of mind. While most of the data to support these views come from functional neuroimaging studies, lesion studies are scant. In the present study, we compared the performance of a group of frontal patients whose lesions involved BA10, a group of frontal patients whose lesions did not affect this area (nonBA10), and a group of healthy controls on tests requiring multitasking and complex theory of mind judgments. Only the group with lesions involving BA10 showed deficits on multitasking and theory of mind tasks when compared with control subjects. NonBA10 patients performed more poorly than controls on an executive function screening tool, particularly on measures of response inhibition and abstract reasoning, suggesting that theory of mind and multitasking deficits following lesions to BA10 cannot be explained by a general worsening of executive function. In addition, we searched for correlations between performance and volume of damage within different subregions of BA10. Significant correlations were found between multitasking performance and volume of damage in right lateral BA10, and between theory of mind and total BA10 lesion volume. These findings stress the potential pivotal role of BA10 in higher order cognitive functions.

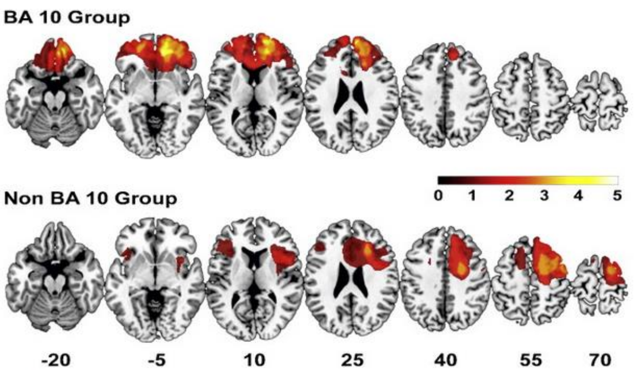



Fig. 1.

# Mentalizing

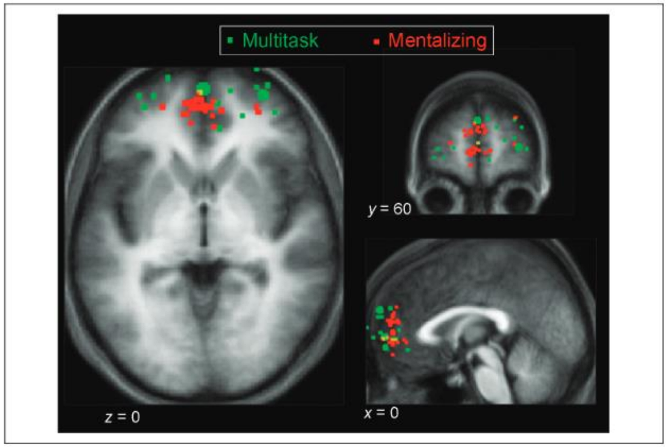
## Functional Specialization within Rostral Prefrontal Cortex (Area 10): A Meta-analysis

Sam J. Gilbert[1], Stephanie Spengler[1], Jon S. Simons[1], J. Douglas Steele[2], Stephen M. Lawrie[3], Christopher D. Frith[1], and Paul W. Burgess[1]

### Abstract

■ One of the least well understood regions of the human brain is rostral prefrontal cortex, approximating Brodmann's area 10. Here, we investigate the possibility that there are functional subdivisions within this region by conducting a meta-analysis of 104 functional neuroimaging studies (using positron emission tomography/functional magnetic resonance imaging). Studies involving working memory and episodic memory retrieval were disproportionately associated with lateral activations, whereas studies involving mentalizing (i.e., attending to one's own emotions and mental states or those of other agents) were disproportionately associated with medial activations. Functional variation was also observed along a rostral–caudal axis, with studies involving mentalizing yielding relatively caudal activations and studies involving multiple-task coordination yielding relatively rostral activations. A classification algorithm was trained to predict the task, given the coordinates of each activation peak. Performance was well above chance levels (74% for the three most common tasks; 45% across all eight tasks investigated) and generalized to data not included in the training set. These results point to considerable functional segregation within rostral prefrontal cortex. ■

**Figure 4.** Location of activations in the Mentalizing and Multitask categories, plotted separately on axial (projected onto $z = 0$), coronal (projected onto $y = 60$), and sagittal (projected onto $x = 0$) slices of a structural scan (mean of 14 normalized T1-weighted images). Where more than one activation occupies the same location, the area of each blob is increased proportionately.



# Autism and Frontal Pole

## A voxel-based investigation of brain structure in male adolescents with autistic spectrum disorder

Gordon D Waiter[a], Justin H.G Williams[b], Alison D Murray[a], Anne Gilchrist[c], David I Perrett[d], Andrew Whiten[d]

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doi:10.1016/j.neuroimage.2004.02.029



### Abstract

Autistic spectrum disorder (ASD) has been associated with abnormal neuroanatomy in many imaging and neuropathological studies. Both global brain volume differences and differences in the size of specific neural structures have been reported. Here, we report a voxel-based morphometric whole brain analysis, using a group specific template, on 16 individuals of normal intelligence with autistic spectrum disorder (ASD), and a group of 16 age-, sex- and IQ-matched controls. Total grey matter volume was increased in the ASD group relative to the control group, with local volume increases in the right fusiform gyrus, the right temporo-occipital region and the left frontal pole extending to the medial frontal cortex. A local decrease in grey matter volume was found in the right thalamus. A decrease in global white matter volume in the ASD group did not reach significance. We found the increase in grey matter volume in ASD subjects was greatest in those areas recognised for their role in social cognition, particularly face recognition (right fusiform gyrus), mental state attribution: 'theory of mind' (anterior cingulate and superior temporal sulcus) and perception of eye gaze (superior temporal gyrus). The picture as a whole may reflect an abnormally functioning social cognitive neural network. We suggest that increased grey matter volume may play a pivotal role in the aetiology of the autistic syndrome.

# Area 10 minicolums in autism

## The Neuropathology of Autism

Manuel F. Casanova, MD

Department of Psychiatry and Behavioral Sciences, University of Louisville, Louisville, Ky.

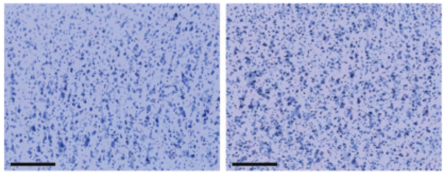

**Figure 3.** The Boolean germ-grain model supposes that a spatial pattern, in this case the Nissl-stained area in a segmented micrograph, is the union of random closed sets (grains) drawn from some distribution and positioned at random points in space (the germ process). This model is a simplification in that it does not account for clustering of the grains, eg the minicolumnar structure. Under these assumptions, the mean grain area ($\bar{A}$) and perimeter ($\bar{U}$), along with the intensity ($\lambda$) of the germ process, completely determine the spatial pattern, providing for a model-based estimate of neuronal cross-section and density. These quantities are found to be reduced and increased, respectively, in autism. Left: cortical area 9, right hemisphere, lamina III from a 25-year-old man without autism. $\bar{A} = 123\ \mu m^2$; $\lambda = 0.0052\ \mu m^{-2}$. Right: the same region from a 24-year-old autistic man. $\bar{A} = 89.1\ \mu m^2$; $\lambda = 0.0069\ \mu m^{-2}$. Scale bars measure 200 µm.

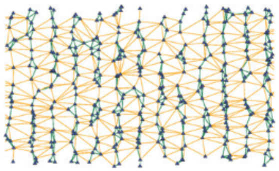

**Figure 4.** The Delaunay triangulation is a graph with vertices belonging to a given point set. Three points are mutually joined by edges of the graph when the circle through those points contains no other point in its interior. This figure illustrates the construction for a randomly generated set of points, clustered into vertical columns. Some edges of the triangulation have been omitted because of boundary effects. For the meaning of the coloring, see Figure 5.

ing a posteroanterior trend across neocortex toward decreased mini-column width. Significant diagnosis by area interactions were found in frontopolar (area 10) and the anterior cingulate gyrus (area 24) of paralimbic cortex (21).

What are the functional implications of increased numbers of narrower mini-columns containing smaller projection neurons? These modular microcircuit assemblies are interconnected by thousands of collateral projections within larger networks. Each mini-column is linked to local networks through myelinated bundles in superficial, or radiate, white matter, and to more distant cortical areas via deeper white matter tracts. The neocortex is presumed to have expanded in evolution through addition of mini-columns by proliferation of their clonal progenitors across an embryonic germinal layer (101, 102). Additive increase in mini-column numbers would entail a geometric increase in short- and long-distance projection fibers in order to maintain a constant degree of transcortical connectivity among modules (61). Longer white matter fibers occupy more space, require disproportionately larger soma to support increased metabolic costs and result in signal processing delays. Selection pressure would therefore be expected to have given rise to modules internally linked by radially oriented processes and integrated into local networks by short collaterals. Proportionately less white matter would be devoted to longer-range connections, encouraging regional functional specialization. Neuropathological descriptions of decreased cell size and narrow mini-columns (20), studies revealing increased superficial white matter (58), and functional imaging studies revealing decreases in activity linking prefrontal and posterior areas (64) support this view. This reorganization might require an increase in frequency of multiple rare polymorphisms at many loci. Combinations of such polymorphisms in turn could support a bias toward a developmental extreme of this evolutionary trend. In primates, more complex prefrontal connections require an extended period of maturation. Developmental insults or epigenetic interactions during this period would unmask underlying genetic vulnerabilities. Autistic syndromes may represent various manifestations of this phenomenon. A putative increase in local interconnectivity and reduced prefrontal transcortical connections in areas subserving cognitive flexibility and prioritizing (area 10) and emotional and social cognition (area 25) is consistent with the clinical picture of stereotypy, rigidity and interpersonal deficits characterizing autism.

### NEUROINFLAMMATION

Classical descriptions of inflammatory processes involve a vascular component leading to the accumulation of cells and fluid within the extravascular space. In this regard autism lacks a vascular component and a classical inflammatory response. Levels of quinolinic acid and neopterin in cerebrospinal fluid are either normal or paradoxically reduced in comparison to controls (139). Samples of cerebrospinal fluid obtained from live patients show normal cell counts and protein electrophoresis. There is no evidence of recruitment of leukocytes into the central nervous system. Reported cellular changes do not support their participation in tissue repair and recovery. Furthermore, the clinical symptoms in autism denote lack of concomitant fever, myalgia, arthralgia, anorexia or somnolescence that would sustain a systemic effect for any given inflammatory agent. Rather, the tissue response and their effects appear confined to the brain and indicate an intact blood–brain barrier.

There is no evidence of an adaptive or specific immune response in the brains of autistic patients (89, 125). Immunocytochemical studies have failed to identify T- and B-lymphocyte infiltration and deposition of immunoglobulin/complement in brain tissue (125). Perivascular CD3 and CD20 lymphocyte cell subsets have been rare and reported in both patients and controls (125). The immune system appears activated exclusively in terms of its innate components, astrocytes and microglial cells and the influx of macrophages (7, 52, 125).

ing a posteroanterior trend across neocortex toward decreased mini-column width. Significant diagnosis by area interactions were found in frontopolar (area 10) and the anterior cingulate gyrus (area 24) of paralimbic cortex (21).

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# Autism and frontal pole

frontiers in
HUMAN NEUROSCIENCE

REVIEW ARTICLE
published: 21 June 2012
doi: 10.3389/fnhum.2012.00184

## A framework for interpreting functional networks in schizophrenia

*Peter C. Williamson*[1]* and *John M. Allman*[2]

[1] *Tanna Schulich Chair in Neuroscience and Mental Health, University of Western Ontario, London, ON, Canada*
[2] *Frank P. Hixon Professor of Neurobiology, Division of Biology, California Institute of Technology, Pasadena, CA, USA*

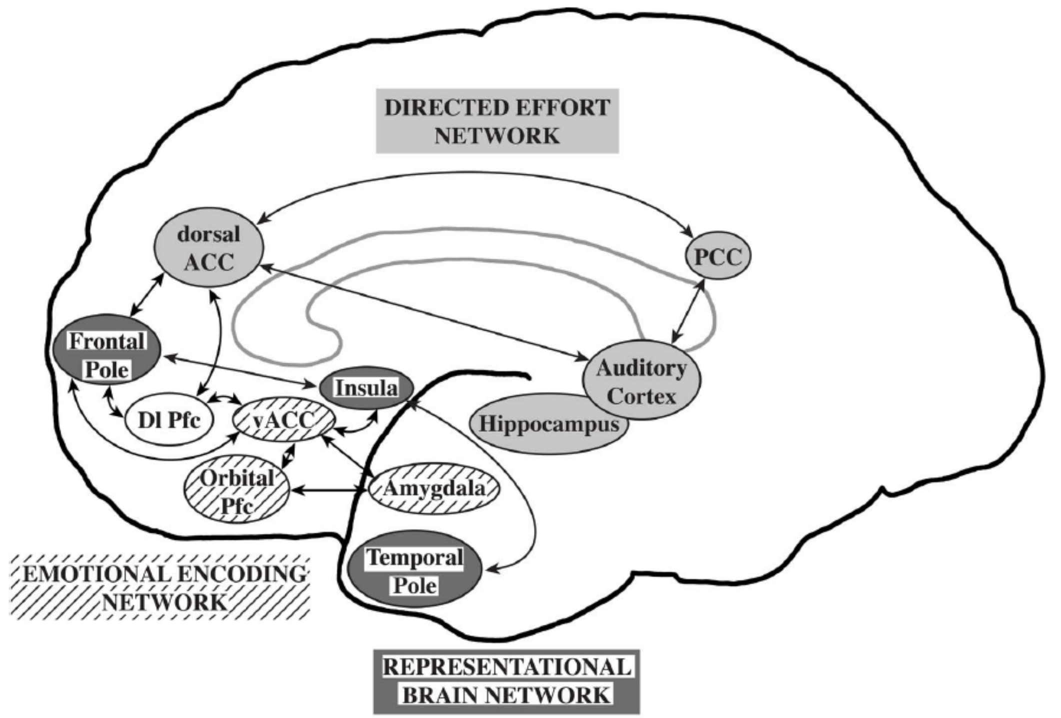



**FIGURE 1 | The representational brain.** The representational brain network (dark gray), proposed to underlie autism, includes the frontal pole, insula, and temporal pole. The directed effort network (light gray), proposed to underlie schizophrenia, includes the dorsal anterior cingulate cortex (ACC), posterior cingulate cortex (PCC), auditory cortex, and hippocampus. The emotional encoding network (lined), proposed to underlie mood disorders, includes the orbital prefrontal cortex (Pfc), ventral anterior ACC, and amygdala. The directed effort and emotional encoding networks interact with the representational network and the dorsolateral prefrontal cortex (Dl Pfc, not shaded). Reprinted with permission from Williamson and Allman. *The Human Illnesses: Neuropsychiatric Disorders and the Nature of the Human Brain.* New York, NY: Oxford University Press, Copyright 2011.

# Autism and abnormal development of area 10

doi:10.1093/brain/awu083 Brain 2014: 137; 1799–1812 | 1799

BRAIN
A JOURNAL OF NEUROLOGY

## Longitudinal changes in cortical thickness in autism and typical development

Brandon A. Zielinski,[1,2,3] Molly B. D. Prigge,[1,4] Jared A. Nielsen,[4] Alyson L. Froehlich,[5] Tracy J. Abildskov,[6] Jeffrey S. Anderson,[4,7] P. Thomas Fletcher,[8,9] Kristen M. Zygmunt,[8] Brittany G. Travers,[10] Nicholas Lange,[11,12,13] Andrew L. Alexander,[10,14,15] Erin D. Bigler[6,16] and Janet E. Lainhart[10,15]

The natural history of brain growth in autism spectrum disorders remains unclear. Cross-sectional studies have identified regional abnormalities in brain volume and cortical thickness in autism, although substantial discrepancies have been reported. Preliminary longitudinal studies using two time points and small samples have identified specific regional differences in cortical thickness in the disorder. To clarify age-related trajectories of cortical development, we examined longitudinal changes in cortical thickness within a large mixed cross-sectional and longitudinal sample of autistic subjects and age- and gender-matched typically developing controls. Three hundred and forty-five magnetic resonance imaging scans were examined from 97 males with autism (mean age = 16.8 years; range 3–36 years) and 60 males with typical development (mean age = 18 years; range 4–39 years), with an average interscan interval of 2.6 years. FreeSurfer image analysis software was used to parcellate the cortex into 34 regions of interest per hemisphere and to calculate mean cortical thickness for each region. Longitudinal linear mixed effects models were used to further characterize these findings and identify regions with between-group differences in longitudinal age-related trajectories. Using mean age at time of first scan as a reference (15 years), differences were observed in bilateral inferior frontal gyrus, pars opercularis and pars triangularis, right caudal middle frontal and left rostral middle frontal regions, and left frontal pole. However, group differences in cortical thickness varied by developmental stage, and were influenced by IQ. Differences in age-related trajectories emerged in bilateral parietal and occipital regions (postcentral gyrus, cuneus, lingual gyrus, pericalcarine cortex), left frontal regions (pars opercularis, rostral middle frontal and frontal pole), left

# Change in functional connectivity in Schizofrenia

frontiers in
HUMAN NEUROSCIENCE

REVIEW ARTICLE
published: 21 June 2012
doi: 10.3389/fnhum.2012.00184

## A framework for interpreting functional networks in schizophrenia

***Peter C. Williamson[1]* and John M. Allman[2]***

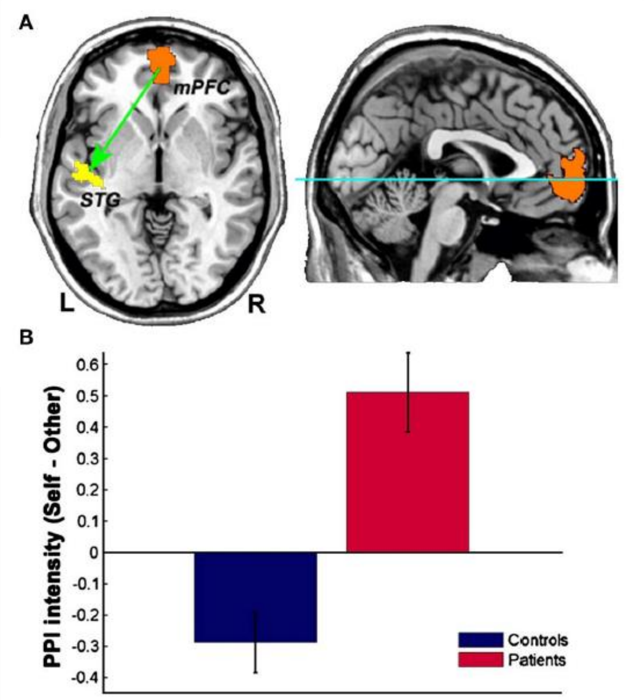
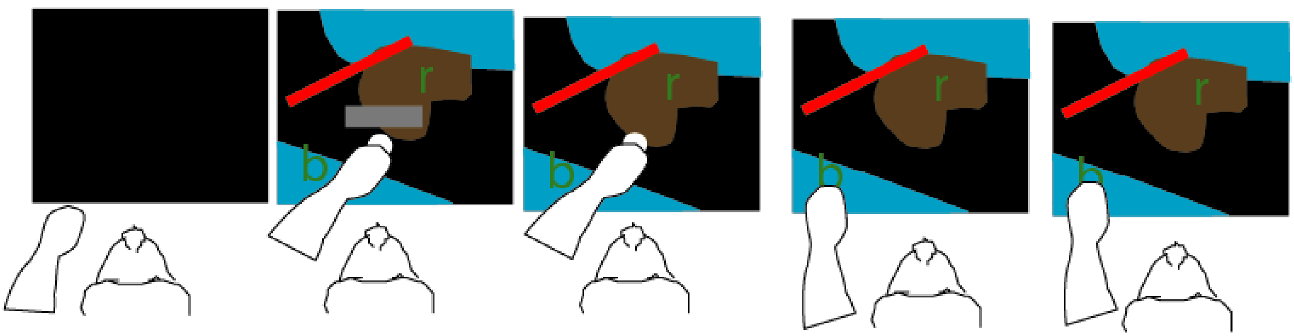
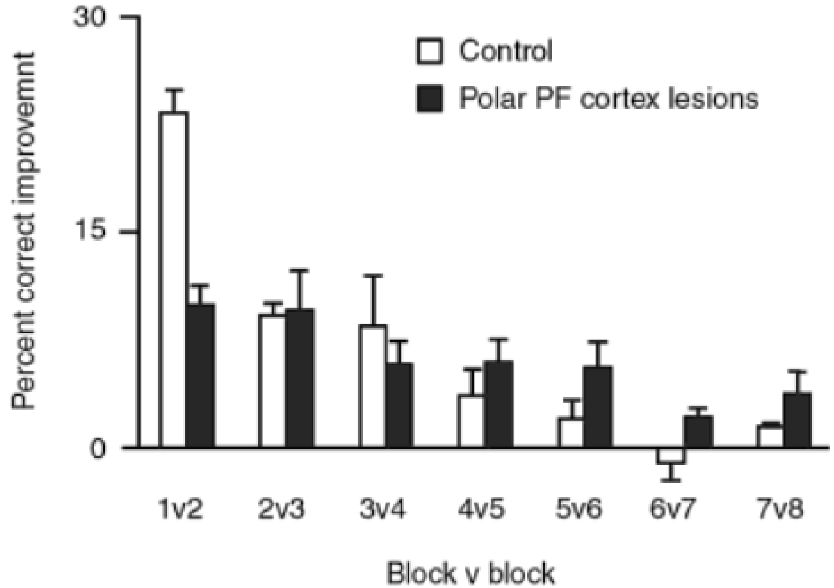



**FIGURE 2 | Changes in functional connectivity with the medial prefrontal cortex in schizophrenia.** The psychophysiological interaction (PPI) analysis revealed that functional connectivity from the medial prefrontal cortex to the left superior temporal gyrus is significantly modulated by source memory condition **(A)** By averaging the PPI intensity over the voxels within the significant cluster for each subject, a significant interaction effect was found: higher connectivity is observed in the Self condition in patients with schizophrenia, whereas healthy subjects display higher connectivity in the Other condition **(B)** Reprinted from Wang et al. (2011). Aberrant connectivity during self-other source monitoring in schizophrenia. *Schizophr. Res.* 125, 136–142 with permission from Elsevier.

# Object-in-place scene learning task

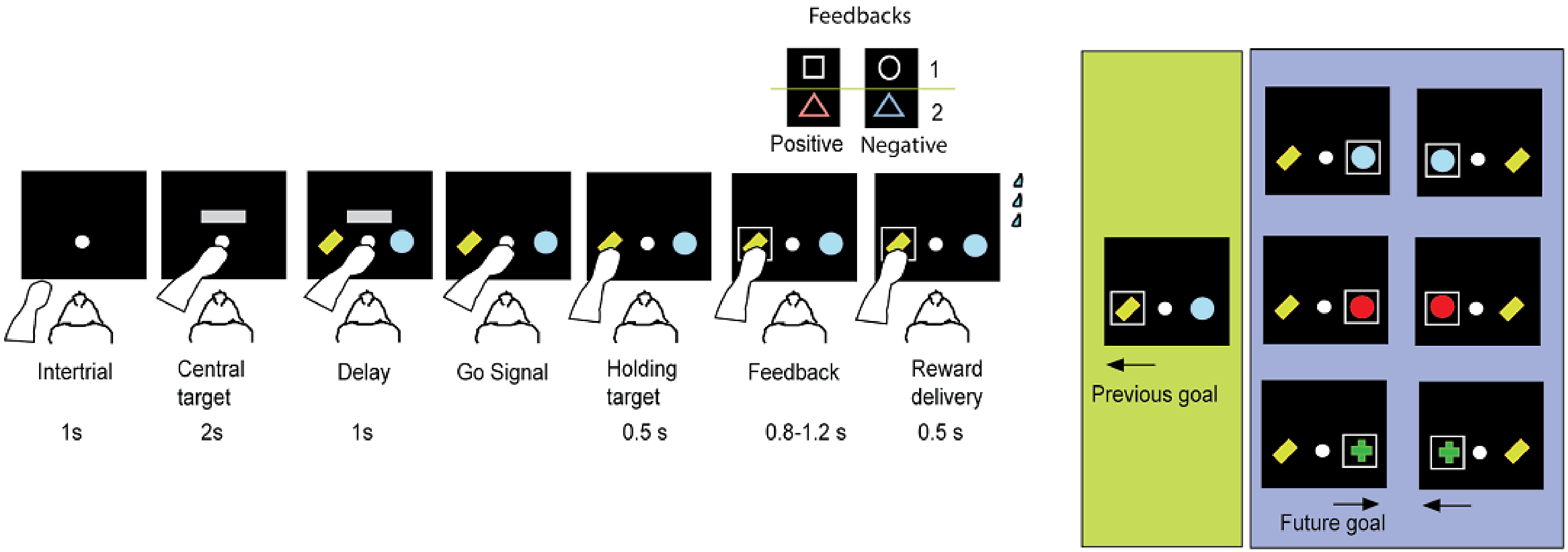



One trial learning is compromised by lesions of the Frontal Pole

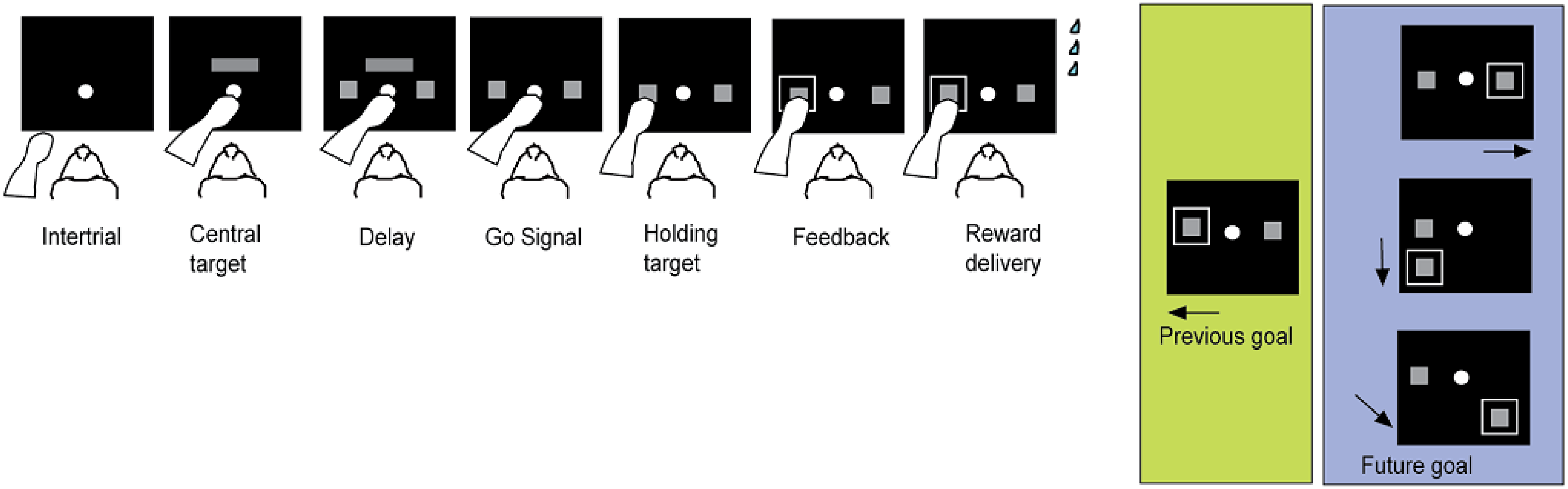



The monitoring activity could be usefull for learning based on single events.

# Object NMTG


Feedbacks
1
2
Positive
Negative
Intertrial
1s
Central target
2s
Delay
1s
Go Signal
Holding target
0.5 s
Feedback
0.8-1.2 s
Reward delivery
0.5 s
Previous goal
Future goal

# Spatial NMTG



# Insula shows social functions

**Current Biology**

Volume 21, Issue 3, 8 February 2011, Pages 195–199

Report

## Emotional and Social Behaviors Elicited by Electrical Stimulation of the Insula in the Macaque Monkey

Fausto Caruana[1, 2, 3], Ahmad Jezzini[1, 3], Beatrice Sbriscia-Fioretti[1], Giacomo Rizzolatti[1, 2], Vittorio Gallese[1, 2]

Show more

doi:10.1016/j.cub.2010.12.042

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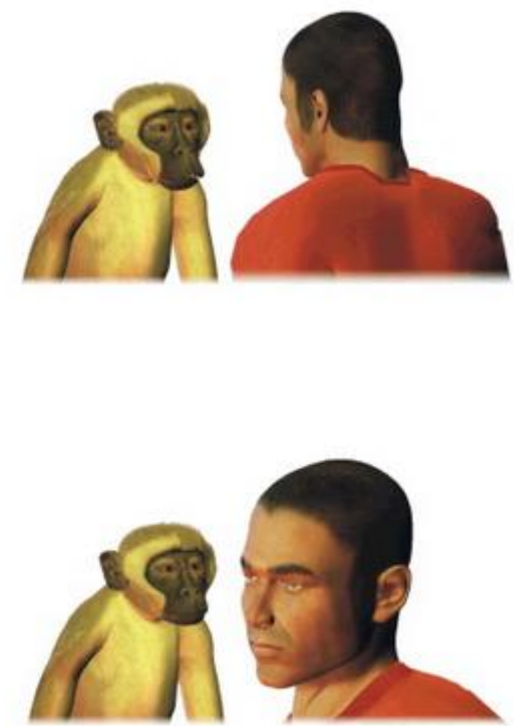
### Summary

Evidence from a large number of brain imaging studies has shown that, in humans, the insula, and especially its anterior part, is involved in emotions and emotion recognition [1, 2, 3, 4, 5, 6, 7 and 8]. Typically, however, these studies revealed that, besides the insula, a variety of other cortical and subcortical areas are also active. Brain imaging studies are correlative in nature, and, as such, they cannot give indications about the necessary contribution of the different centers involved in emotions. In the present study, we aimed to define more clearly the role of the insula in emotional and social behavior of the monkey by stimulating it electrically. Using this technique, one may determine whether direct activation of the insula can produce specific emotional or social behaviors and exactly which parts of this structure are responsible for these behaviors. The results showed that two emotional behaviors, a basic one (disgust) and a social one (affiliative state), were easily elicited by electrical stimulation of specific parts of the insula. Both behaviors were characterized by specific motor and vegetative responses and by a dramatic change in the monkey's responsiveness to external stimuli.



Stimulation evokats lips smaking behavior only under condition of human eye contact.

# TPO is sensitive to gaze direction

Proc R Soc Lond B Biol Sci. 1985 Jan 22;223(1232):293-317.

**Visual cells in the temporal cortex sensitive to face view and gaze direction.**

Perrett DI, Smith PA, Potter DD, Mistlin AJ, Head AS, Milner AD, Jeeves MA.

**Abstract**

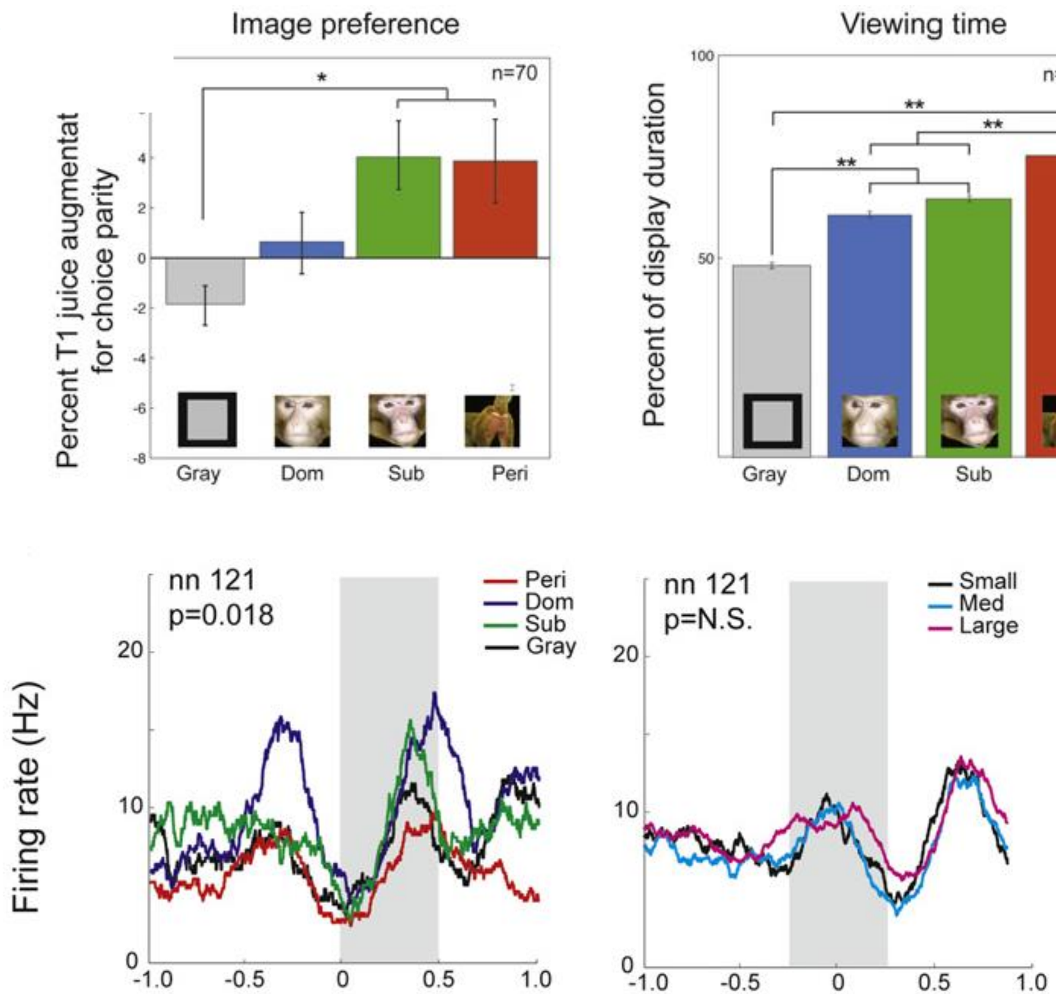
The direction of eye gaze and orientation of the face towards or away from another are important social signals for man and for macaque monkey. We have studied the effects of these signals in a region of the macaque temporal cortex where cells have been found to be responsive to the sight of faces. Of cells selectively responsive to the sight of the face or head but not to other objects (182 cells) 63% were sensitive to the orientation of the head. Different views of the head (full face, profile, back or top of the head, face rotated by 45 degrees up to the ceiling or down to the floor) maximally activated different classes of cell. All classes of cell, however, remained active as the preferred view was rotated isomorphically or was changed in size or distance. Isomorphic rotation by 90-180 degrees increased cell response latencies by 10-60 ms. Sensitivity to gaze direction was found for 64% of the cells tested that were tuned to head orientation. Eighteen cells most responsive to the full face preferred eye contact, while 18 cells tuned to the profile face preferred averted gaze. Sensitivity to gaze was thus compatible with, but could be independent of, sensitivity to head orientation. Results suggest that the recognition of one type of object may proceed via the independent high level analysis of several restricted views of the object (viewer-centred descriptions).

# Orbitofrontal cortex

## Social Signals in Primate Orbitofrontal Cortex

Karli K. Watson[1,2,*] and Michael L. Platt[1,2]

Current Biology 2012



# Dorsolateral prefrontal cortex

Can neurons that encode previous and future goals be agent-specific?

Behavioral/Systems/Cognitive

## Representation of Future and Previous Spatial Goals by Separate Neural Populations in Prefrontal Cortex

Aldo Genovesio, Peter J. Brasted, and Steven P. Wise

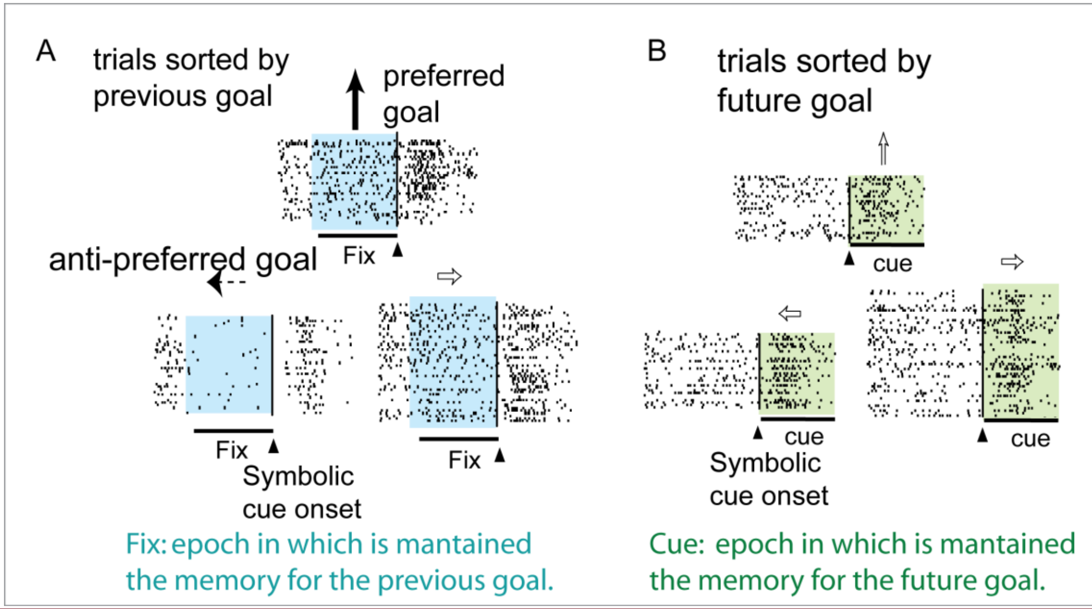
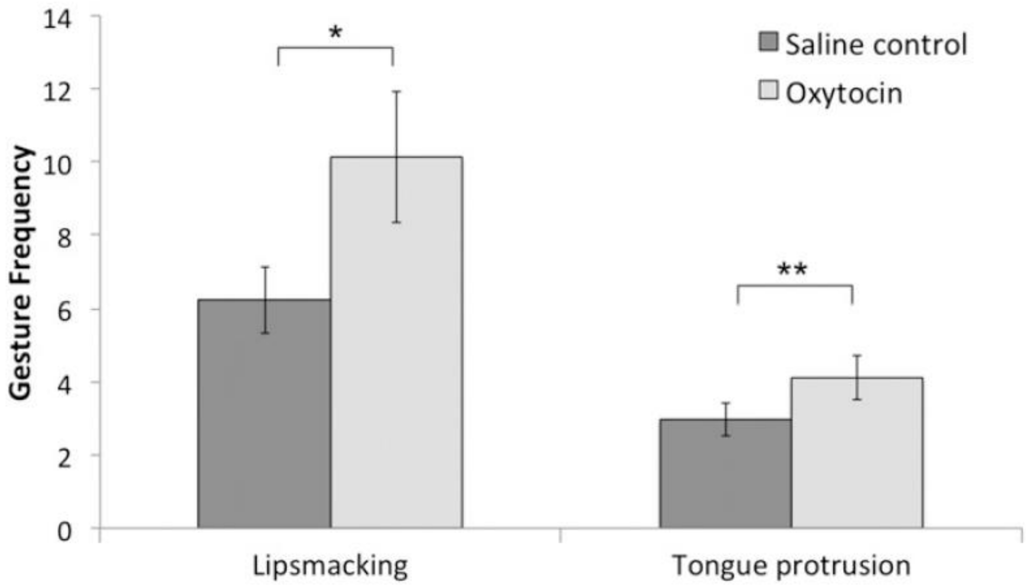



Fig. 1

# Oxytocin

## Inhaled oxytocin increases positive social behaviors in newborn macaques

Elizabeth A. Simpson[a,b,1], Valentina Sclafani[b], Annika Paukner[a], Amanda F. Hamel[c], Melinda A. Novak[c], Jerrold S. Meyer[c], Stephen J. Suomi[a], and Pier Francesco Ferrari[b]

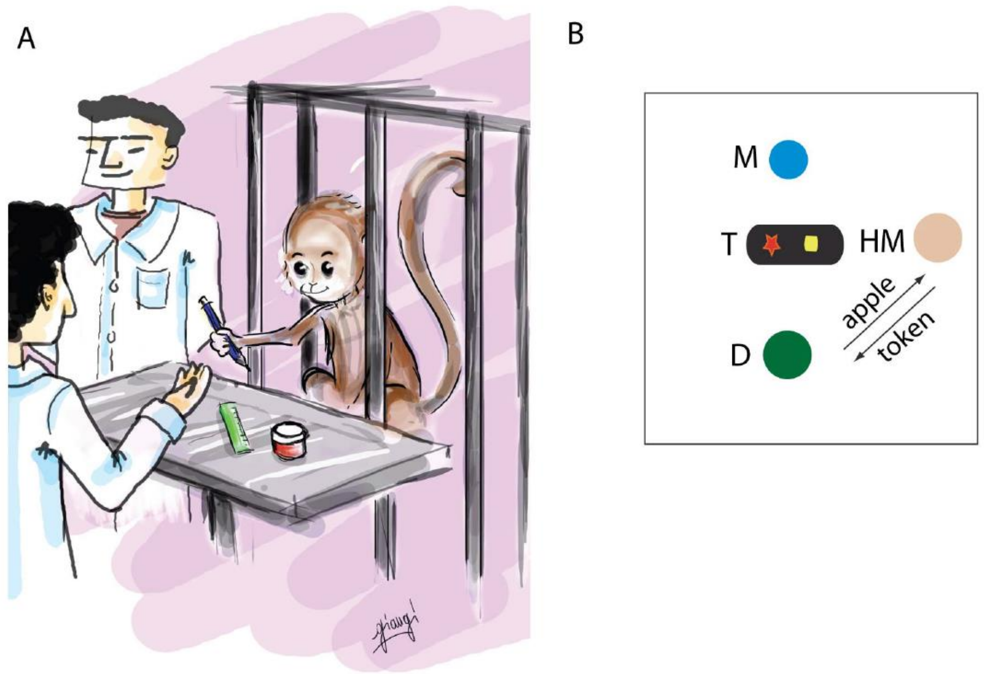


# Observation learning is possible in H-M

OPEN ACCESS Freely available online PLOS ONE

## Macaque Monkeys Can Learn Token Values from Human Models through Vicarious Reward

Sara Bevacqua, Erika Cerasti, Rossella Falcone, Milena Cervelloni, Emiliano Brunamonti, Stefano Ferraina, Aldo Genovesio*

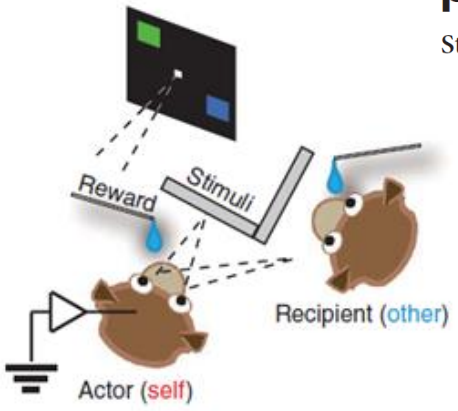


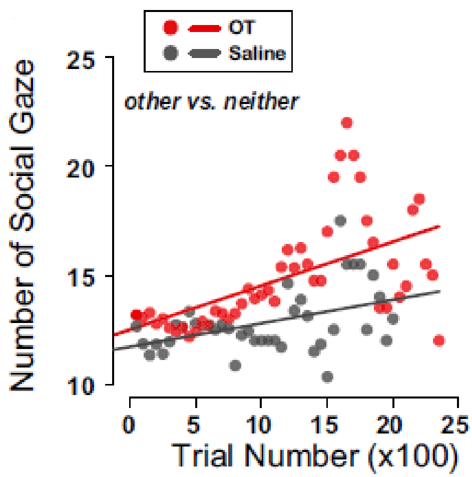
# Oxtocin increases prosocial behaviour

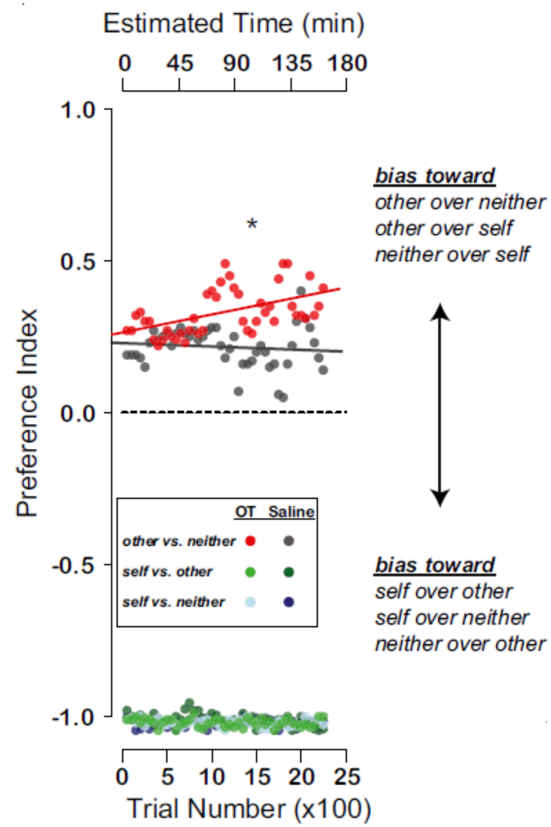
## Neuronal reference frames for social decisions in primate frontal cortex

Steve W C Chang[1,2], Jean-François Gariépy[2] & Michael L Platt[1–3]

nature neuroscience



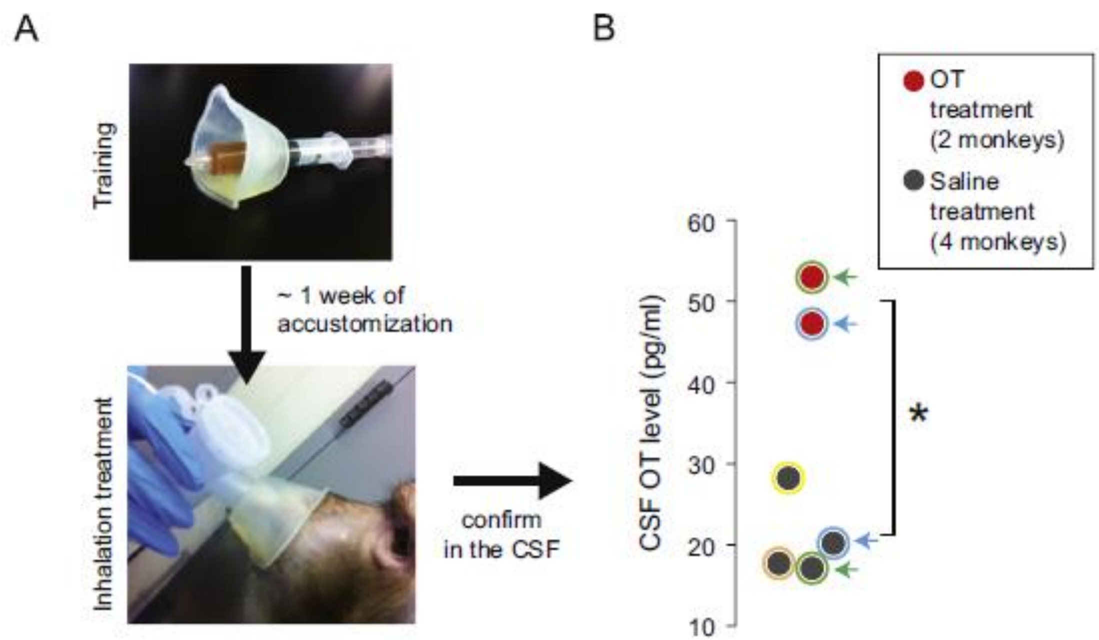



# Oxytocin inhalation

Inhalation of oxytocin increeases its concentration in the cerebrospinal fluid

BRAIN RESEARCH 1580 (2014) 57–68



# Monkeys represents others' knowledge

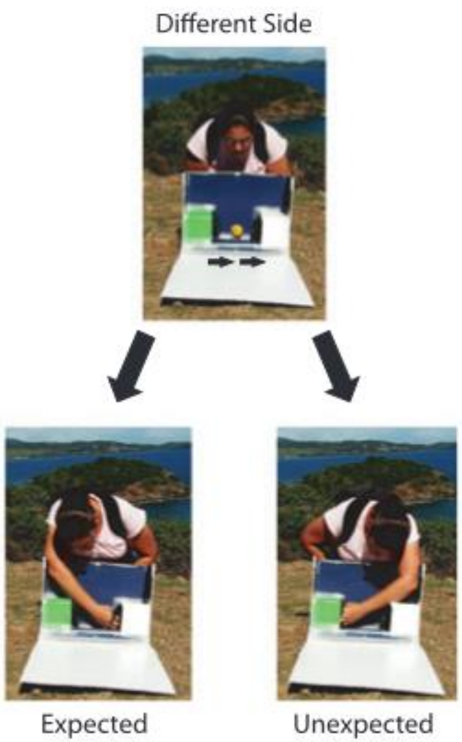
**Developmental Science**

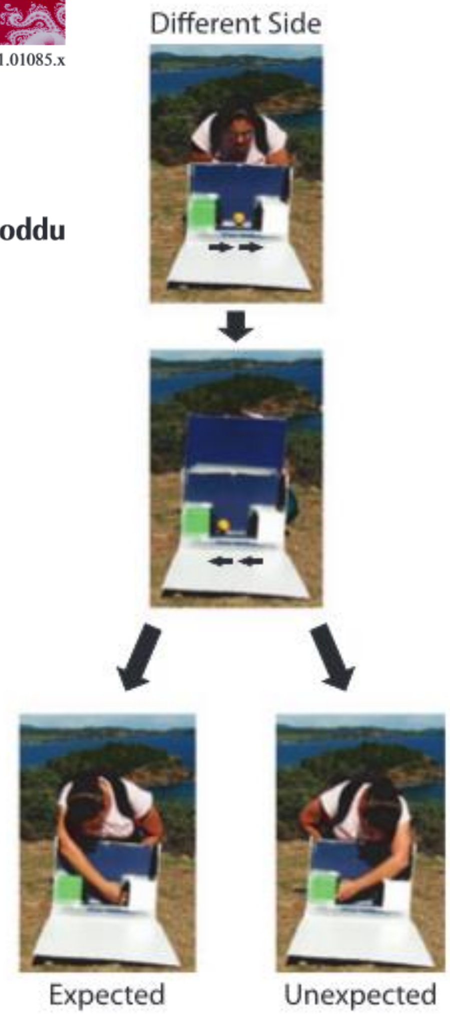
Developmental Science 14:6 (2011), pp 1406–1416 DOI: 10.1111/j.1467-7687.2011.01085.x

**PAPER**

## Monkeys represent others' knowledge but not their beliefs

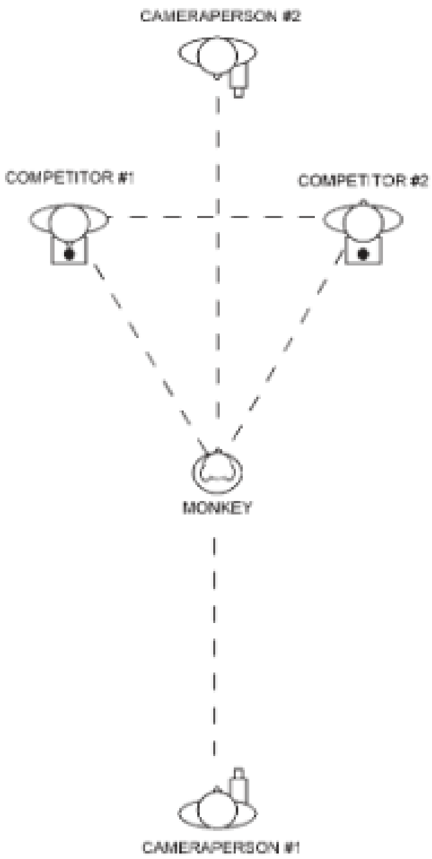
**Drew C.W. Marticorena, April M. Ruiz, Cora Mukerji, Anna Goddu and Laurie R. Santos**



# Attribution of perceptions

Experiment 1

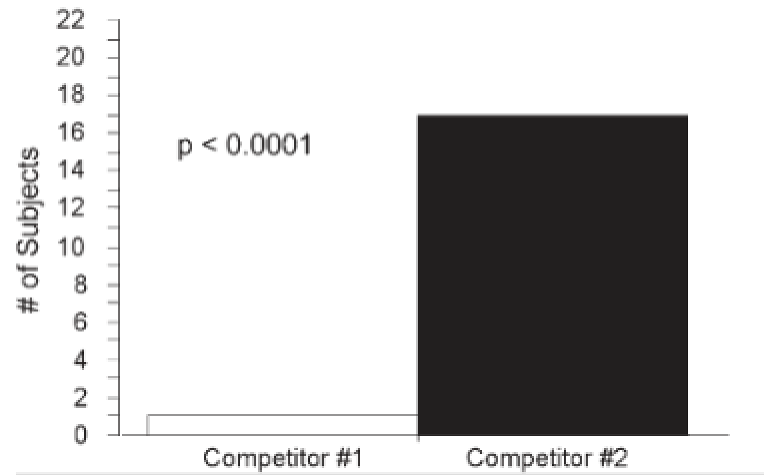



Current Biology, Vol. 15, 447–452, March 8, 2005, ©2005 Elsevier Ltd All rights reserved. DOI 10.1016/j.cub.2004.12.076

## Rhesus Monkeys Attribute Perceptions to Others

Jonathan I. Flombaum* and Laurie R. Santos
Department of Psychology
Yale University
New Haven, CT 06520

Monkeys approch the experimenter that cannot see the grape




Subjects were allowed to approach the grape in front of one of the two competitors while two camerapersons filmed them.

# Capuchins understand intentions

Developmental Science

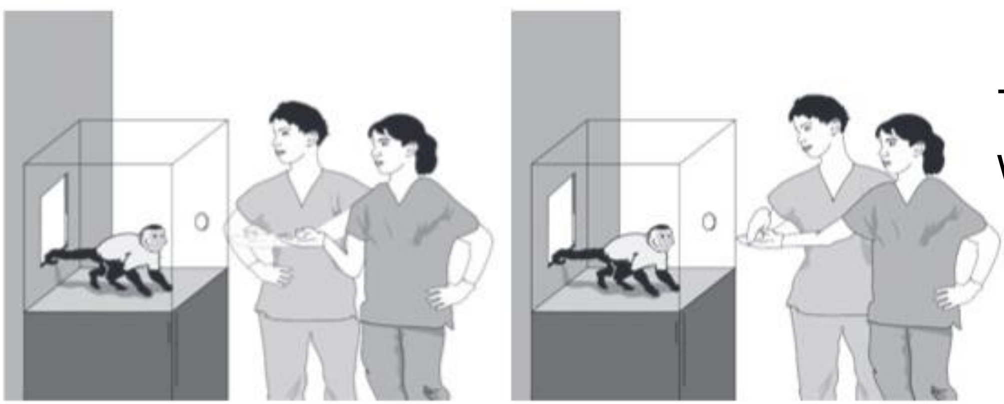
Developmental Science 12:6 (2009), pp 938–945 DOI: 10.1111/j.1467-7687.2009.00840.x

PAPER

## 'Unwilling' versus 'unable': capuchin monkeys' (*Cebus apella*) understanding of human intentional action

Webb Phillips,[1] Jennifer L. Barnes,[1] Neha Mahajan,[1] Mariko Yamaguchi[2] and Laurie R. Santos[1]

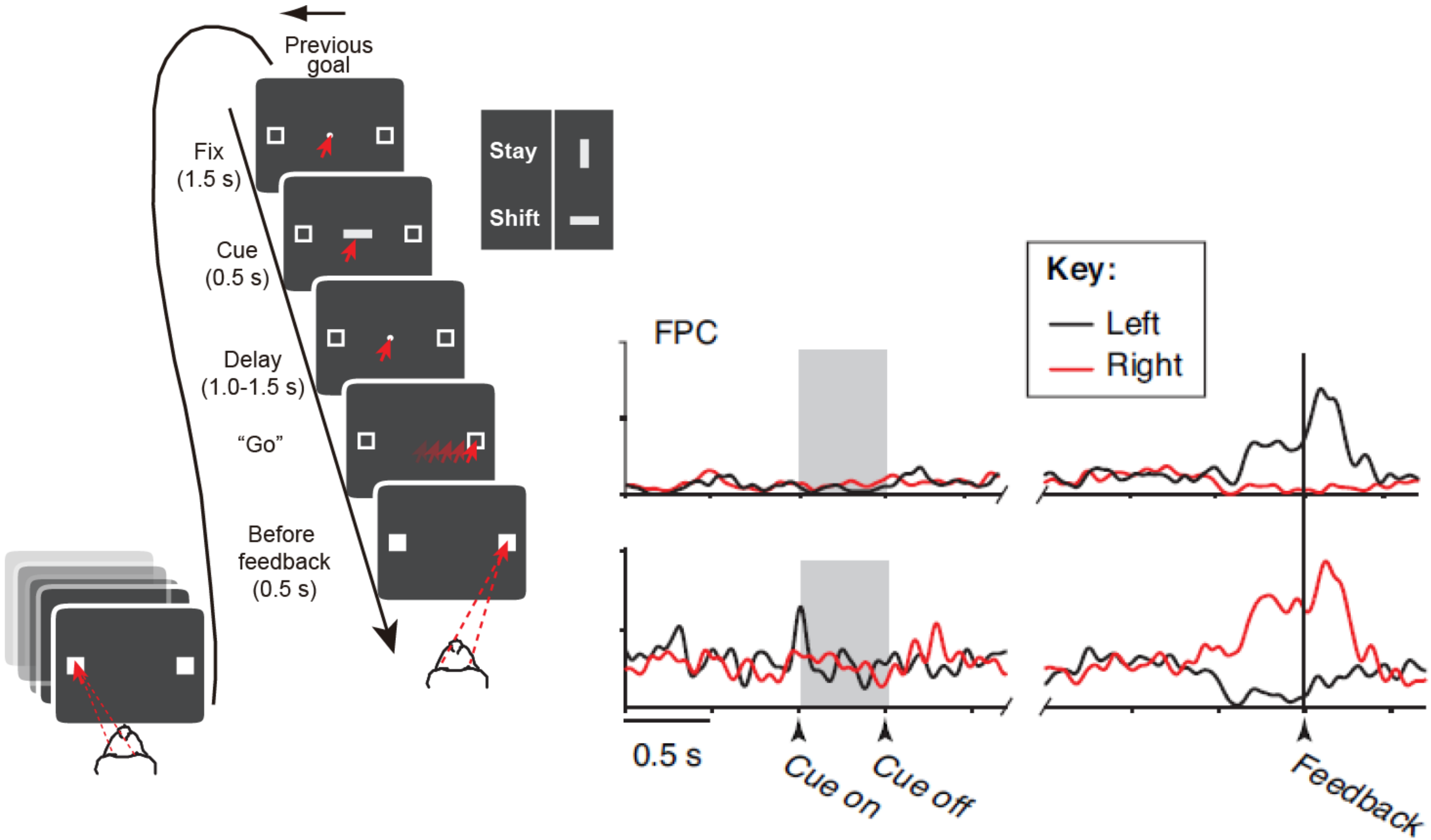
Unwilling vs. unable in capuchin monkeys



The monkey stays longer to wait in the unable condition.

*A depiction of unwilling (left) versus unable (right) test events in Experiment 2.*

# Frontal Pole previously used task



# Differences between prefrontal areas