# Decision Making

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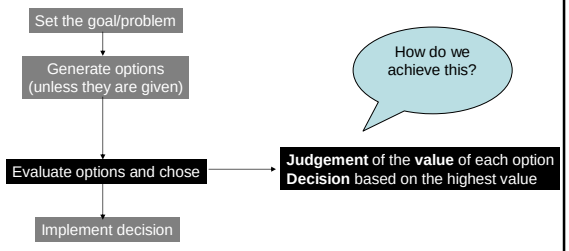
Room C80
Drop in hours Monday 1.30 to 2.30
Tuesday 3 to 4

# I. Introduction

## Basic steps of decision making




## Decision Making under Uncertainty

**Tversky & Kahneman's Asian disease problem**
"Imagine that the USA is preparing for the outbreak of an unusual Asian disease which is expected to kill 600 people.
Two alternative programs to combat disease have been proposed.
Assume that the exact scientific estimates of the consequences of the programs are as follows:

Program A
200 people will be saved

Program B
There is a 1/3 chance that 600 people will be saved, otherwise no one will be saved"

Program C
400 people will die

Program D
There is a 1/3 chance that no one will die, otherwise 600 people will die"

## Social Decision Making

**Ultimatum Game (Güth et al., 1982)**

£ 100 at stake

Simon will make an offer to split the money with you

You can either accept or reject the offer

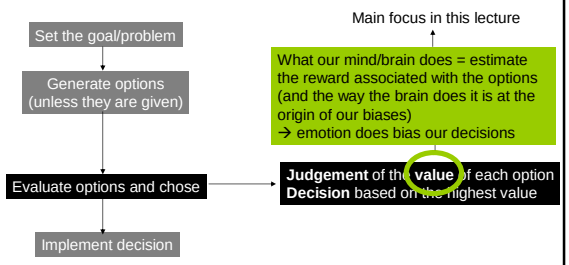
If you accept, the money will be distributed accordingly
If you reject, none of you receives any money

| | | |
|---|---|---|
| Andrew | £50 – | You £50 |
| Steven | £55 – | You £45 |
| Patrick | £60 – | You £40 |
| Mike | £70 – | You £30 |
| Tim | £80 – | You £20 |
| Simon | £95 – | You £5 |
| Oliver | £98 – | You £2 |
| Henry | £99 – | You £1 |
| Mark | £100 – | You £0 |

## What decision-makers actually do…

- Often, decision-makers do NOT take rationale decisions
- Alternative decisions are not random, rather systematic biases
- So, what governs our decisions?
  - Behavioural theories (economics)
  - What happens in the mind and brain (cognitive neuroscience - neuroeconomics)

## Decision making from the Neuroeconomics point of view




## II. Basics about the brain

1. The brain and basic emotions
2. The reward system
3. Hot and cold processing in the brain

## 1. The brain and basic emotions

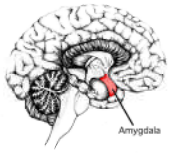
No one-to-one mapping

1. Several brain regions are associated with one emotion

2. A given brain region can be associated with more than one emotion

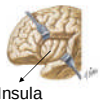
3. Brain regions associated with emotions are not exclusively processing emotions

## Amygdala and fear




- Responds to
  - loud noises, looming and sudden movements, painful stimuli, fearful faces, emotionally laden stimuli
  - signals, memories and images that were previously associated with danger

## Insula and pain/disgust




- Important for the experience of pain and several basic emotions (especially disgust)

Painful response

## II. Basics about the brain

1. The brain and basic emotions
2. The reward system
3. Hot and cold processing in the brain

## 2. The reward system

Basic mechanisms of stimulus – reward/punishment association:

Reinforcement learning

Time 1: Tone → no response
Time 2: Tone → electric shock
Time 3: Tone → defensive response

Extinction

Time 1: Tone → defensive response BUT NO electric shock follows
Time 2: Tone → no electric shock
Time 3: Tone → NO defensive response ANYMORE (extinction)

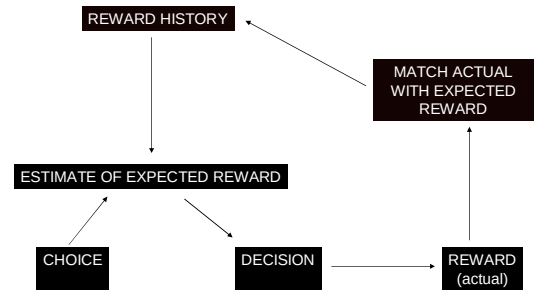
Reversal learning

Time 1: Button 1 gives bad food; Button 2 gives good food → press Button 2
Time 2: Button 1 gives good food; Button 2 gives bad food → press Button 1

Flexibility

## 2. The reward system

reinforcement learning, extinction and reversal learning
all operate in situations of decision making



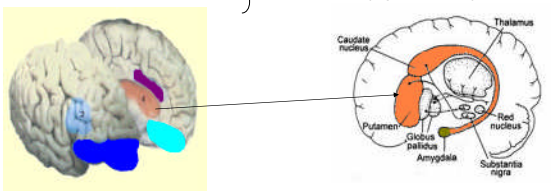

## 2. The reward system

**Key brain areas of the reward system**:

Common monetary unit….

- orbitofrontal cortex
- ventromedial prefrontal cortex
- anterior cingulate cortex
- striatum (esp. ventral)
- amygdala (esp. basolateral)

**Whatever the reward:**
- pleasant sensory stimuli (e.g., food)
- drugs
- financial reward
- cultural rewards (e.g., art, branded goods)
- social reward (e.g., trust, love)

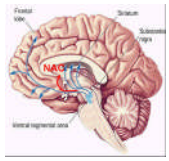



Adapted from http://brainmind.com/

## 2. The reward system

**Key neurotransmitter in the reward system**:

Dopamine

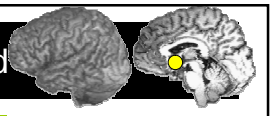


Abnormal dopamine system
leads to decision making problems:

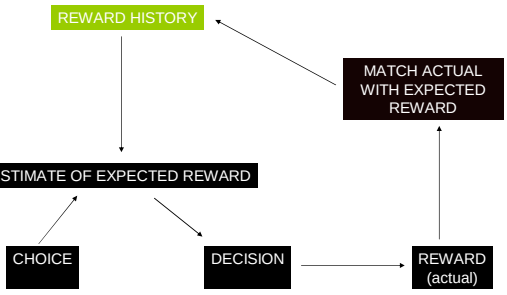
- ADHD
- schizophrenia,
- obsessive-compulsive behavior,

etc..

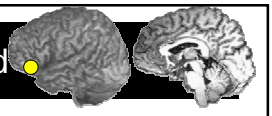
## 2. The reward

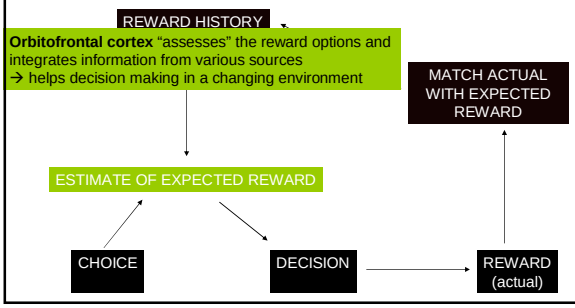


**Amygdala and striatum** are critical in linking a stimulus to a reward

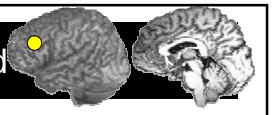



## 2. The reward





## 2. The reward



REWARD HISTORY

MATCH ACTUAL WITH EXPECTED REWARD

ESTIMATE OF EXPECTED REWARD

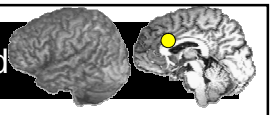
**Lateral prefrontal:**
- adjusts behaviour

CHOICE

DECISION

REWARD (actual)

## 2. The reward



REWARD HISTORY

**Posterior medial prefrontal/Anterior cingulate:**
- monitors performance in relation to reward
- detects conflict (failure to get reward) or changes in probability to get reward
- feeds in to history of reward (history of what happened over a series of trials)

MATCH ACTUAL WITH EXPECTED REWARD

ESTIMATE OF EXPECTED REWARD

CHOICE

DECISION

REWARD (actual)

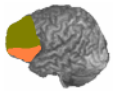
# II. Basics about the brain

1. The brain and basic emotions
2. The reward system
3. Hot and cold processing in the brain

## 3. Hot and cold processing

| HOT | COLD |
|---|---|
| "Valuation" = Ventral and medial areas | Other processes (e.g. working memory, planning, retrieval from long-term memory) = Dorsolateral areas |

Ventral view



Lateral view

# III. Emotion & decision making under uncertainty

1. Emotional response to risk
2. Emotional response to framing
3. Regret and decision making

## 1. Emotional response to risk

Iowa Gambling Task:

Bad decks
High immediate win
BUT long-term loss

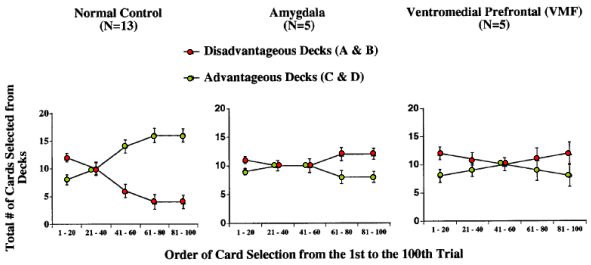
Good decks
Low immediate win
BUT long-term win

| | A | B | C | D |
|---|---|---|---|---|
| Gain per card | $100 | $100 | $50 | $50 |
| Loss per 10 cards | $-1250 | $-1250 | $-250 | $-250 |
| Net per 10 cards | -$250 | -$250 | +$250 | +$250 |

*(Bechara et al., 1999, Journ. Neurosci.)*

# 1. Emotional response to risk

Evidence from Neuropsychology:

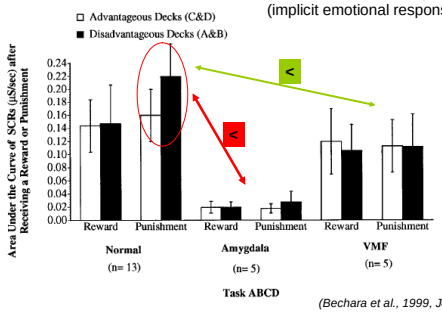



*(Bechara et al., 1999, Journ. Neurosci.)*

# 1. Emotional response to risk

Evidence from Neuropsychology:

Skin Conductance Response (implicit emotional response)




*(Bechara et al., 1999, Journ. Neurosci.)*

# 1. Emotional response to risk

Evidence from Neuropsychology:

Both patients with amygdala lesions and orbitofrontal lesions have deficits in decision making.

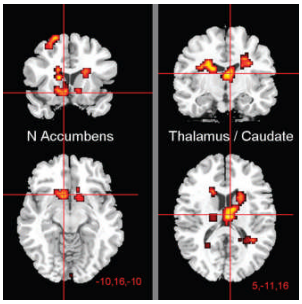
For **amygdala** patients, no emotional response at all.

For **orbitofrontal** patients, some emotional response but no specific response to punishment from the bad decks.

*(Bechara et al., 1999, Journ. Neurosci.)*

# 1. Emotional response to risk

Evidence from fMRI:



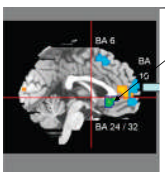

Activation associated with winning compared to loosing

➔ mainly reward system

*(Lawrence et al., 2008, Cerebral Cortex)*

# 1. Emotional response to risk

Evidence from fMRI:

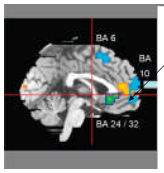



Activation associated with Decision making task compared to a Control task ➔ ventromedial prefrontal cortex

*(Lawrence et al., 2008, Cerebral Cortex)*

# 1. Emotional response to risk

Evidence from fMRI:




Activation associated with the avoidance of bad decks ➔ orbitofrontal cortex (but not exclusively)

*(Lawrence et al., 2008, Cerebral Cortex)*

# 1. Emotional response to risk

Conclusions from neuropsychology and from fMRI:

The **striatum** (caudate) associated with pleasure, positive reward

The **amygdala** is associated with an emotional response to risk

The **ventromedial prefrontal cortex** and the **orbitofrontal cortex** in particular integrate emotional information and non-emotional information to guide decision making.

# III. Emotion & decision making under uncertainty

1. Emotional response to risk
2. Emotional response to framing
3. Regret and decision making

# 2. Emotional response in the framing effect

Program A
200 lives will be saved
200 people will be saved

=

Program C
200 lives will be saved
400 people will die
**Framing effect**

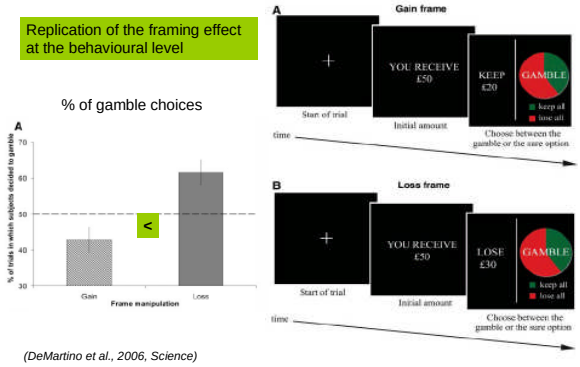
Program B
1/3 chance to save 600 lives
There is a 1/3 chance that 600 people will be saved, otherwise no one will be saved"

=

Program D
1/3 chance to save 600 lives
There is a 1/3 chance that no one will die, otherwise 600 people will die"

# 2. Emotional response in the framing effect

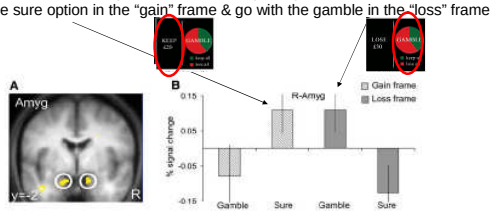
Replication of the framing effect at the behavioural level




*(DeMartino et al., 2006, Science)*

# 2. Emotional response in the framing effect

Region activated when participants
go for the sure option in the "gain" frame & go with the gamble in the "loss" frame



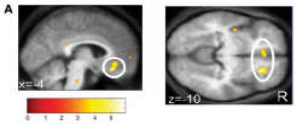

Amygdala is activated when people follow the frame

*(DeMartino et al., 2006, Science)*

# 2. Emotional response in the framing effect

Region activated when participants
Reason rationally instead of following the frame

Gambles EQUALLY often in the loss frame than the gain frame
➔ decision is independent of frame




Orbitofrontal activation correlates with the rationality index

*(DeMartino et al., 2006, Science)*

## 2. Emotional response in the framing effect

Conclusions:

**Amygdala** – emotional response to salient reinforcement stimuli → **sensitive to frame**

**Orbitofrontal** – integrates information from various sources (not only amygdala) for estimating the reward → more sensitive to **rational decisions** than the amygdala

(thankfully, we can learn to be more rational!)

## 2. Emotional response in the framing effect

Your predictions for brain-damaged patients?


Will the following patients gamble more in the loss frame than the gain frame?

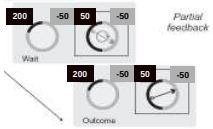
Patients with amygdala lesions?
Patients with orbitofrontal lesions?

# III. Emotion & decision making under uncertainty

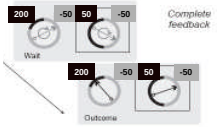
1. Emotional response to risk
2. Emotional response to framing
3. Regret and decision making

## 3. Regret and Decision Making


PARTIAL FEEDBACK
If not a good outcome:
**disappointment**




COMPLETE FEEDBACK
If not a good outcome:
**regret**

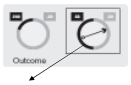




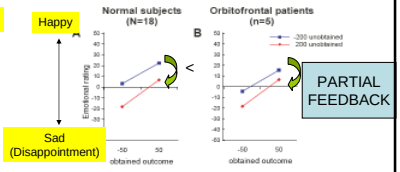
*(Camille et al., 2004, Science)*

## 3. Regret and Decision Making

Explicit emotional judgement




*= Unobtained outcome can be*
*better than obtained*
*worse than obtained*




Overall OFC = normals for disappointment

For both (normals and OFC patients)
(1) More disappointment if lose

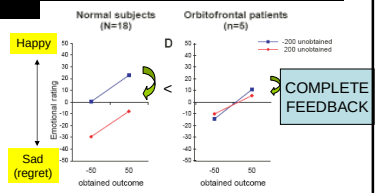
(2) Even more disappointment if the unobtained outcome was better (although slightly less for OFC patients)

*(Camille et al., 2004, Science)*

## 3. Regret and Decision Making

Explicit emotional judgement


*= Unobtained outcome can be*
*better than obtained*
*worse than obtained*




OFC = impaired for regret

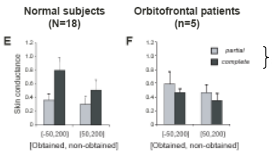
For normals regret if the unobtained outcome was better

But for OFC patients: NO regret

*(Camille et al., 2004, Science)*

# 3. Regret and Decision Making

Implicit emotional measure (skin conductance response)




Difference between partial and complete
= signature of regret

Normals:
Complete > Partial
➔ regret

OFC patients:
Complete <= Partial
➔ NO regret

*(Camille et al., 2004, Science)*

# 3. Regret and Decision Making

Evidence from Neuropsychology:

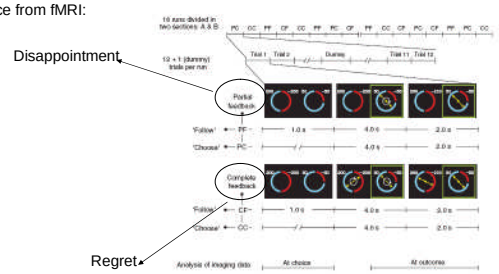
Orbitofrontal cortex is necessary to experience regret

But, is regret something we experience after the decision?

**Or is regret already influencing us BEFORE we take our decision?**

# 3. Regret and Decision Making

Evidence from fMRI:

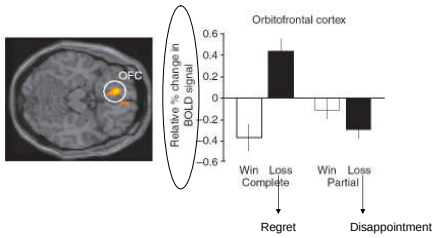



*(Coricelli et al., 2005, Nature Neuroscience)*

# 3. Regret and Decision Making

Evidence from fMRI:

(1) Confirmation in normal subjects that the OFC is involved in regret

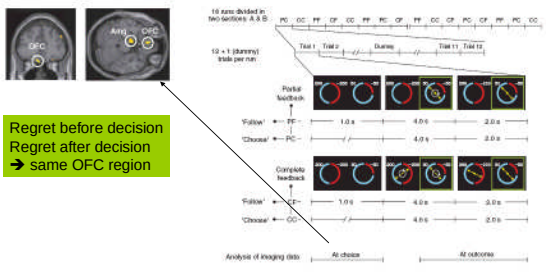



*(Coricelli et al., 2005, Nature Neuroscience)*

# 3. Regret and Decision Making

Evidence from fMRI:

(2) OFC activation AT THE DECISION TIME (not only after the decision)




Regret before decision
Regret after decision
➔ same OFC region

*(Coricelli et al., 2005, Nature Neuroscience)*

# 3. Regret and Decision Making

Conclusions from neuropsychology and from fMRI:

Orbitofrontal cortex
(1) is linked to regret/counterfactual reasoning

(2) is activated not only after the outcome of a decision but also BEFORE a decision

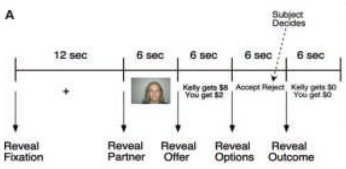
➔ anticipated regret influences our decisions!

# IV. Emotion & social decision making

1. Fairness and decision making
2. Emotional response to moral decision making

## 1. Fairness and decision making

Evidence from fMRI:

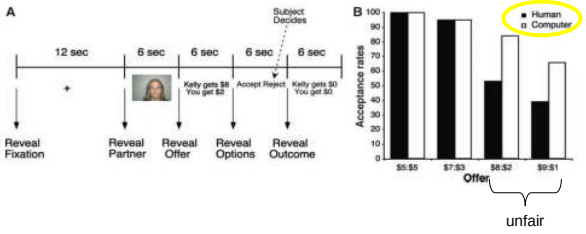



*(Sanfey et al., 2003, Science)*

## 1. Fairness and decision making

Evidence from fMRI:

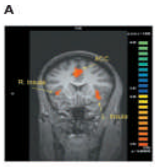
Replication of the "unfair" effect at the behavioural level

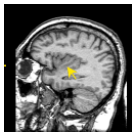



*(Sanfey et al., 2003, Science)*

## 1. Fairness and decision making

Region activated when participants reject an "unfair" offer



Insula (pain, disgust) is heavily connected to amygdala, striatum and orbitofrontal cortex

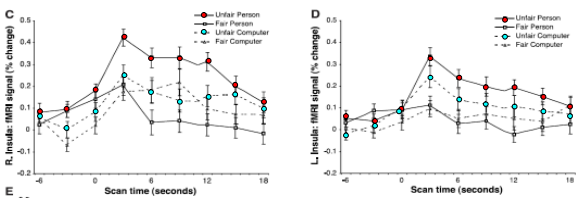
*(Sanfey et al., 2003, Science)*

## 1. Fairness and decision making

Region activated when participants reject an "unfair" offer

Signal change in the Right insula

Signal change in the Left insula

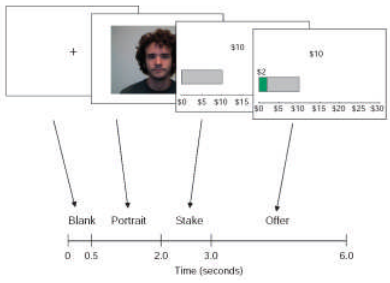



More disgust by an unfair deal from a person than from the computer!

*(Sanfey et al., 2003, Science)*

## 1. Fairness and decision making

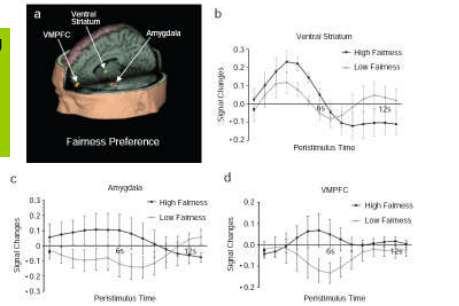
Evidence from fMRI:




*(Tabibnia et al., 2008, Psychological Science)*

## 1. Fairness and decision making

Activation during fair offers: striatum, amydgala and ventromedial prefrontal cortex




*(Tabibnia et al., 2008, Psychological Science)*

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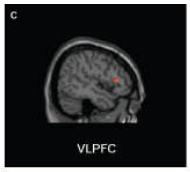
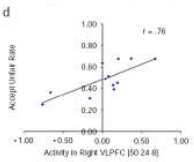



Activation when participants accept an unfair offer: ventrolateral prefrontal cortex

*(Tabibnia et al., 2008, Psychological Science)*

## 1. Fairness and decision making

Conclusions from fMRI

**Insula** – activated in case of an unfair deal → **moral disgust?**

**= altruistic punishment**: for the sake of the community, bad behaviour should be punished (even if it means that we punish ourselves)

**Ventrolateral prefrontal cortex** : activated when we go against moral disgust (and hence when we accept an unfair offer)

## 1. Fairness and decision making

Your predictions for brain-damaged patients?

Henry €99 – Vous €1

Will the following patients accept or reject the offer?

Patients with lesions to the insula?
Patients with lesions to the ventrolateral prefrontal cortex?

## IV. Emotion & social decision making

1. Fairness and decision making
2. Emotional response to moral decision making

## 2. Emotional response to moral decision making

The murder was sent to jail

vs

Some children live in the street (unpleasant condition)

He shot the victim to death

vs

He licked the dirty toilet (emotionally evocative statement)

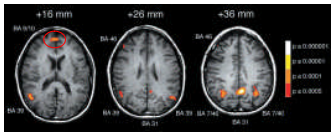
↓

**Ventromedial prefrontal cortex activation**

*(Moll et al., 2002b, The Journal of Neuroscience; Moll et al., 2002, Neuroimage)*

**Personal moral** vs **Impersonal moral**

**More ventromedial prefrontal cortex activation**




*(Greene et al., 2001, Science)*

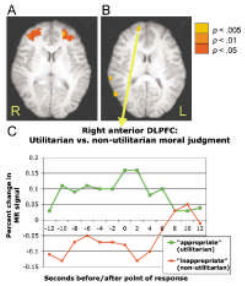
**Non-Utilitarian response** vs **Utilitarian response**

"Don't smother the baby"

➔ don't do the harmful act
➔ automatic emotional aversion for the harmful act

"The baby will die no matter what; therefore, smother the baby, save everyone else"

➔ collective good
➔ general reasoning



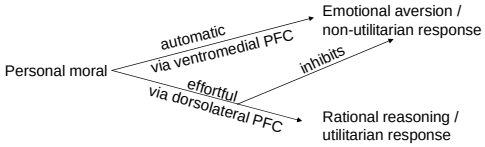

**More anterior cingulate and dorsolateral prefrontal cortex activation**

*(Greene et al., 2004, Neuron)*

# 3. Emotional response to moral decision making

- Dual system model: competition/conflict between distinct cognitive and emotional processes to moral judgements

Dr Joshua Greene (Harvard)




What would happen in the case of patients with ventromedial prefrontal cortex? Will it be harder or easier for them to give a non-utilitarian response?

Decision making situation

**EMOTIONAL PROCESSING (quick)**

- **Amygdala** sensitive to salient emotional information (framing effect)
- **Insula** involved in pain, disgust (moral unfairness)
- **Striatum** involved in computing the reward value associated with a stimulus
- **Ventromedial prefrontal cortex** involved in the emotional reaction to morally difficult situations and situations that involve risk

**NON-EMOTIONAL PROCESSING (more effortful)**

- **Dorsolateral prefrontal cortex** involved in working memory, planning, retrieval and selection of information from memory

**INTEGRATION**

- **orbitofrontal cortex/ventrolateral prefrontal cortex** involved in regret (emotion is linked to counterfactual thinking), in overriding the framing effect and in overriding moral disgust