The Neural Mechanisms of Risky Decision Making

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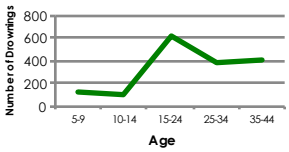
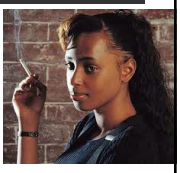
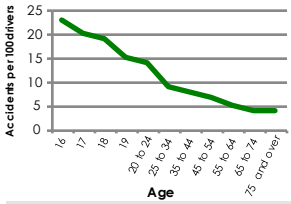
Decision Making

- **Finances:** Save money or spend it?
- **Eating:** Indulge in a second dessert?
- **Medical:** Medication with side effects?
- **Underage drinking:** Risk of getting caught
- **Drugs:** Risk of overdose
- **Unprotected sex:** Risk of HIV

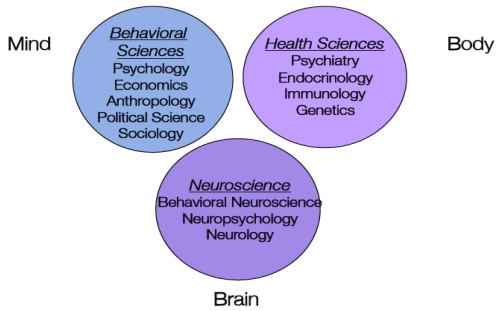
Adolescent Risk Taking





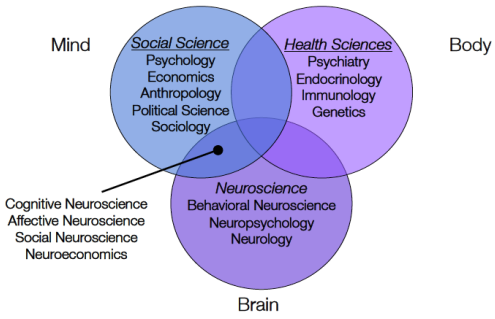


Multidisciplinary Science



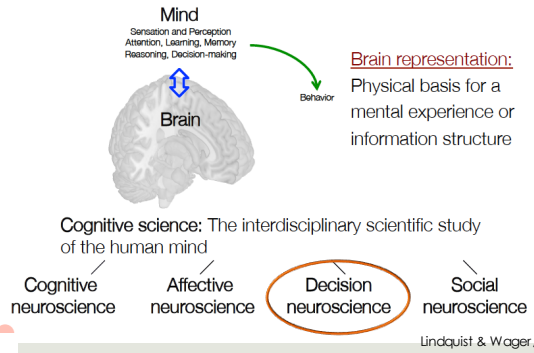
Lindquist & Wager, 2015

Multidisciplinary Science



Lindquist & Wager, 2015

MRI + Cognitive Science



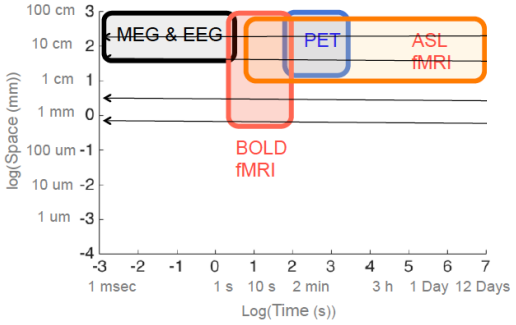
Lindquist & Wager, 2015

Functional brain imaging

- Functional brain imaging can be used to study both cognitive and affective processes.
- Modalities include:
  - Positron emission tomography (PET)
  - Functional magnetic resonance imaging (fMRI)
  - Electroencephalography (EEG)

Lindquist & Wager, 2015

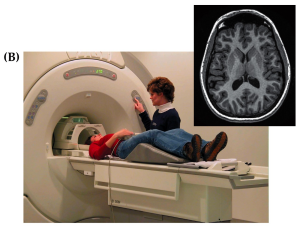
Human neuroimaging



Lindquist & Wager, 2015

Magnetic Resonance Imaging (MRI)

- An MR scanner consists of an electromagnet with a very strong magnetic field (1.5-7.0 Tesla)
- **Earth's magnetic field** = .000005 Tesla
- 3 Tesla magnet is ~60,000 times stronger than the Earth's magnetic field.



PRINCIPLES OF COGNITIVE NEUROSCIENCE 2e, Box 2A (Part 2)
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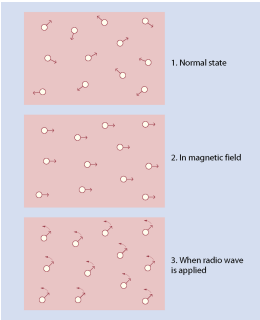
Lindquist & Wager, 2015

MRI Principles

Principles:

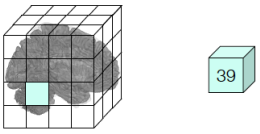
1. Tissues are full of protons (H^+)
2. Protons in a magnetic field align themselves and oscillate in an equilibrium state
3. Protons exposed to a directed radiofrequency (RF) pulse of magnetism absorb energy
4. When the RF pulse is removed, protons release energy as they relax toward their equilibrium state



From: William W. Seeley, MD; UCSF

fMRI data

- Each image consists of ~100,000 'voxels' (cubic volumes that span the 3D space of the brain).
- Each voxel corresponds to a spatial location (x, y, z) in the brain.



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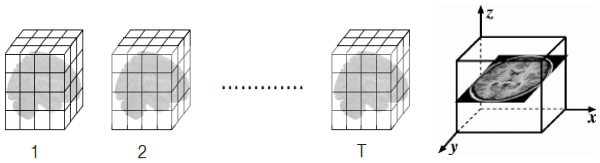
fMRI data

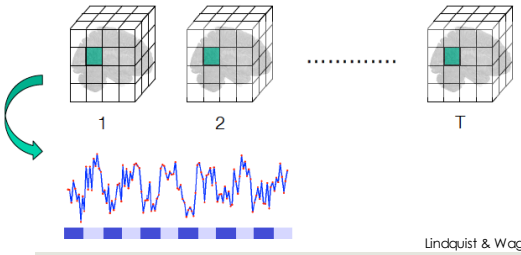
- During the course of an experiment several hundred images are acquired (~ one every 2s).



Lindquist & Wager, 2015

fMRI data

- Tracking the intensity over time gives us a time series.



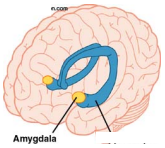
Lindquist & Wager, 2015

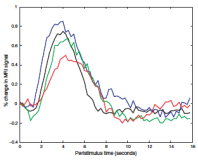
BOLD fMRI

- fMRI uses the **Blood Oxygenation Level Dependent (BOLD)** signal.
- BOLD fMRI measures the ratio of oxygenated to deoxygenated hemoglobin in the blood.
- BOLD fMRI does not measure neuronal activity directly--it measures the metabolic demands (oxygen consumption) of active neurons.

Lindquist & Wager, 2015

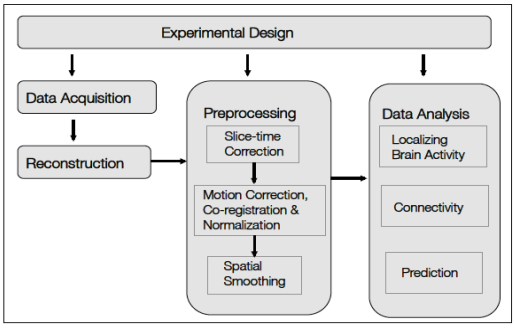
fMRI = Functional Magnetic Resonance Imaging





Stimulus → Increase in neuronal activity → Increase in blood flow to that neuronal region = **hemodynamic response function**

Data Processing Pipeline



Lindquist & Wager, 2015

Risky Choice Framing Problems

Problem 1

A disease outbreak is expected to kill 600 people.
You must choose between two programs (A or B) to fight the disease:

A = 200 people will be saved

B = 1/3 probability that 600 people will be saved, 2/3 probability that no one will be saved

Basic paradigm (Tversky & Kahneman, 1986)

Problem 2

A disease outbreak is expected to kill 600 people.
You must choose between two programs (A or B) to fight the disease:

A = 400 people will die

B = 2/3 probability that 600 people will die, 1/3 probability that no one will die

Basic paradigm (Tversky & Kahneman, 1986)

Risky Choice Framing Problems

Disease outbreak expected to kill 600 people.
You must choose between two programs (A or B) to fight the disease:

GAIN

A = 200 people will be saved *(sure)* **200 saved**

B = 1/3 probability that 600 people will be saved, 2/3 probability that no one will be saved *(risky)*

LOSS

A = 400 people will die *(sure)* **600-400 = 200 saved**

B = 2/3 probability that 600 people will die, 1/3 probability that no one will die *(risky)*

Basic paradigm (Tversky & Kahneman, 1986)

Risky Choice Framing Problems

Adults derive the gist!

Disease outbreak expected to kill 600 people. You must choose between two programs (A or B) to fight the disease:

GAIN

A = 200 people will be saved *(sure)*

B = 1/3 probability that 600 people will be saved, 2/3 probability that no one will be saved *(risky)*

(Saving some people better than saving none.)

LOSS

A = 400 people will die *(sure)*

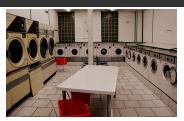
B = 2/3 probability that 600 people will die, 1/3 probability that no one will die *(risky)*

(None dying is better than some dying.)

Fuzzy-Trace Theory

Verbatim

92 quarters



Gist

A lot of quarters

Verbatim → Age → **Gist**

Reyna, 2012

Fuzzy-Trace Theory

Survey example

- Risk of contracting HIV from unprotected sex = "a 1/2000 chance"
- Risk of contracting HIV from unprotected sex = "a small chance"

Gist processing leads to better decision making!

Can we cue gist-based processing in adolescents to make their decision making resemble adult decision making?

fMRI Experiment: Adolescent Risk Taking

- How does representation of risk and reward information affect risky decision making?
  - Adolescents versus adults
  - Relationship between reward sensitivity and risky choice

Decisions task completed in MRI scanner: Experimental Design

- **Between-subjects factors:**
  - Age (adolescents, adults)
  - Hunger (non-hungry, hungry)
- **Within-subjects factors:**
  - Frame (gain, loss)
  - Fuzzy-trace truncation (verbatim, mixed, gist)
  - Reward type (candy, money)
  - Magnitudes (1, 6, 20)

Fuzzy-Trace Theory Manipulation

Condition	Sure Option	Risky Option	Prediction
Gist	Win $20 for sure.	2/3 probability of winning nothing.	LARGE Framing Effect
	SOME	NONE	
Mixed	Win $20 for sure.	1/3 probability of winning $60; 2/3 probability of winning nothing.	NORMAL Framing Effect
	SOME	SOME or NONE	
Verbatim	Win $20 for sure.	1/3 probability of winning $60.	NO Framing Effect
	SOME	SOME	

Stimulus Presentation

You have entered a raffle and $60 is at stake. Which would you choose?

4 seconds
PREAMBLE

A: Win $30 for sure.

B: 50% probability you win $60 and 50% probability you win nothing.

7 seconds
CHOICE

How confident are you in your decision?

1 2 3 4 5

4 seconds
CONFIDENCE RATING

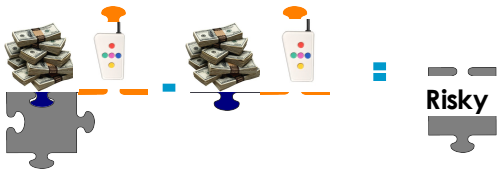
+

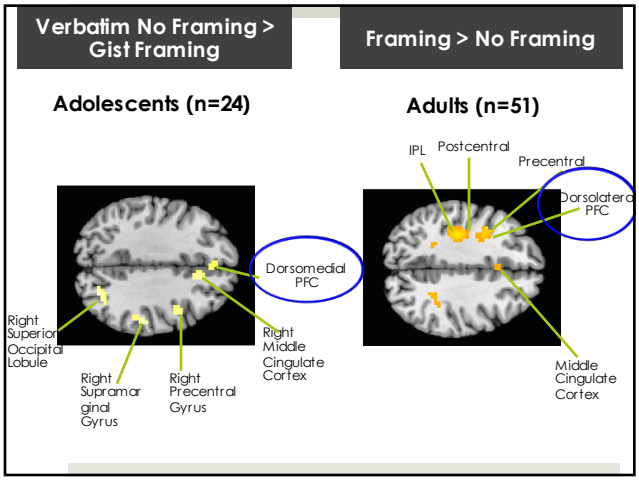
4, 6, 8 seconds
INTERTRIAL INTERVAL

Whole Brain Contrasts

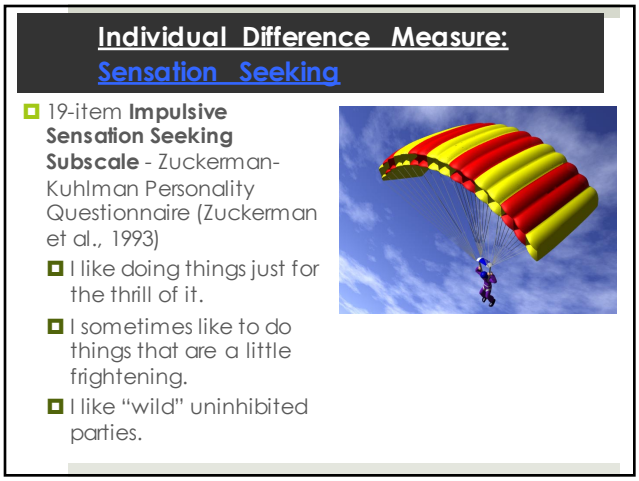
- Activation in one experimental condition – activation in another experimental condition

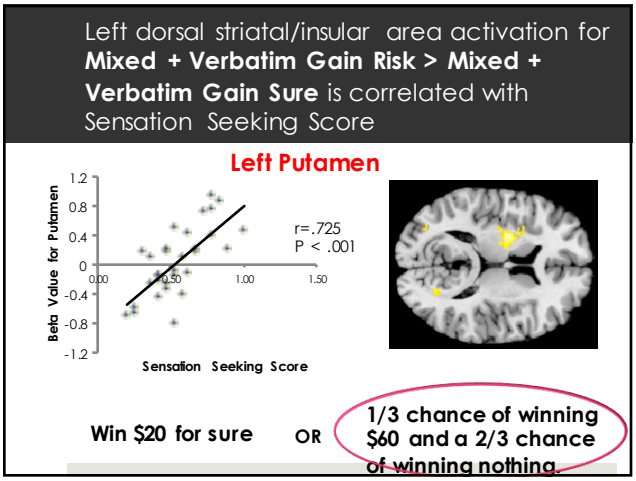
Risky > Sure




Verbatim No Framing > Gist Framing
Framing > No Framing
Adolescents (n=24)
Adults (n=51)
IPL
Postcentral
Precentral
Dorsolateral PFC
Dorsomedial PFC
Right Superior Occipital Lobule
Right Supramarginal Gyrus
Right Precentral Gyrus
Right Middle Cingulate Cortex
Middle Cingulate Cortex


Individual Differences May Affect Decision Making
Milkyway


Individual Difference Measure:
Sensation Seeking
19-item Impulsive Sensation Seeking Subscale - Zuckerman-Kuhlman Personality Questionnaire (Zuckerman et al., 1993)
I like doing things just for the thrill of it.
I sometimes like to do things that are a little frightening.
I like "wild" uninhibited parties.


Left dorsal striatal/insular area activation for Mixed + Verbatim Gain Risk > Mixed + Verbatim Gain Sure is correlated with Sensation Seeking Score
Left Putamen
Beta Value for Putamen
1.2
0.8
0.4
0
-0.4
-0.8
-1.2
0.00
0.50
1.00
1.50
Sensation Seeking Score
r=.725
P < .001
Win $20 for sure
OR
1/3 chance of winning $60 and a 2/3 chance of winning nothing.

Summary

- fMRI is an incredibly powerful tool that allows us to examine activation in the entire brain in a matter of seconds.
- Risky decisions can be modulated as a function of the way information about risks and rewards is presented.
- There are specific gist-based processing areas (dorsolateral prefrontal cortex) and verbatim-based processing areas (dorsomedial prefrontal cortex) in the brain.
- People higher in sensation seeking show greater putamen activation during risky choice for gains.

Thank you!