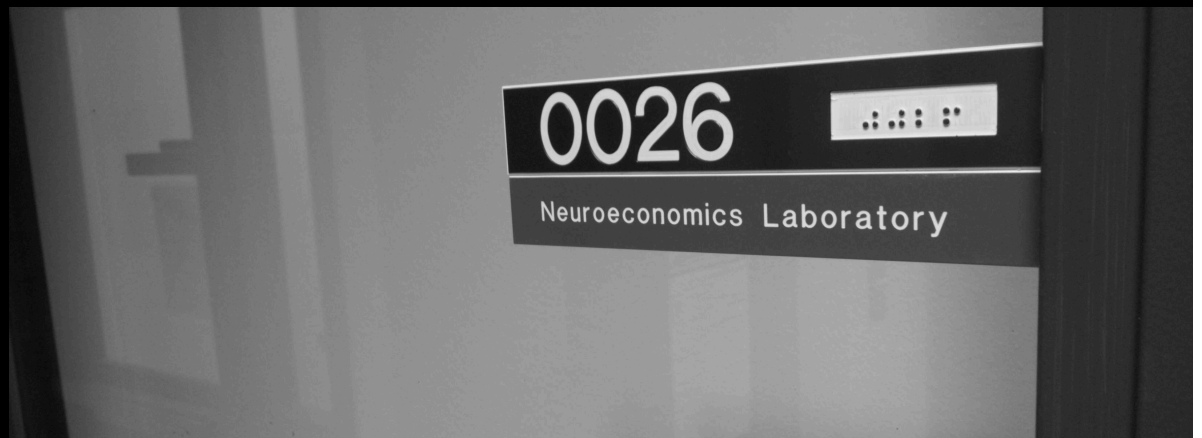


The Neuroscience of Human Decision Making

Dr. Olav E. Krigolson
University of Victoria



Part I. Theory

Utilitarianism

People seek actions that increase utility and avoid actions that decrease utility

-Mill, 1861

Decision Making

Our ability to process multiple alternatives and choose the option that maximizes utility



Huygens, 1657

Expected Value = Value x Probability

Expanded Form

$$EV = \text{Gain} \times P_G - \text{Cost} \times P_C$$

The Problem with Value...



The Problem with Probability...



1 in 13.3 million

chance of **contracting Ebola in America** this year
(based on a model of 12 imported cases of Ebola
in the course of a year)



1 in 11 million

chance of **dying in a plane crash**
for an American this year



1 in 9.6 million

chance of **dying from a lightning strike**
for an American this year



1 in 5.2 million

chance of **dying from a bee sting**
for an American this year



1 in 3.7 million

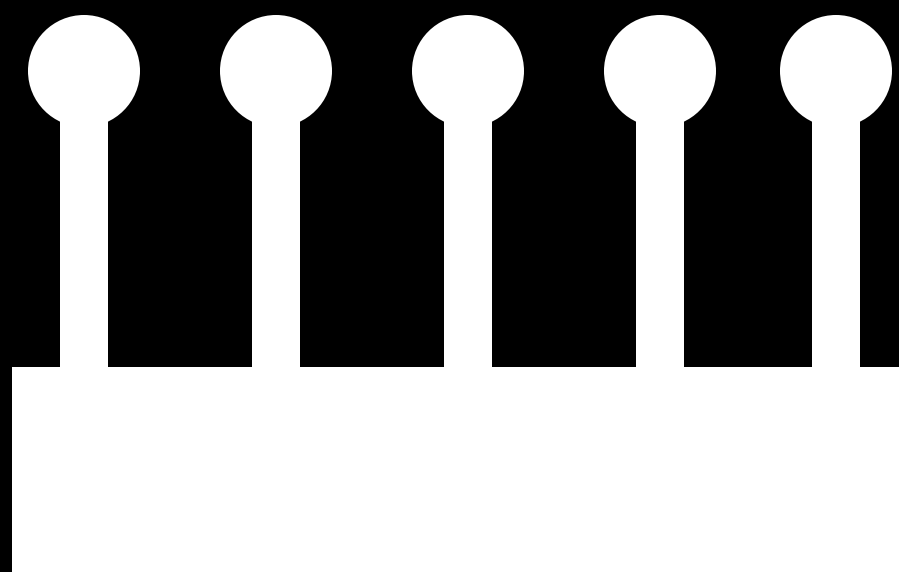
chance of being **killed by a shark**
in your lifetime (worldwide)



1 in 9100

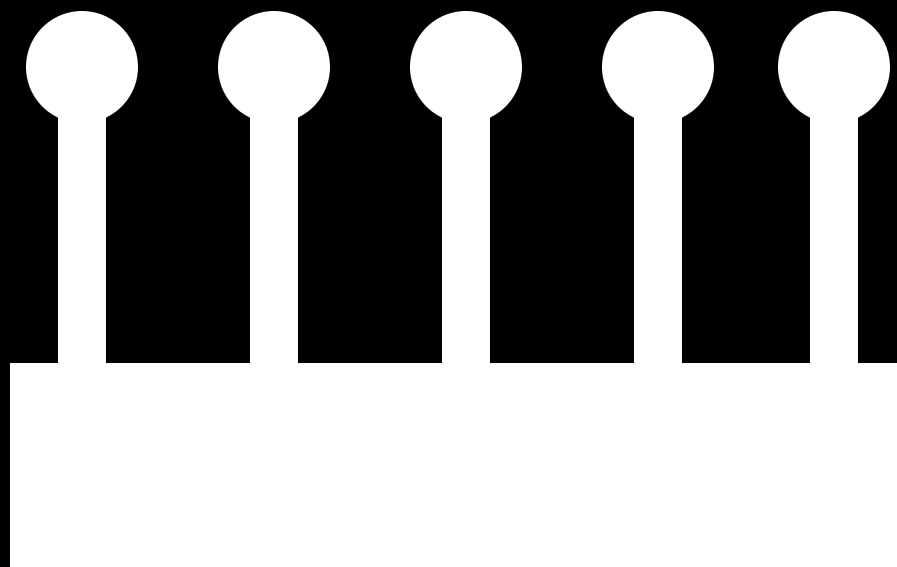
chance of being **killed in a car accident**
in America this year

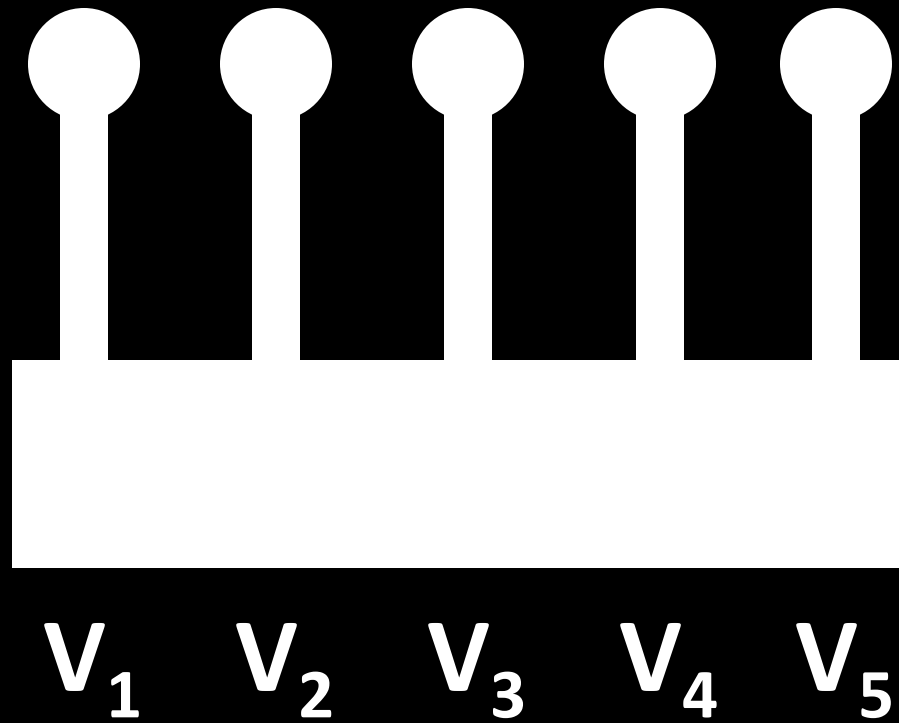
The Problem with Huygens



\$

?

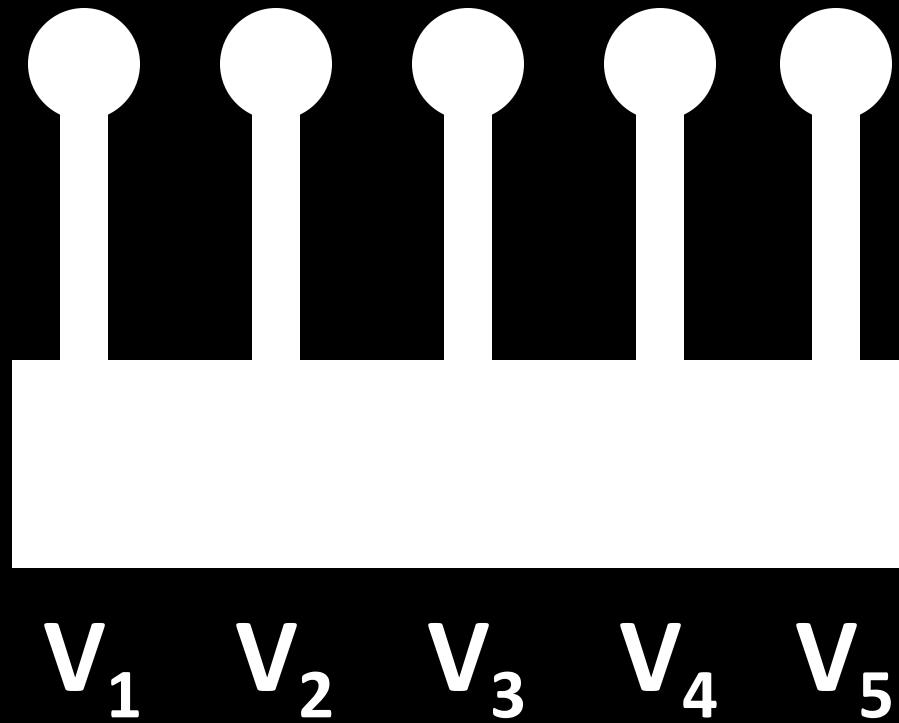




Where: $V_n = \sum r_n / \text{attempts}_n$

Decision Making

1. Always choose the highest value option



Where: $V_n = \sum r_n / \text{attempts}_n$

Decision Making

1. Always Choose the Highest Value Option
2. Exploration versus Exploitation



R_1

R_2

R_3

R_4

R_5

3.8

3.9

3.95

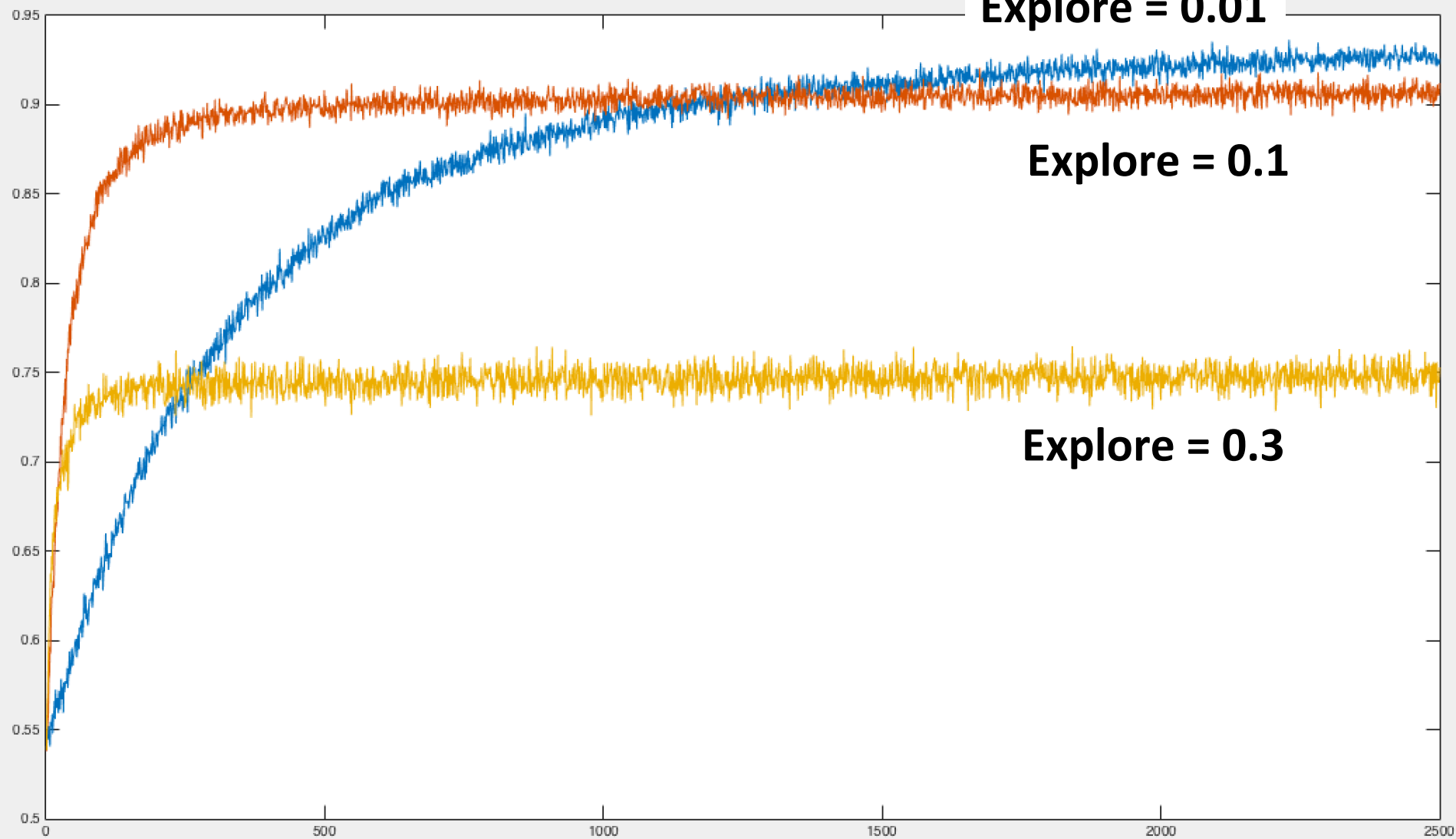
1.0

2.0

Explore = 0.01

Explore = 0.1

Explore = 0.3



Why Explore?

1. Unknown Values

2. Changing Environments

Should exploration rates change over time?

A Sample Problem

Problem 1

Would you play a gamble that has a 40% chance to win \$1000 or a 70% chance to win \$600?

Other Problems...

Consider...

Problem 1: In addition to whatever you own, you have been given \$1000.
You are now asked to choose of these option
50% chance to win \$1000 OR get \$500 for sure.

Problem 2: In addition to whatever you own, you have been given \$2000.
You are now asked to choose of these option
50% change to lose \$1000 OR lose \$500 for sure.

Consider...

Problem 1: In addition to whatever you own, you have been given \$1000.

You are now asked to choose of these option
50% chance to win \$1000 OR **get \$500 for sure**

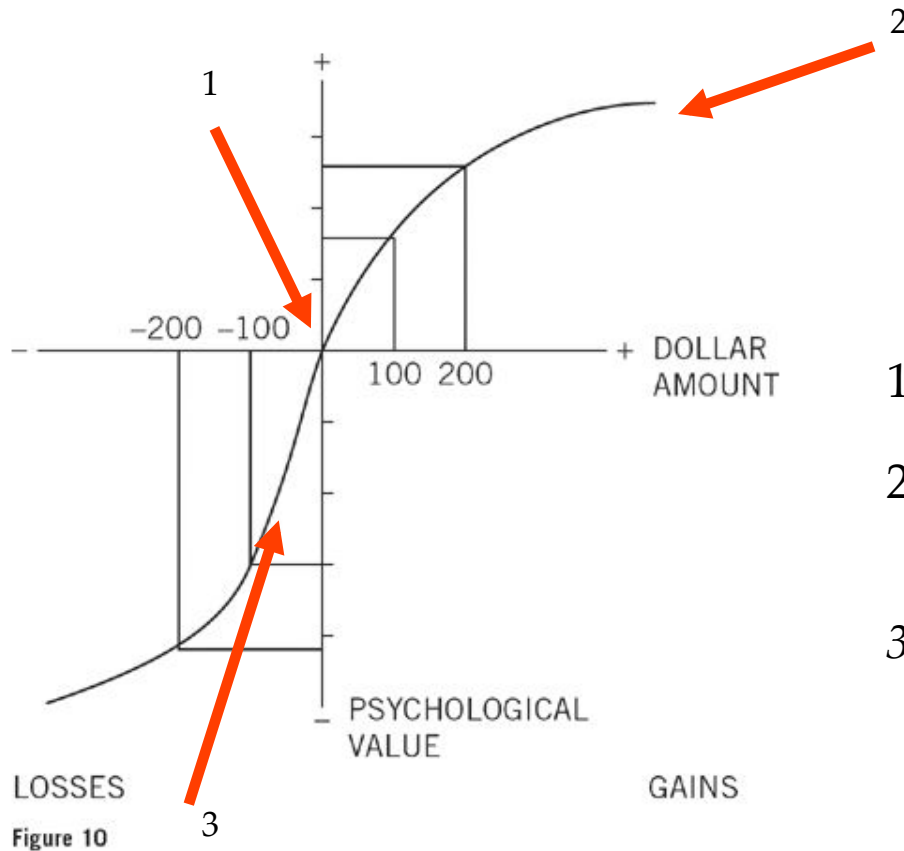
Problem 2: In addition to whatever you own, you have been given \$2000.

You are now asked to choose one of these options:
50% chance to lose \$1000 OR lose \$500 for sure

Prospect Theory

Daniel Kahneman and Amos Tversky

Prospect Theory



1. Neutral reference point
2. Diminishing sensitivity to gains and losses
3. S is not symmetrical

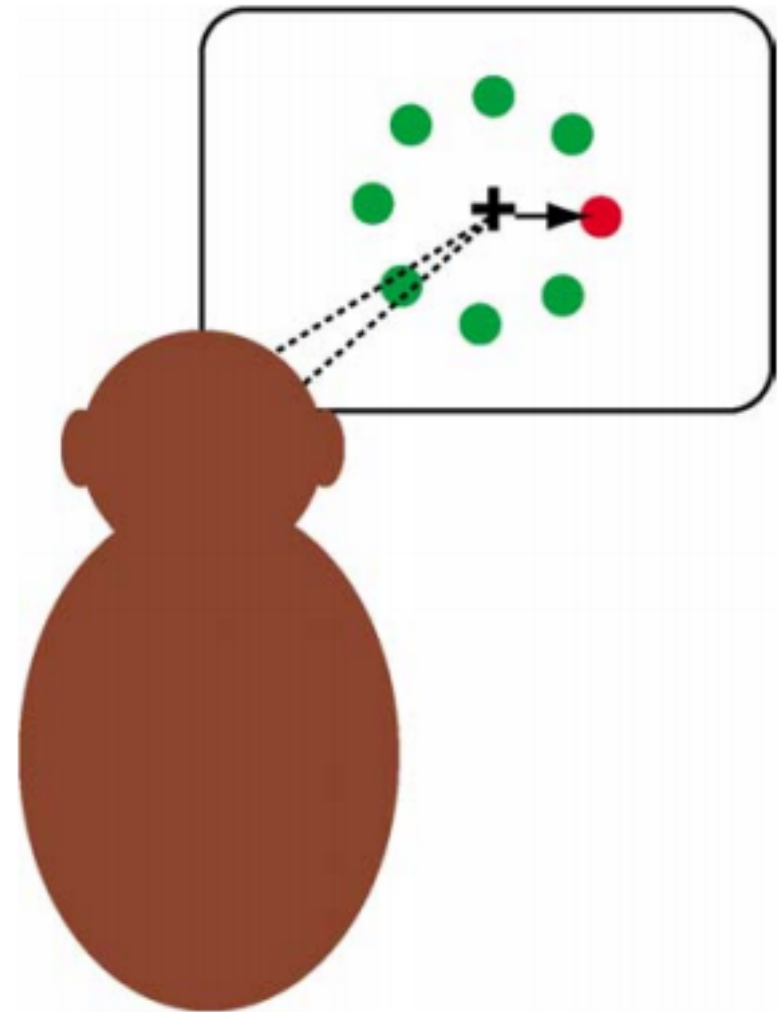
Figure 10

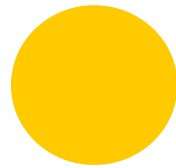
LOSS AVERSION

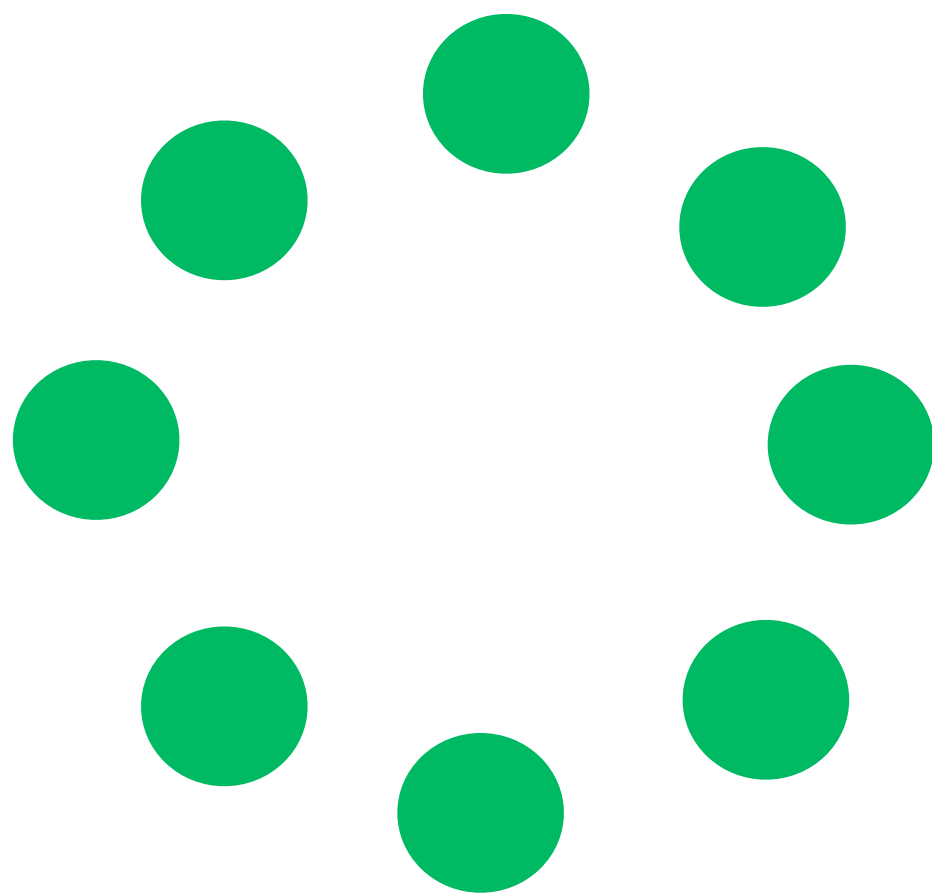
Part II. Experimental Data

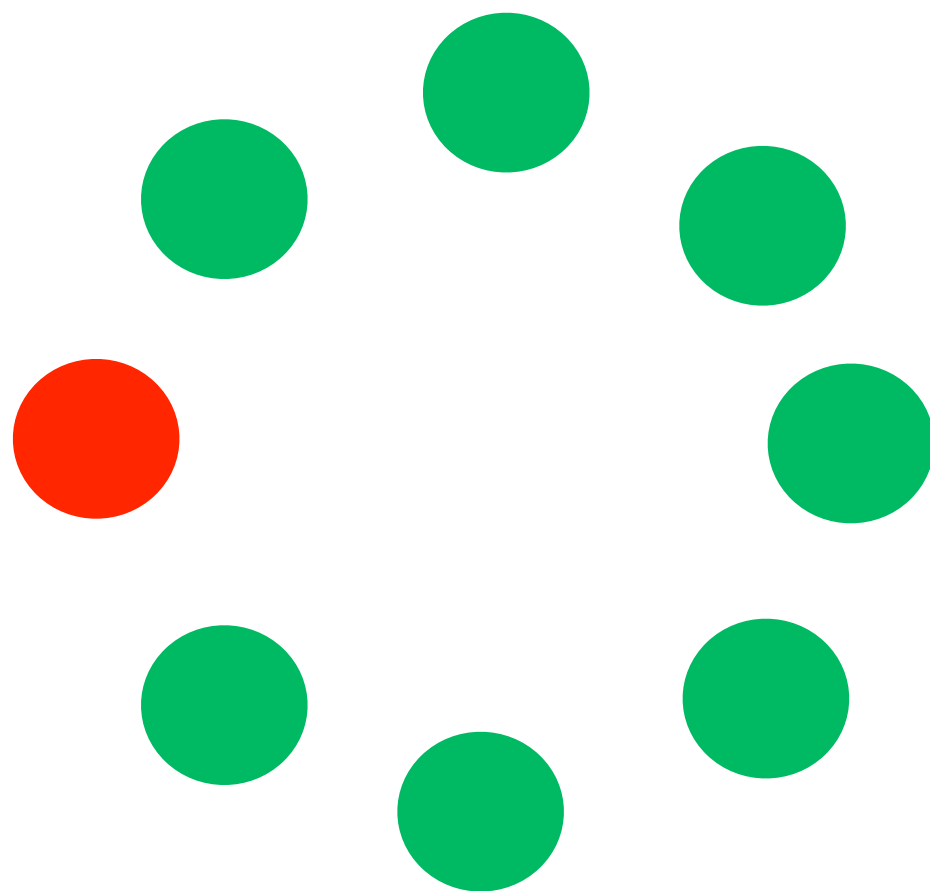
Hanes & Schall, 1996

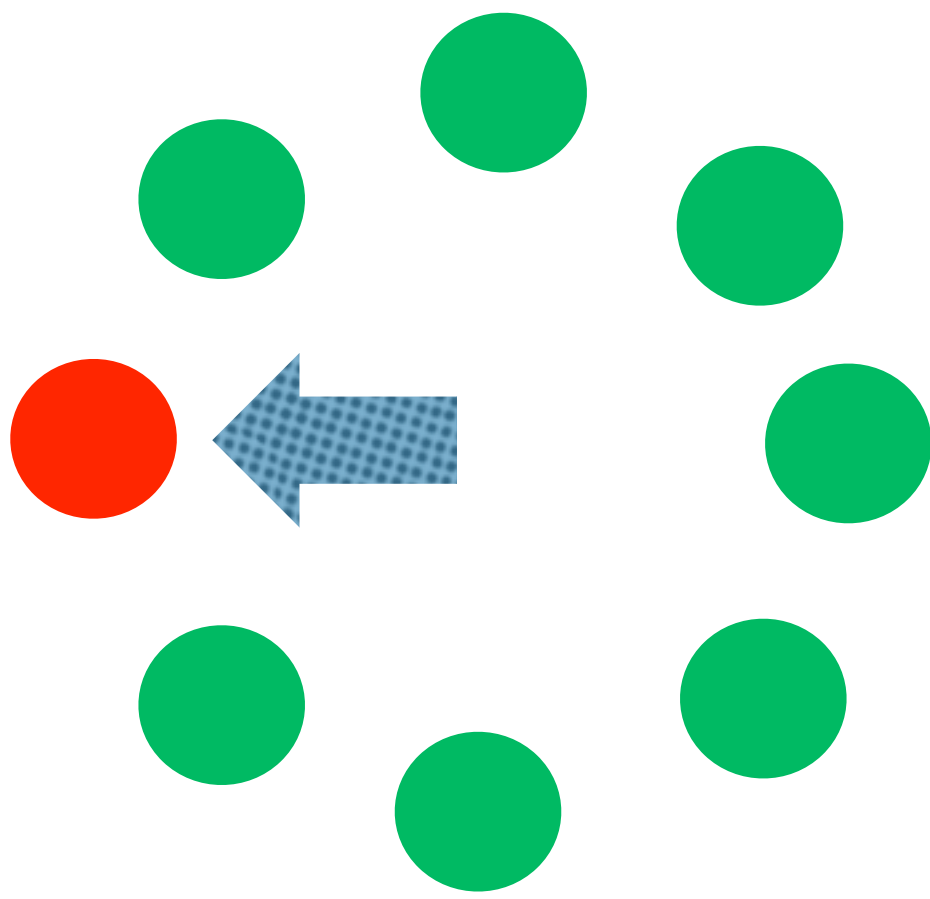
- Monkey is situated in a chair, trained to stare at a blank screen
- Recording of neuronal activity in PPC
- Stimulus onset (circle of green circles)
- Monkey chooses odd dot
- Monkey receives juice







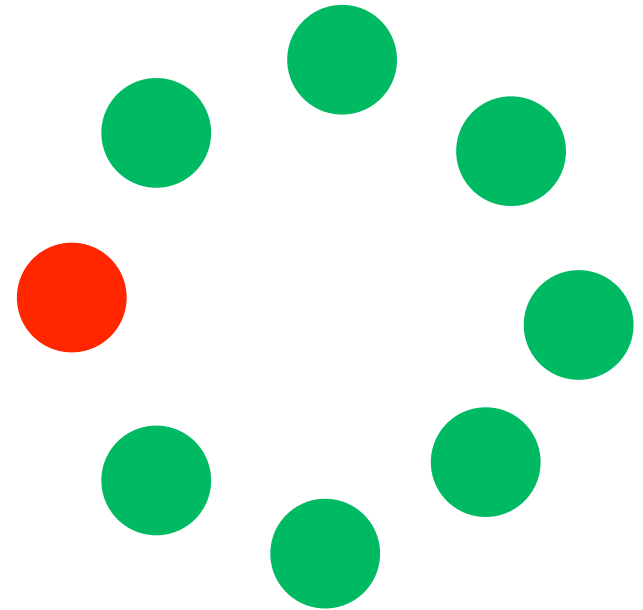






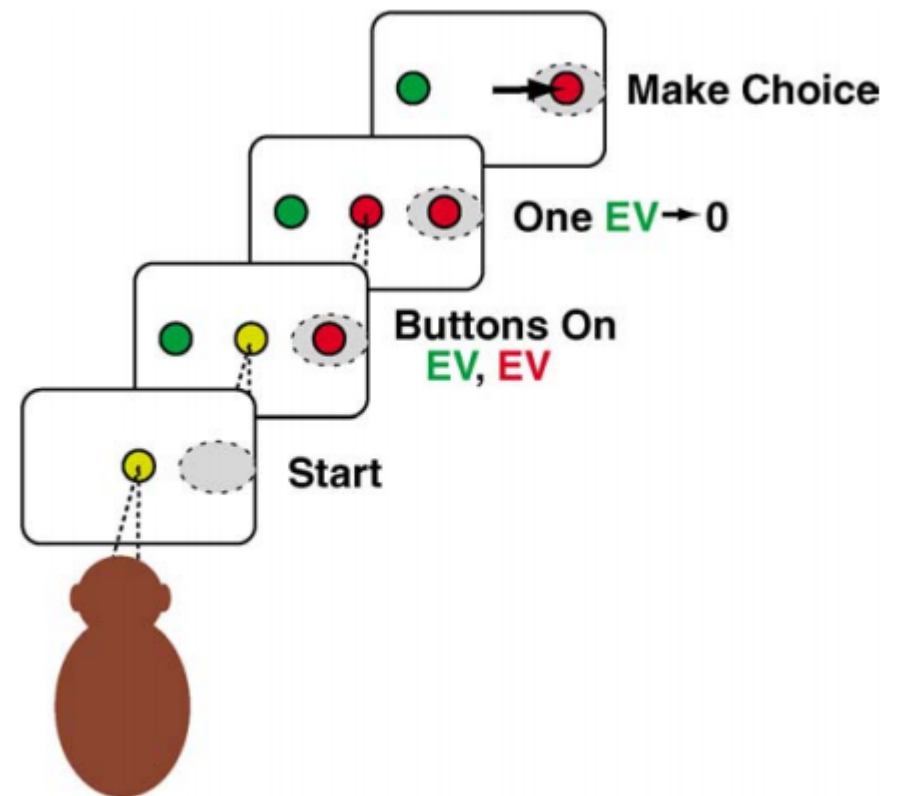
Hanes & Schall, 1996

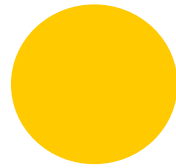
- all neurons activate upon viewing of the stimulus
- firing rates suppressed for all non-relevant targets
- conclusion: neurons are encoding the rewarding nature of target

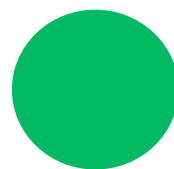
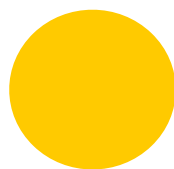
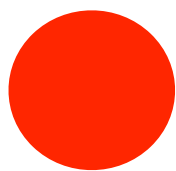


Glimcher et al. 2004

- do neurons encode choice values?

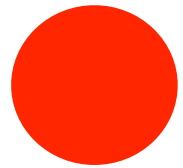




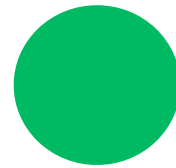








0.8 ml juice

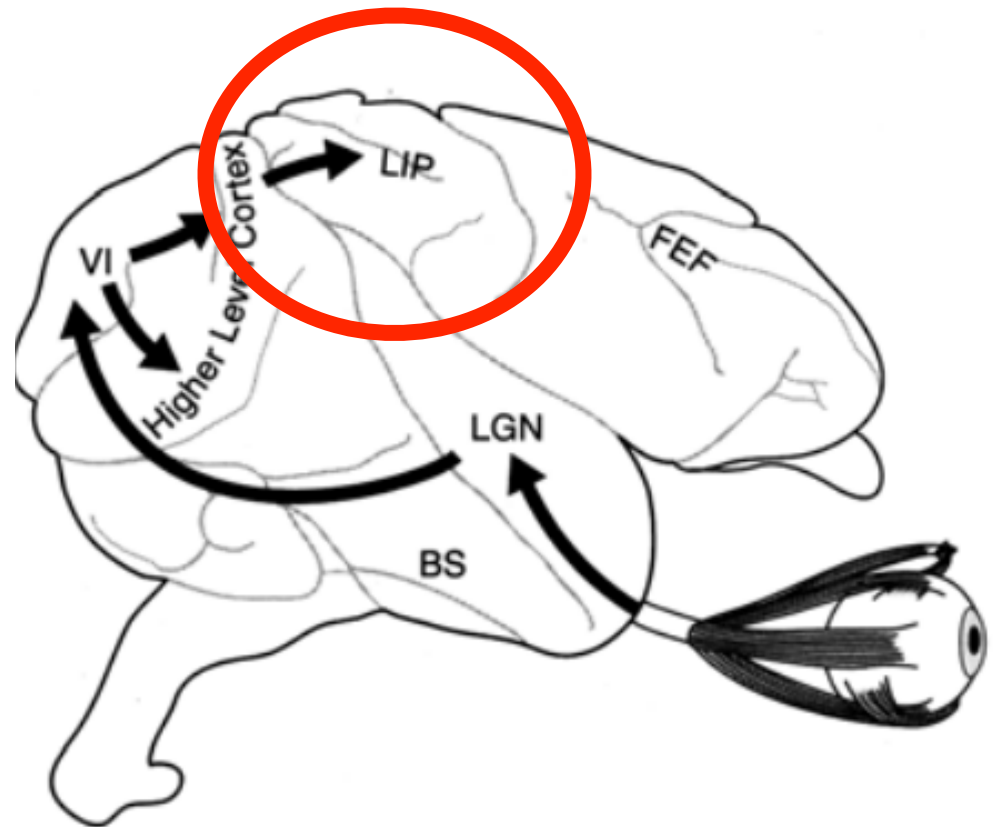


0.2 ml juice

Glimcher et al. 2004

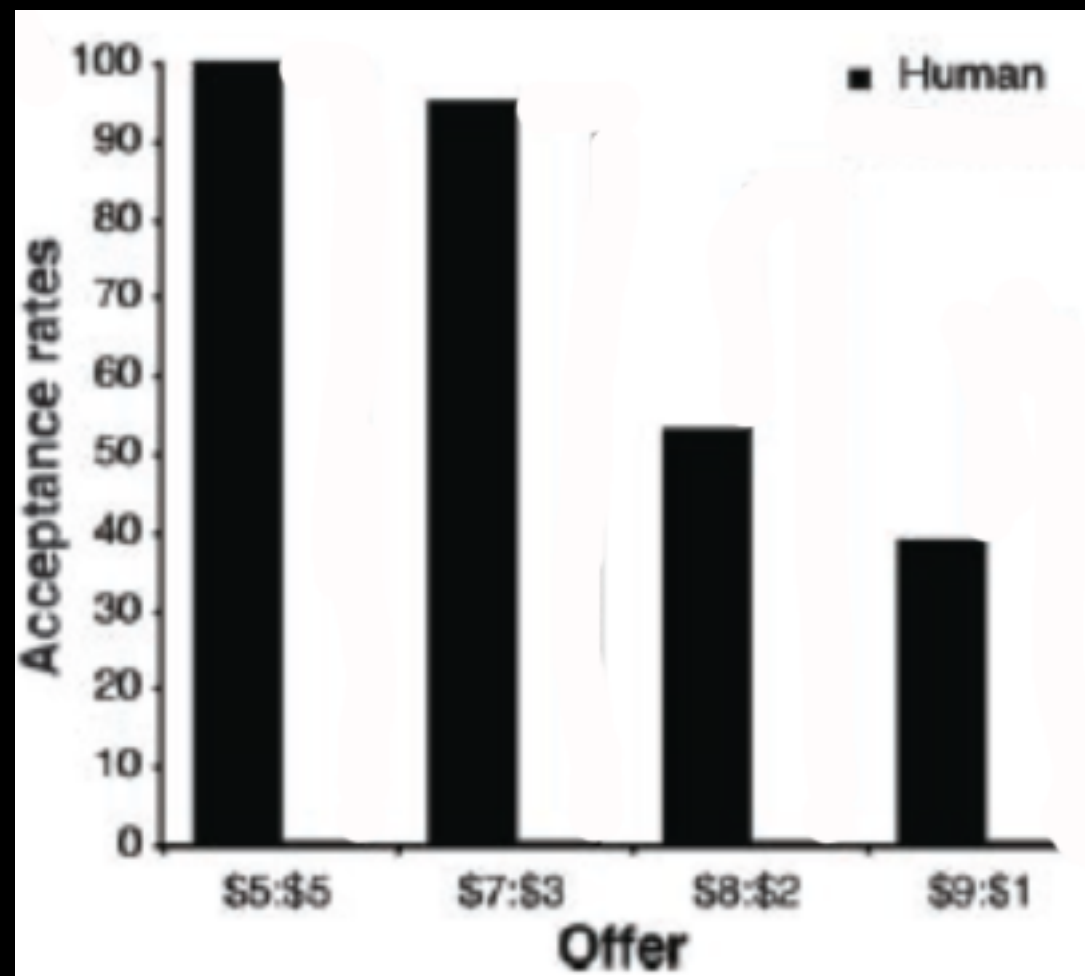
$$\frac{LeftReward}{LeftReward + RightReward} = FiringRate.$$

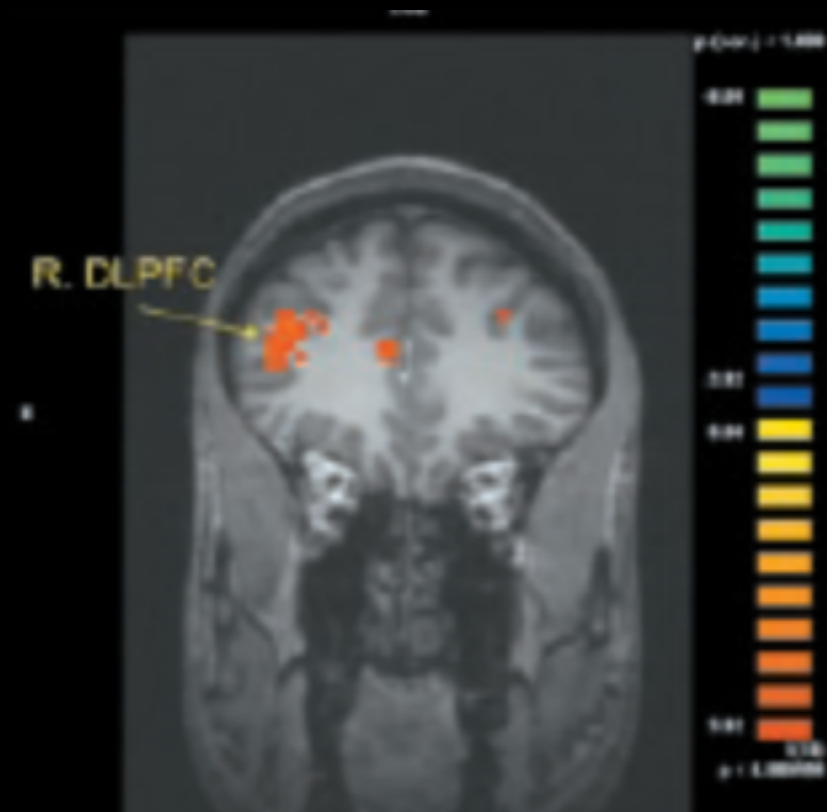
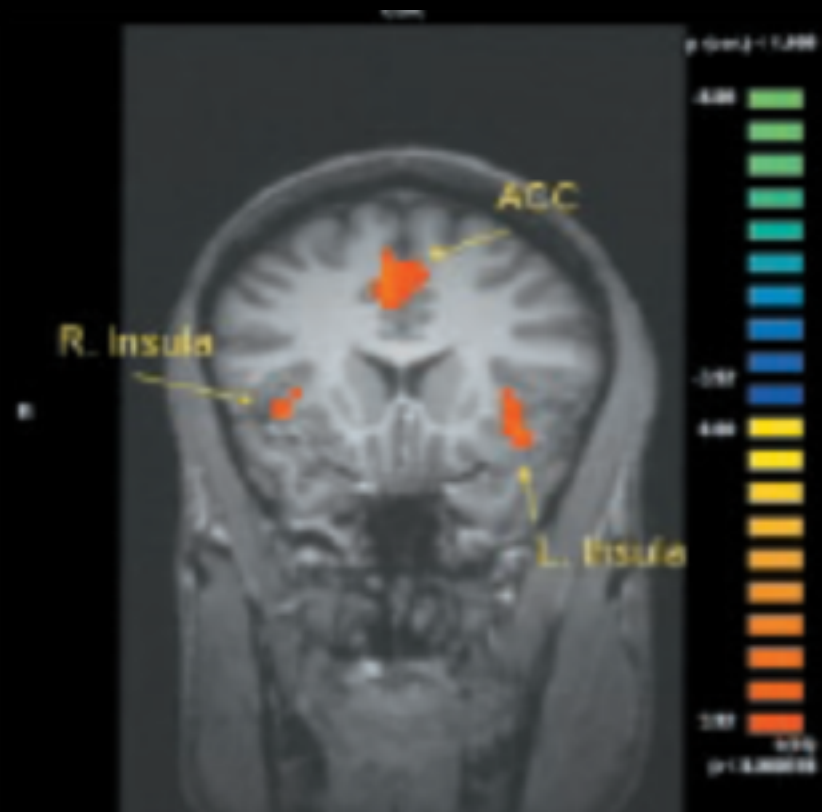
Neurons in the the lateral intraparietal cortex (LIP) scaled in firing rate to expected utility

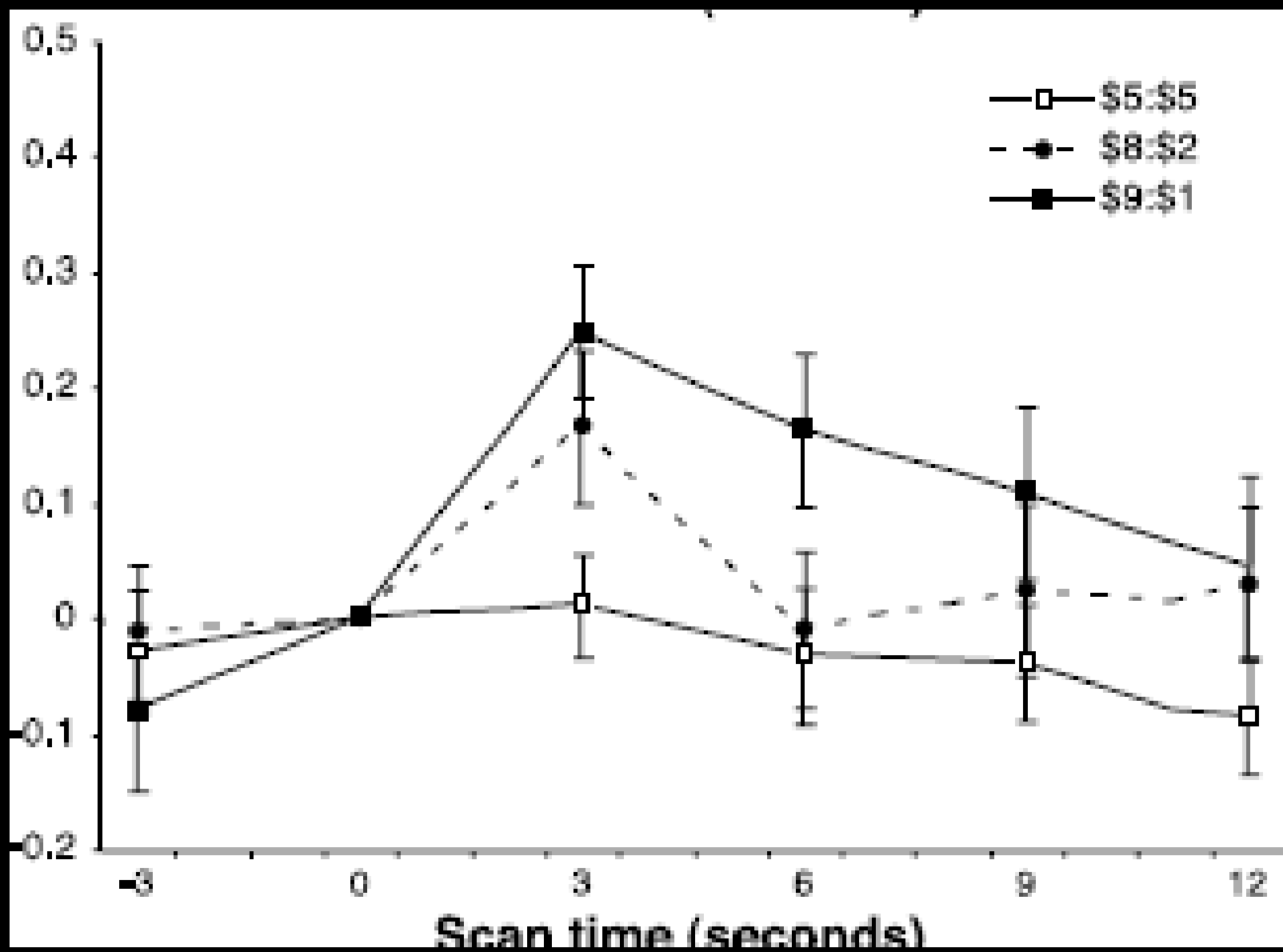


Part III. Multiple Decision Systems
Logical vs Emotional Systems
(and yet another problem with Huygens)

The Ultimatum Game

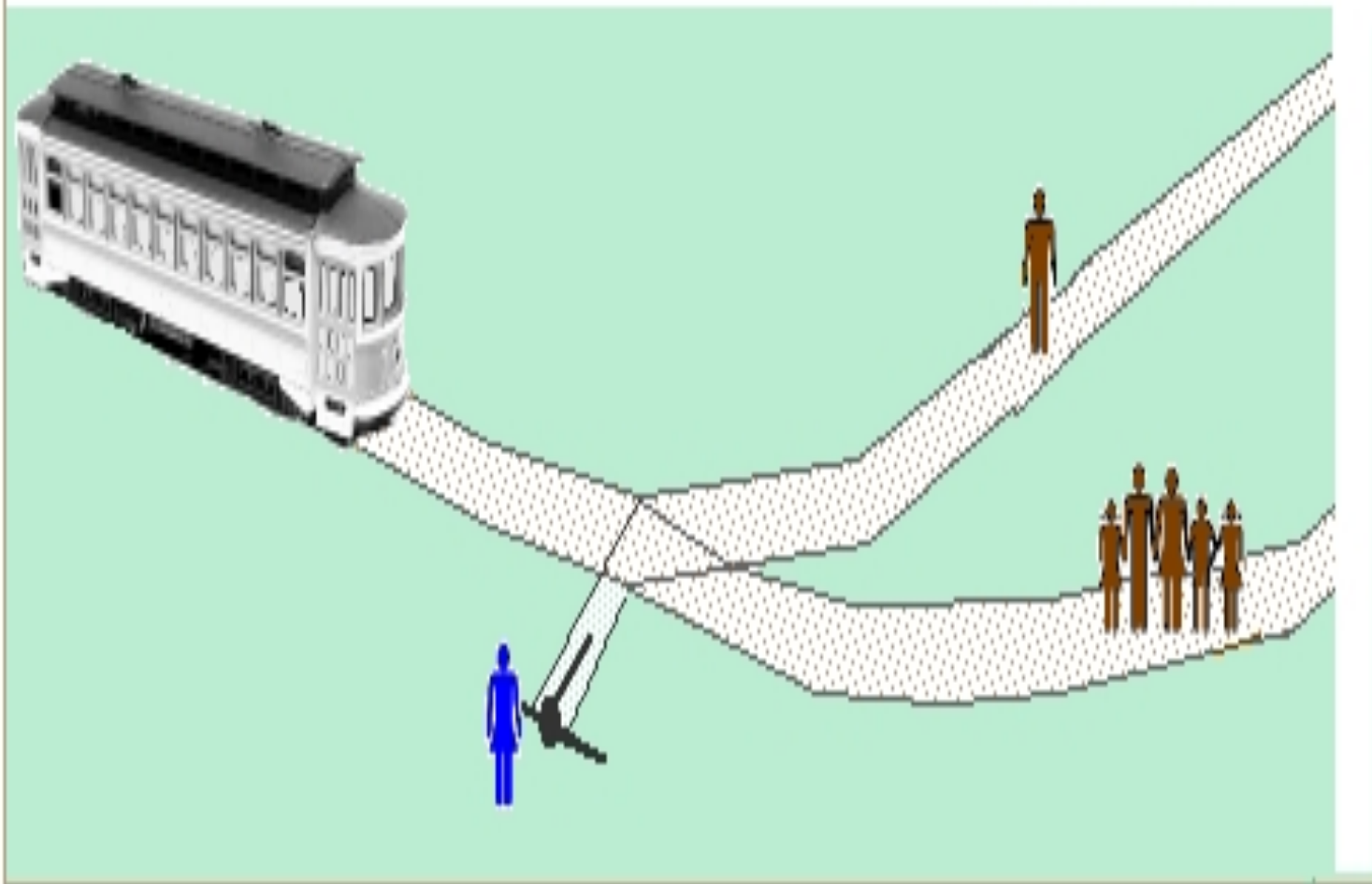






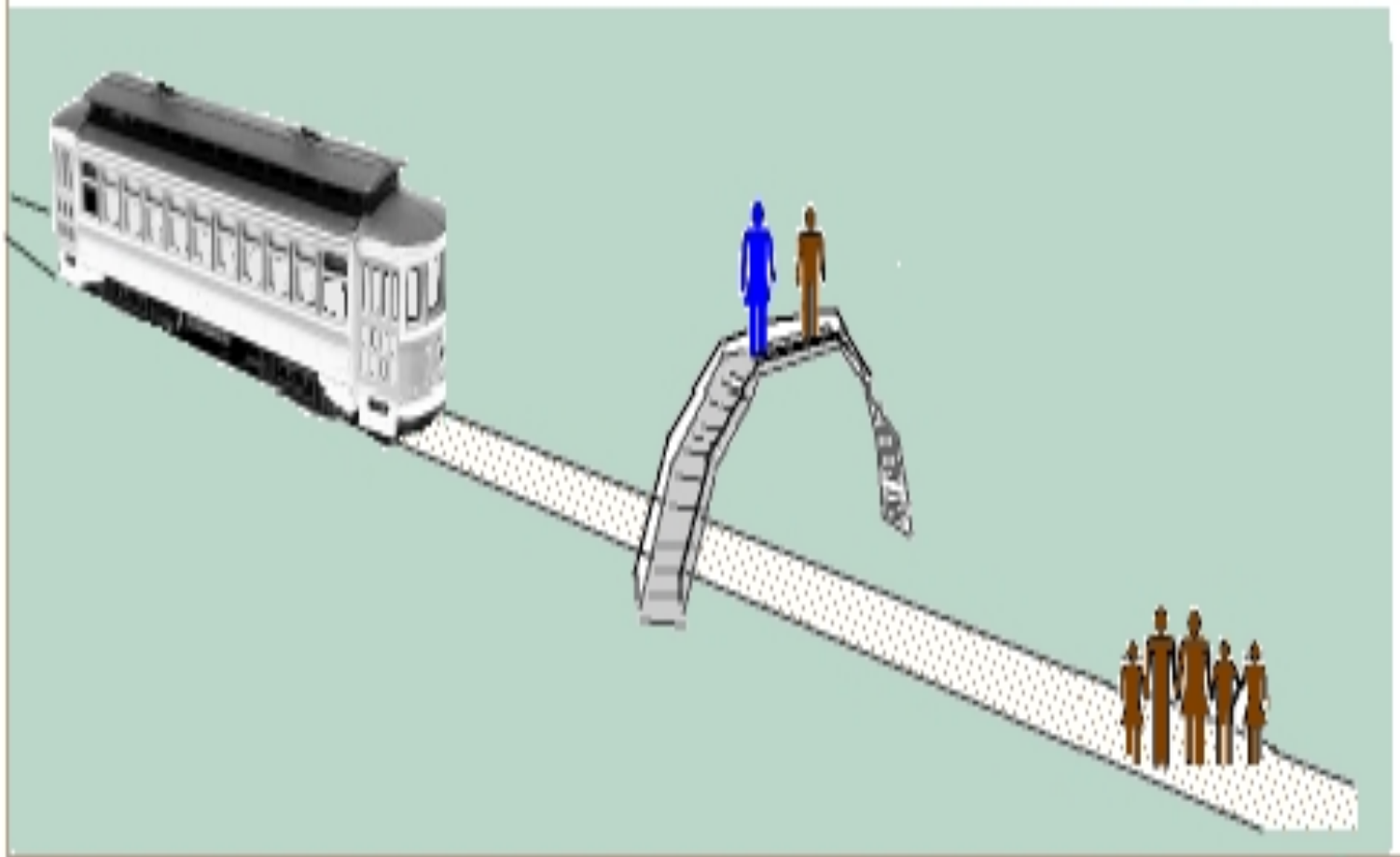


The Trolley Dilemma



Greene et al., 2004

The Footbridge Dilemma

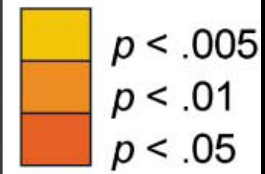
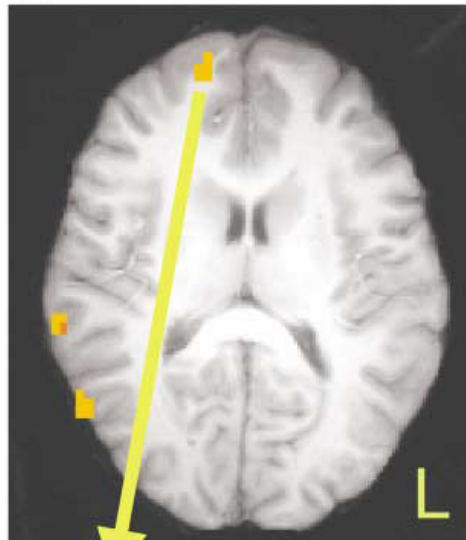


Greene et al., 2004

A

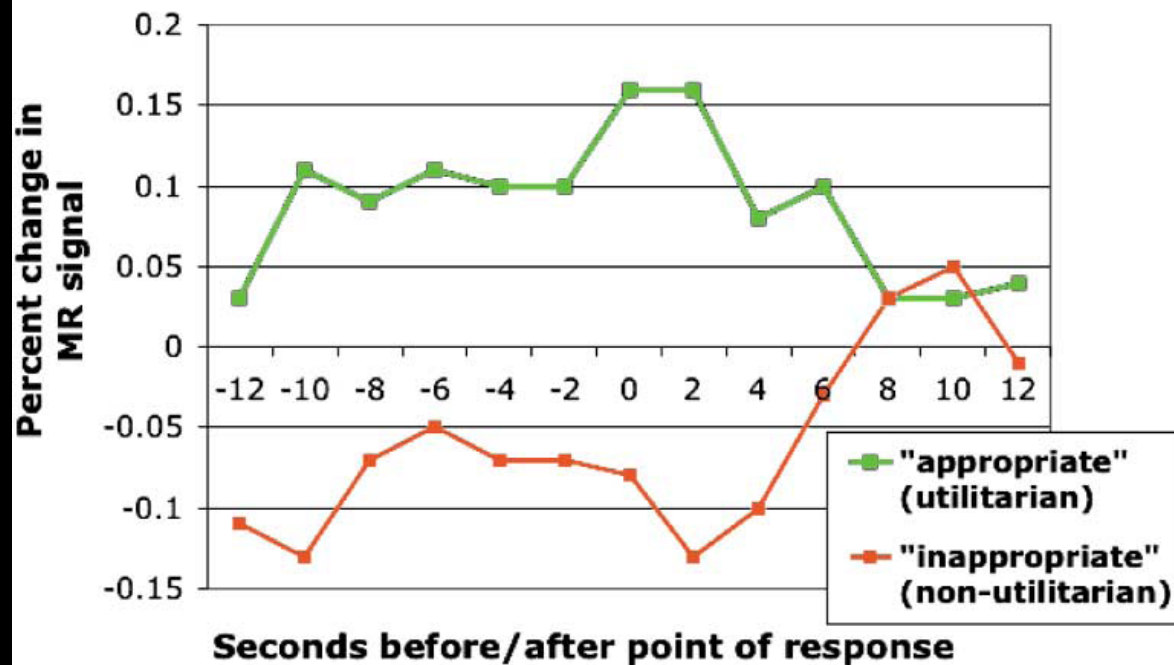


B



C

Right anterior DLPFC: Utilitarian vs. non-utilitarian moral judgment



Greene et al., 2004

Sample Problem

You and your childhood friend have the dream job. Hard work and persistence has you both in positions of management. For whatever reason, your friend's attitude takes a turn for the worse and he makes a very questionable decision, putting five other people's jobs in jeopardy. Your boss does not suspect your friend is to blame. His mistake will cost five people their jobs if you don't step forward with what the truth. Either...

A) Explain to your boss the truth, and save the five people's jobs or...



B) Remain silent and let the five innocent coworkers take the blame but your friend's job remains safe.



Part III. Multiple Decision Systems
System I vs System II
(and yes, Huygens would not have thought of this either)

System I
"Fast"

System II
"Slow"



Kahneman (2011)

$$2 + 2 =$$

“bread and ...”



$$13678 / 13 =$$

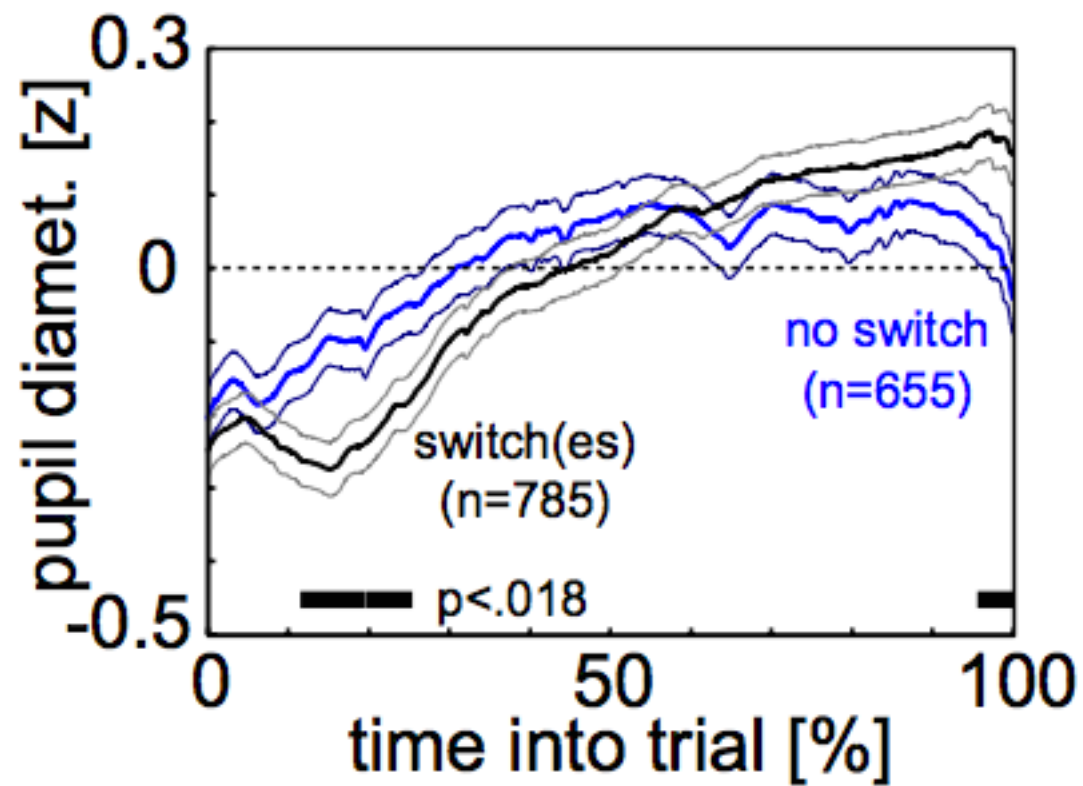
“the third highest mountain in BC is ...”



System II



System I ?



Part IV.
Work from my Laboratory

A Universal Model of Diagnostic Reasoning

Pat Croskerry, MD, PhD

Abstract

Clinical judgment is a critical aspect of physician performance in medicine. It is essential in the formulation of a diagnosis and key to the effective and safe management of patients. Yet, the overall diagnostic error rate remains unacceptably high. In more than four decades of research, a variety of approaches have been taken, but a consensus approach toward diagnostic decision making has not emerged.

In the last 20 years, important gains have been made in psychological research on

human judgment. Dual-process theory has emerged as the predominant approach, positing two systems of decision making, System 1 (heuristic, intuitive) and System 2 (systematic, analytical). The author proposes a schematic model that uses the theory to develop a universal approach toward clinical decision making. Properties of the model explain many of the observed characteristics of physicians' performance. Yet the author cautions that not all medical reasoning and decision making falls neatly into one or

the other of the model's systems, even though they provide a basic framework incorporating the recognized diverse approaches. He also emphasizes the complexity of decision making in actual clinical situations and the urgent need for more research to help clinicians gain additional insight and understanding regarding their decision making.

Acad Med. 2009; 84:1022–1028.



READ (80s)

A 38 yr old man, dx 18 yrs ago with ulcerative colitis is referred to your clinic with itching & abnormal liver enzymes.

Medical Hx: Non-smoker. Drinks 1-2 beers/d. No hx of blood transfusions. No IV drug use or high risk sexual behavior. No psych illness. No family hx of liver disease. Has had 3 courses of prednisone for ulcerative colitis flares which happen approximately every 6 yrs.

Recent Hx: Completed course of corticosteroids (prednisone) 6 months ago. Complains of mild, generalized itching for past 3 months. No skin rash noted. Taking Asacol (mesalamine) 3g/d for ulcerative colitis maintenance.

Assessment: No diabetes, joint pains or lung disease.

Physical exam normal. Normal BMI. Has 1 soft non-bloody BM/d.

Eating well. No abdominal pain. Ultrasound reveals normal gallbladder with no biliary dilatation.

ALT 45 (7-40)	AST 32 (5-35)	Alk Phos 536 (30-145)	GGT 540 (20-35)	INR 1.0 (0.9-1.1)
Total Bili 12 (5-22)	Hgb 155 (140-180)	WBC 9.1 (3.5-12)	PLT 180 (150-400)	

MCQ (20s)

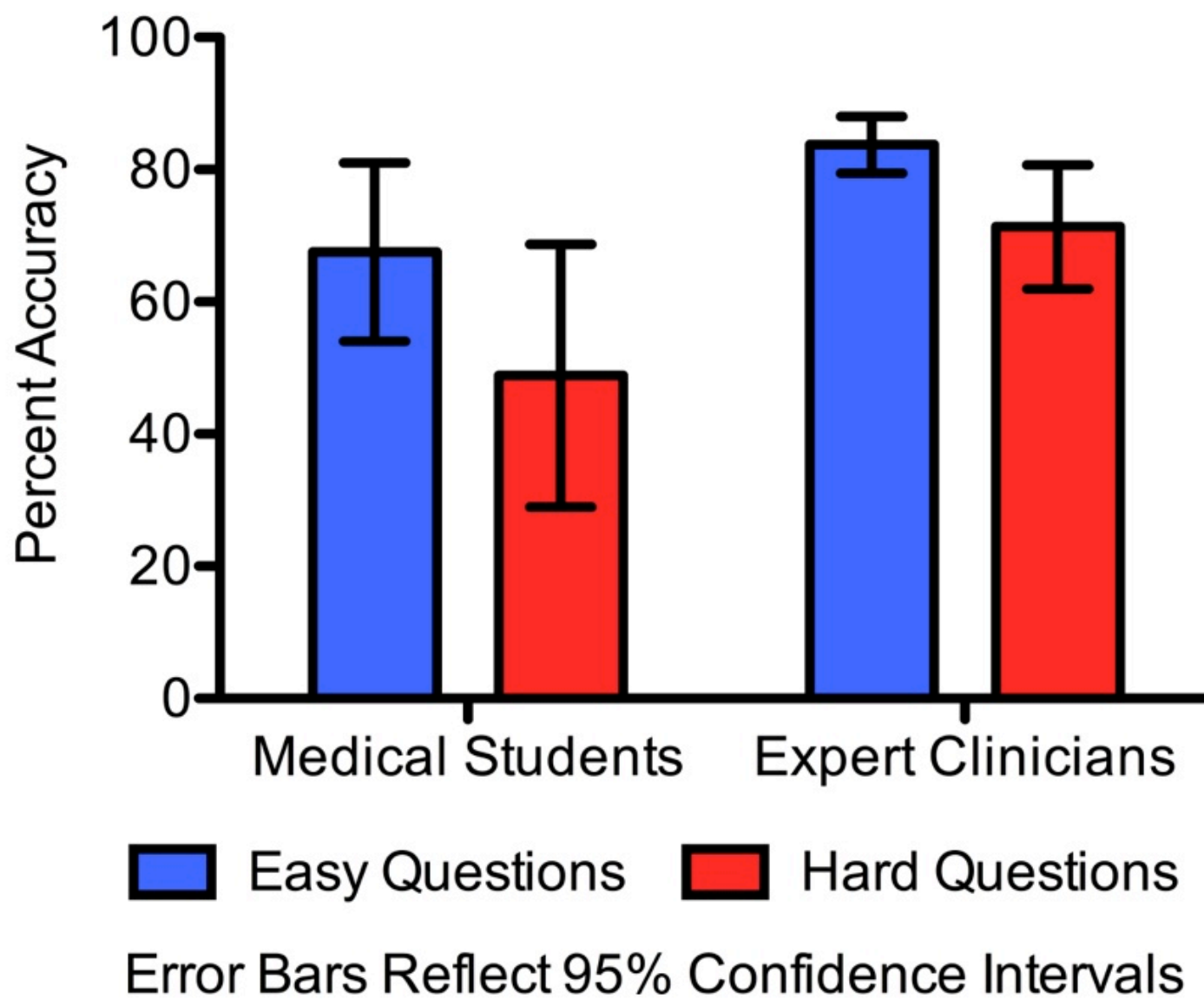
What is the most likely diagnosis?

- A. Primary biliary cirrhosis
- B. Viral Hepatitis B
- C. Choledocholithiasis
- D. Primary sclerosing cholangitis

Feedback (20s)

What is the most likely diagnosis?

- ☒ A. Primary biliary cirrhosis
- ☐ B. Viral Hepatitis B
- ☐ C. Cholelithiasis
- ☒ D. Primary sclerosing cholangitis



READ (80s)

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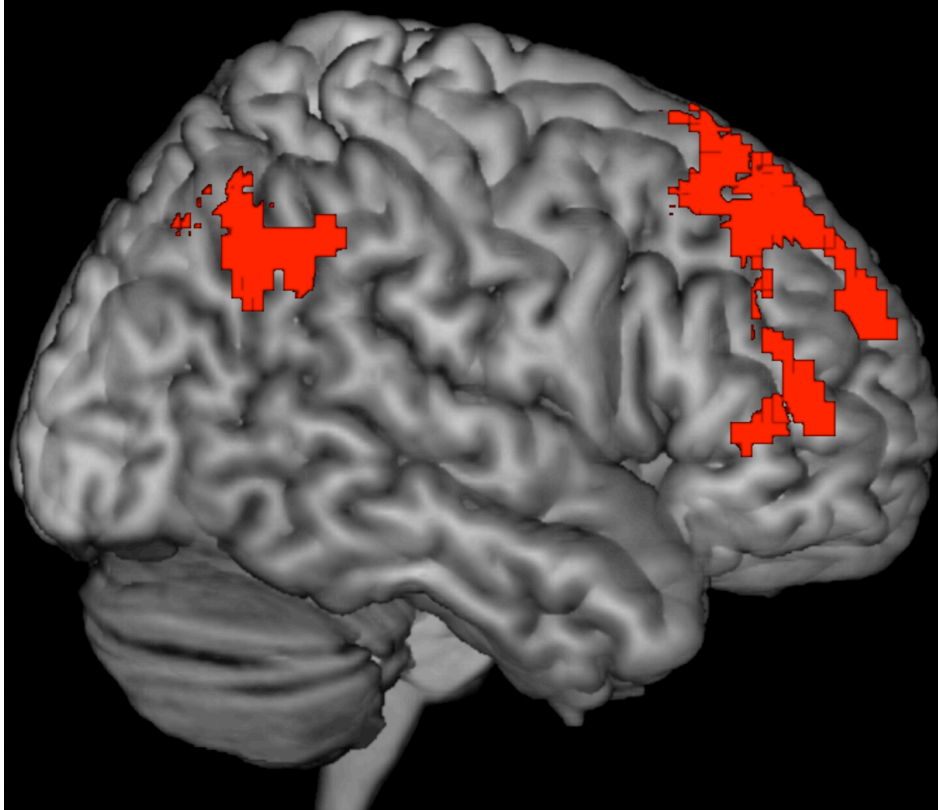
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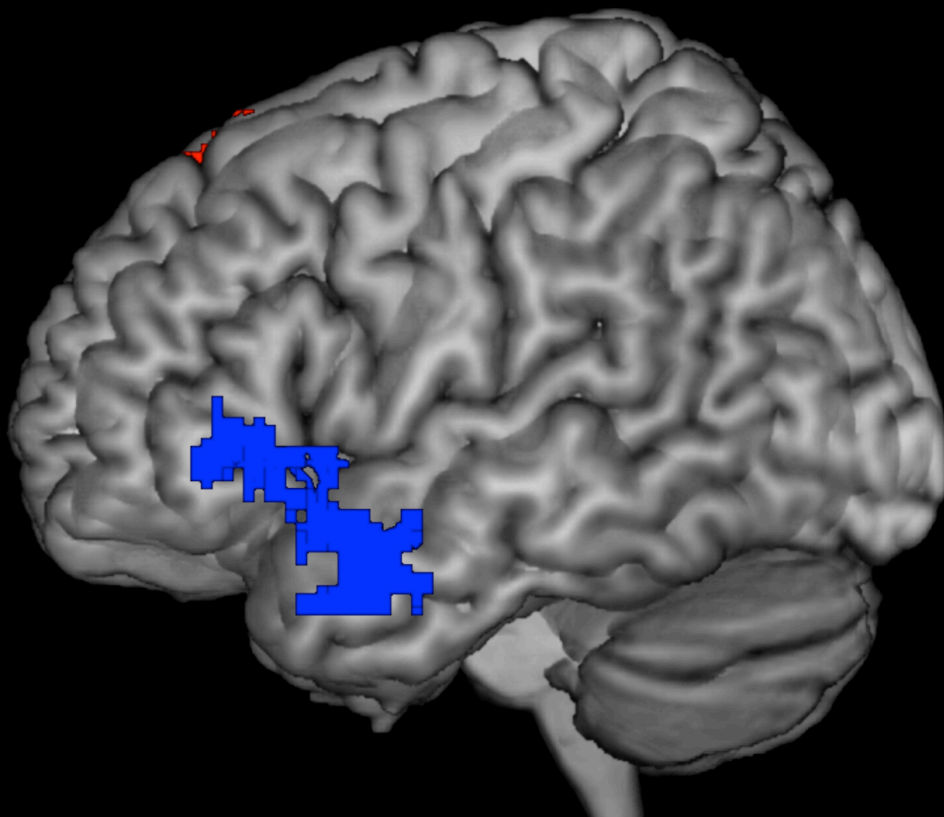
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Total Bili 12 (5-22)	Hgb 155 (140-180)	WBC 9.1 (3.5-12)	PLT 180 (150-400)	

Right



Experts
Holistic, Experience Based Imagery

Left

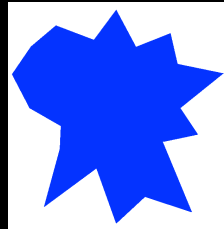
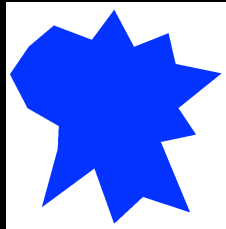


Novices
Analytic, Book Based Knowledge

Electroencephalographic Evidence for System I and System II

Trial Order

+



+

"Correct"

C

400-600ms

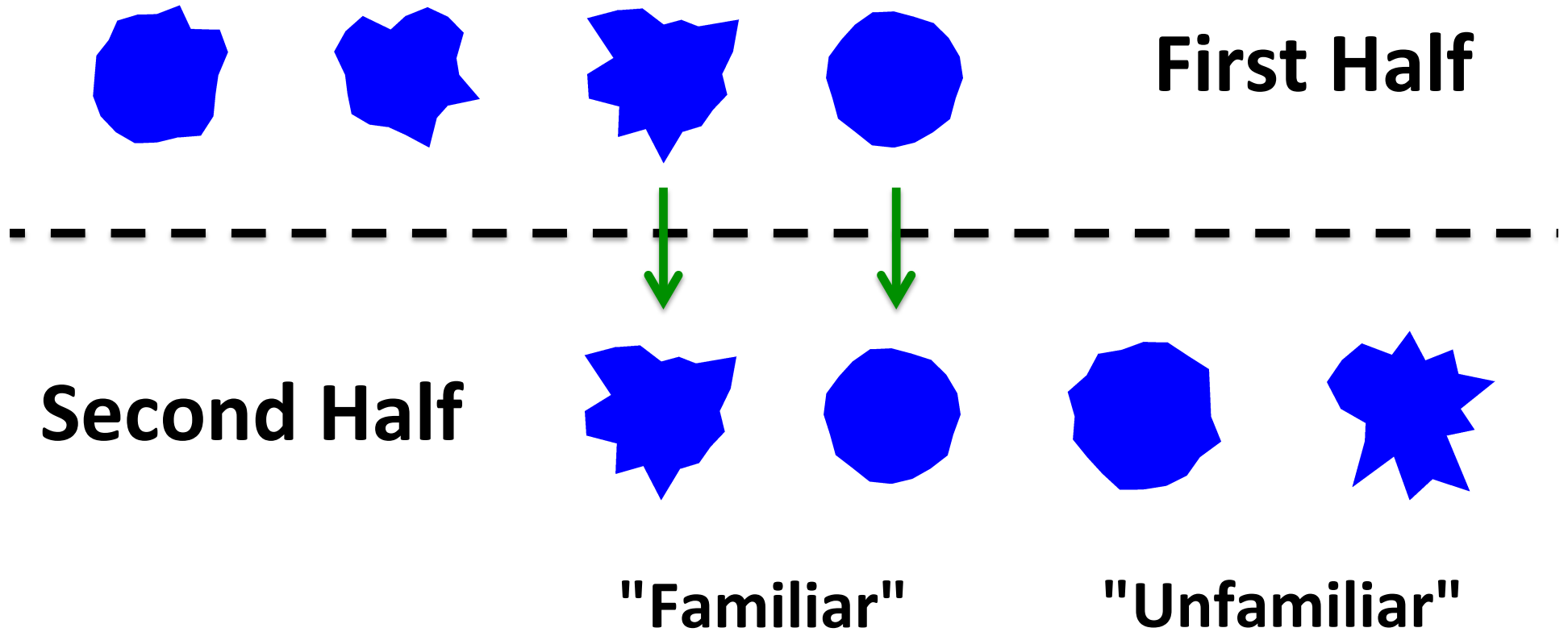
800-1200ms

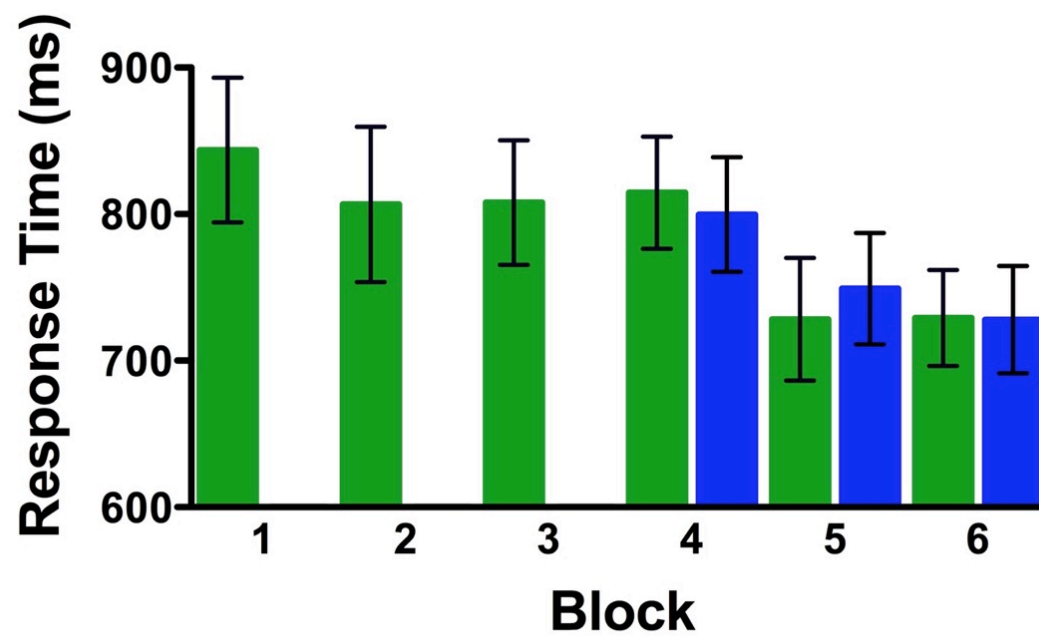
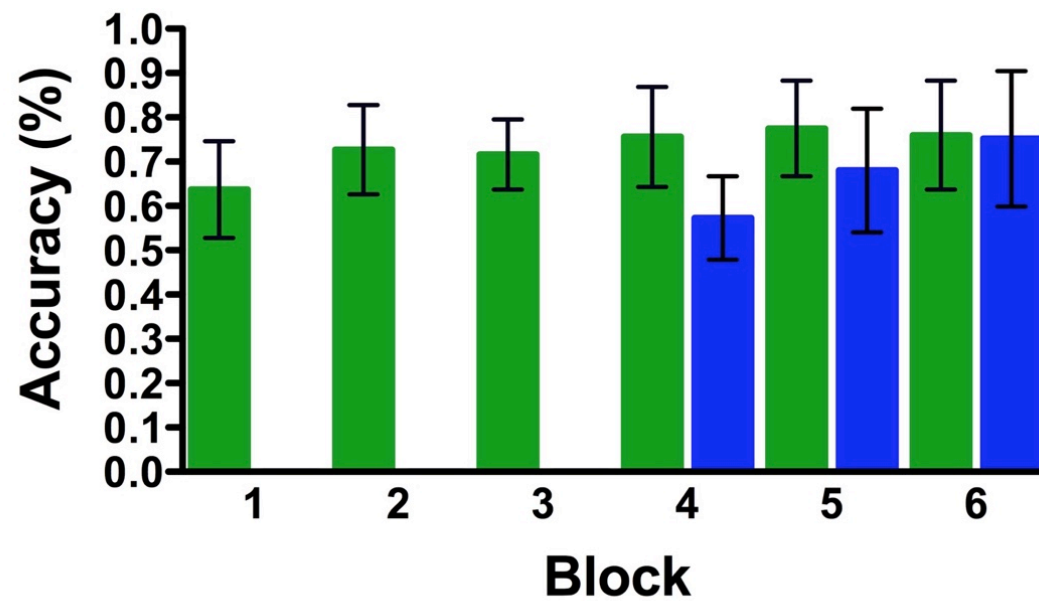
700-1000ms

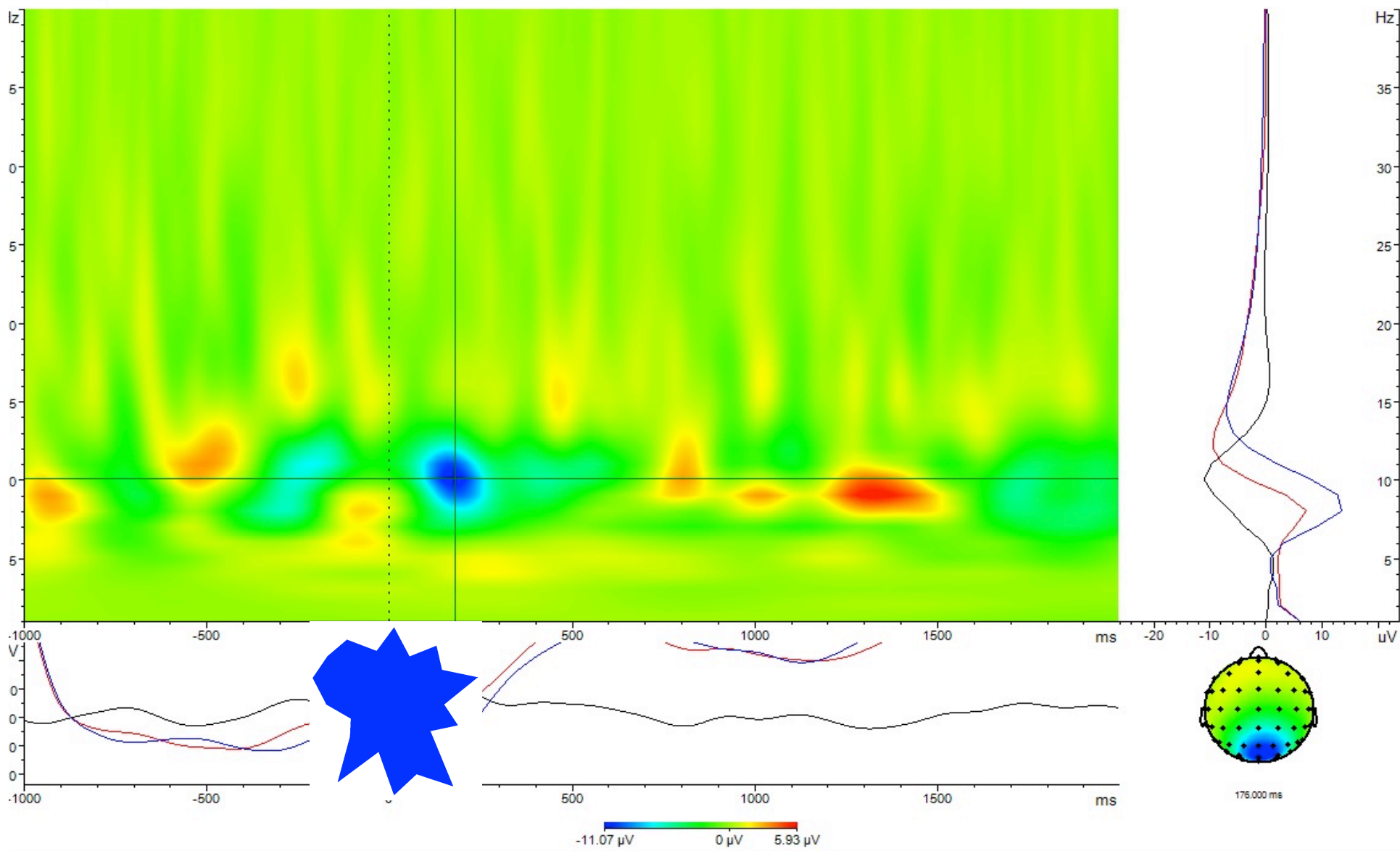
400-600ms

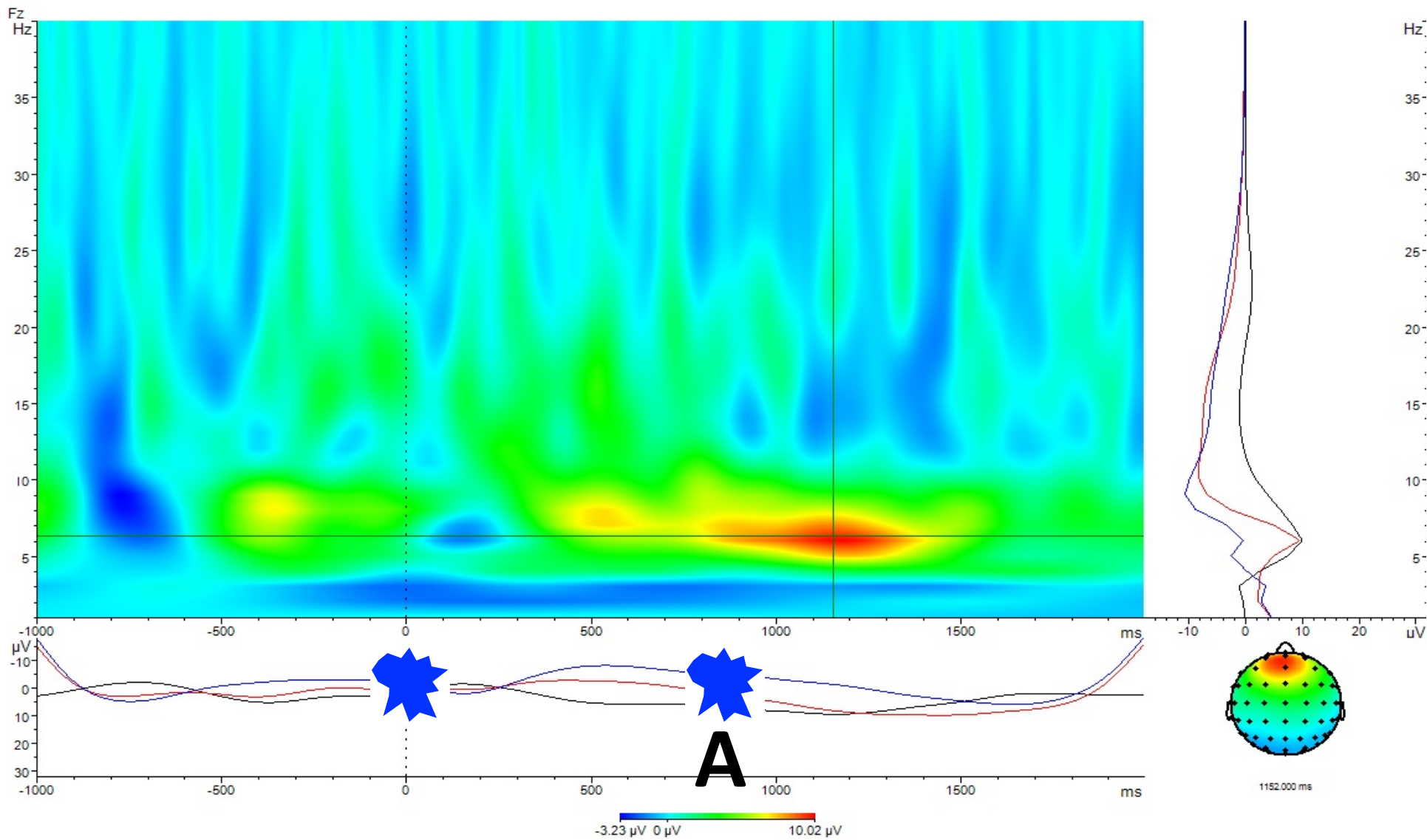
1000 ms

Block Order









Part V. Other Factors

Ownership

+



Krigolson et al., 2013

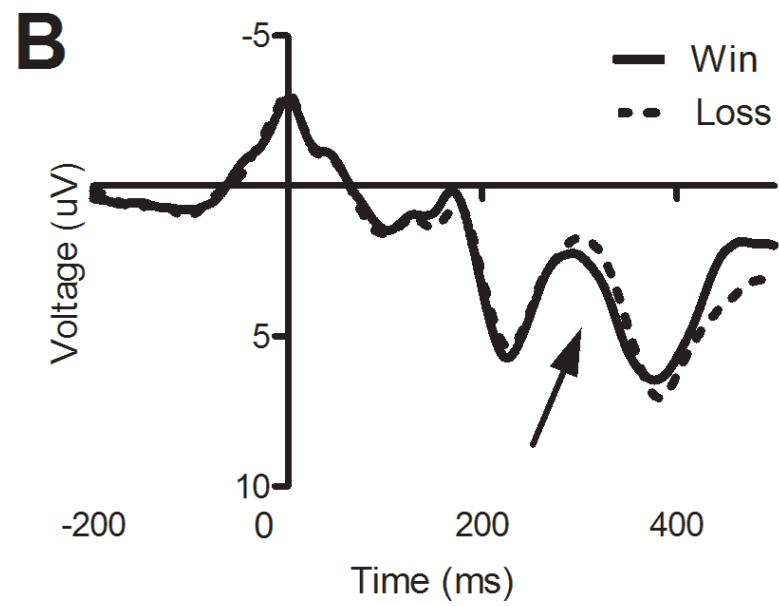
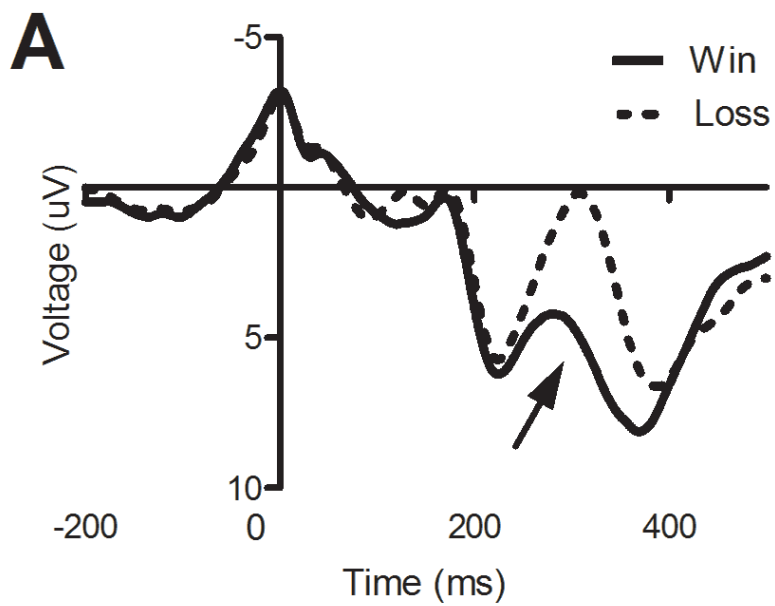


Krigolson et al., 2013

+

Krigolson et al., 2013

Win!



So why do you do the dumb things
you do?

Emotional vs Logical
System I vs System II

Other Factors: Age, Alcohol, etc