Statistical Decision Theory as a Framework for Cognition and Action

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Probabilistic Models of Cognition
July 23, 2007

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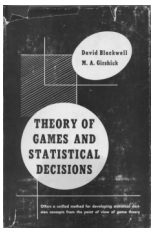
Statistical Decision Theory

John Von Neumann

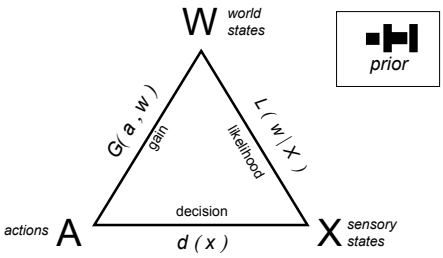
Abraham Wald

Oskar Morgenstern



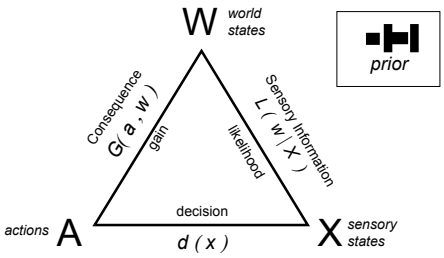
1954

Bayesian Decision Theory



Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Bayesian Decision Theory



Perception - Cognition - Action

Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Bayesian Decision Theory

Choose the decision rule d(x) that maximizes Expected Bayes Gain:*

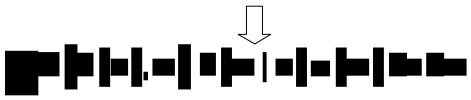
MAXIMIZE EXPECTED GAIN

**details of the calculation are left to natural selection*

Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Bayesian Decision Theory

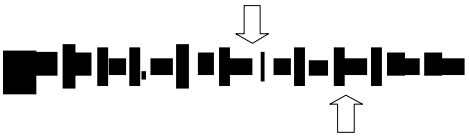
Geisler (1989)



Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Bayesian Decision Theory

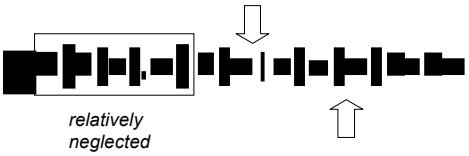
Geisler (1989)



Knill & Richards (1996)

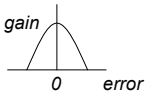
Bayesian Decision Theory

Geisler (1989)



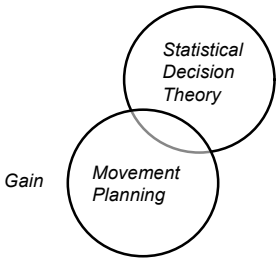
relatively neglected

Knill & Richards (1996)



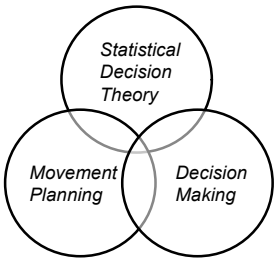
Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Overview



Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Overview



Maloney (2002) in Heyer & Mausfeld [eds], Cambridge.

Outline

⇨ *•decision making under risk*

•movement planning under risk
- *Expt. 1 spatial uncertainty*
- *Expt. 2*
- *Expt. 3*
- *Expt. 4*
- *Expt. 5 temporal uncertainty*
- *Expt. 6*

•decision making and movement planning
- *Expt. 7*
- *Expt. 8*
- *Expt. 9*

•conclusion

Decision Making under Risk

… is a choice among probability distributions on mutually-exclusive ***outcomes***

$200,000 $100,0000 -$50,000 $0

Decision Making under Risk

… is a choice among probability distributions on mutually-exclusive outcomes

	$200,000	*$100,0000*	*-$50,000*	*$0*
A	*0.1*	*0.0*	*0.0*	*0.9*

Decision Making under Risk

… is a choice among probability distributions on mutually-exclusive outcomes

	$200,000	*$100,0000*	*-$50,000*	*$0*
A	*0.1*	*0.0*	*0.0*	*0.9*
B	*0.0*	*0.5*	*0.5*	*0.0*

Decision Making under Risk

… is a choice among probability distributions on mutually-exclusive outcomes

	$200,000	*$100,0000*	*-$50,000*	*$0*
A	*0.1*	*0.0*	*0.0*	*0.9*
B	*0.0*	*0.5*	*0.5*	*0.0*
C	*0.5*	*0.4*	*0.0*	*0.1*

Decision Making under Risk

… is a choice among probability distributions on mutually-exclusive outcomes

	$200,000	*$100,0000*	*-$50,000*	*$0*
A	*0.1*	*0.0*	*0.0*	*0.9*
B	*0.0*	*0.5*	*0.5*	*0.0*
C	*0.5*	*0.4*	*0.0*	*0.1*

Choose a probability distribution across outcomes.

Decision Making under Risk

How should we choose?

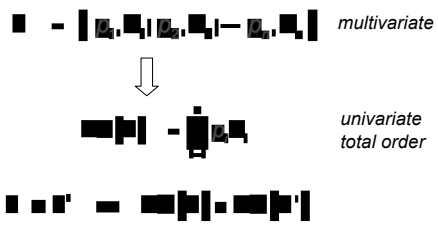
Normative Theories

How do we choose?

Descriptive Theories

Decision Making under Risk

Maximizing Expected Gain: Normative



Arnauld & Nichol (1662)

Decision Making under Risk

How should we choose?

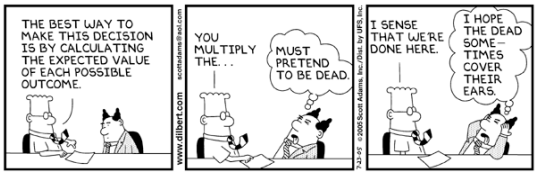
Normative Theories

How do we choose?

Descriptive Theories

Maximize Expected Gain (Value)

Dilbert



*Movement planning is now an **economic** problem ….*

Decision Making under Risk

Deviations from Maximum Expected Gain

•Distortions of perceived value

•Loss aversion

•Distortions of probability

.
.
.

Distortions of Value

1738

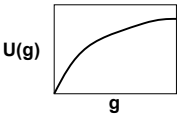
A: (0.5, $20,000; 0.5, 0)

B: ($9,500)

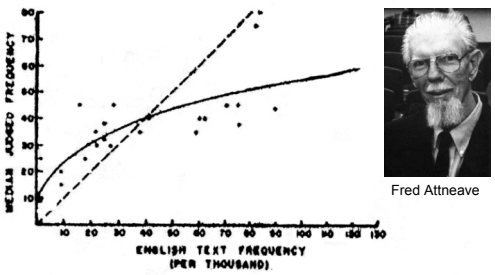
Maximize expected utility

Expected Utility Theory

Daniel Bernoulli



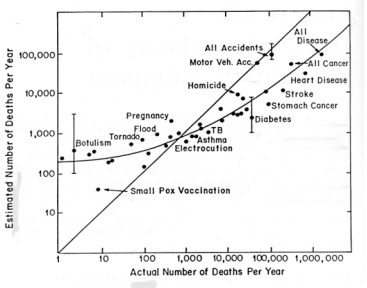
Distortions of Probability



Fred Attneave

Attneave, F. (1953) Psychological probability as a function of experienced frequency. *Journal of Experimental Psychology, 46*, 81-86.

Distortions of Probability



Sarah Lichtenstein

Paul Slovic

Baruch Fischhoff

Lichtenstein, S., Slovic, P., Fischhoff, B., Layman, M. & Coombs, B. (1978). Judged frequencies of lethal events. *Journal of experimental Psychology: Human Learning and Memory, 4*, 551 – 578.

Independence Axiom

1953

Problem 1

A: (0.20, $24000; 0.70, $20000)
B: (0.95, $20000)

Maurice Allais

Independence Axiom

1953

Problem 1

A: (0.20, $24000; 0.70, $20000)
B: (0.95, $20000)

Problem 2

A': (0.20, $24000; 0.20, $20000)
B': (0.45, $20000)

Maurice Allais

Independence Axiom

1953

Problem 1

A: (0.20, $24000; 0.70, $20000)
B: (0.95, $20000) ⇦

Problem 2

A': (0.20, $24000; 0.20, $20000) ⇦
B': (0.45, $20000)

Maurice Allais

Independence Axiom

1953

Problem 1

A: (0.20, $24000; 0.70, $20000)
B: (0.95, $20000) ⇦

Problem 2

A': (0.20, $24000; 0.20, $20000) ⇦
B': (0.45, $20000)

Maurice Allais

[redacted]

Independence Axiom

1953

Problem 1

A: (0.20, $24000; 0.70, $20000)
B: (0.95, $20000) ⇦

Problem 2

A': (0.20, $24000; 0.20, $20000) ⇦
B': (0.45, $20000) ⇦

Maurice Allais

Just added (0.50, $20000) *to A,B*

Independence Axiom

1953

Independence Axiom

Adding 0.5U($20000) to all lotteries shouldnot affect preference if EUT holds.

Allais Paradox

It does. Human subjects violate EUT.

Non-linear distortions of probability

Maurice Allais

ECONOMETRICA

VOLUME 47 MARCH, 1979 NUMBER 2

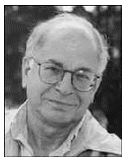
PROSPECT THEORY: AN ANALYSIS OF DECISION UNDER RISK

BY DANIEL KAHNEMAN AND AMOS TVERSKY[1]

Decision making under risk based on non-linear distortions of value and of probability.

Gross exaggeration of small probabilities.

Amos Tversky



Daniel Kahneman

"Cognitive Illusions"

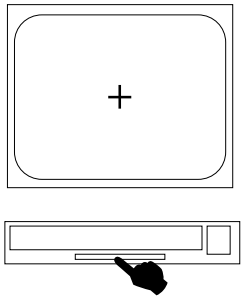
Kahneman& Tversky

Human decision making is a distortion, a caricature of optimal decision making.

Optimality seen in a funhouse mirror

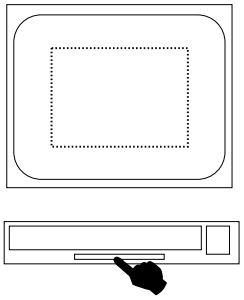
A Different Kind of Decision under Risk …

Experimental Task



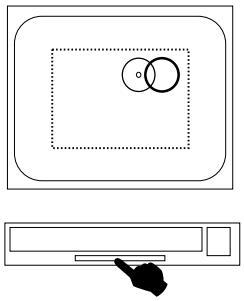
Start of trial: display of fixation cross (1.5 s)

Experimental Task



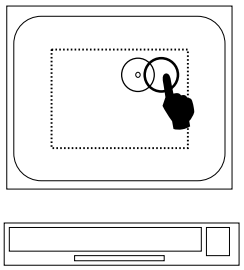
Display of response area, 500 ms before target onset (114.2 mm x 80.6 mm)

Experimental Task

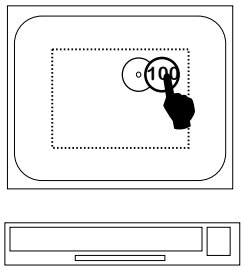


Target display (700 ms)

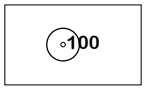
Experimental Task



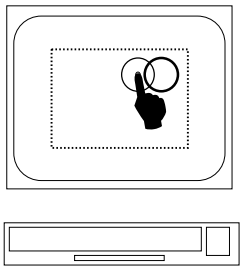
Experimental Task



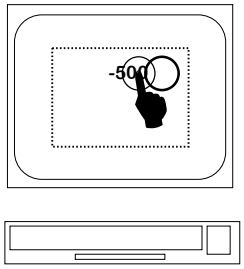
The green target is hit:
+100 points



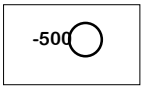
Experimental Task



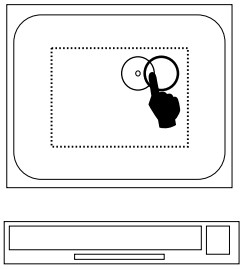
Experimental Task



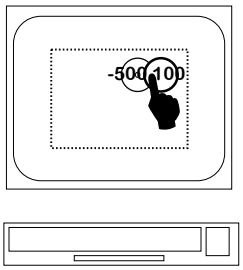
The red target is hit:
-500 points



Experimental Task



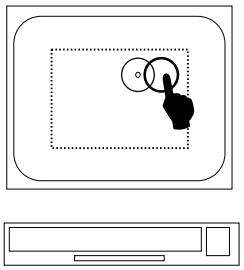
Experimental Task



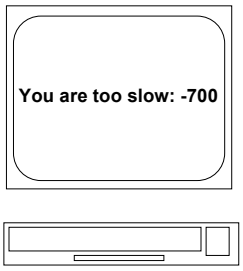
Scores add if both targets are hit:

-500 100

Experimental Task

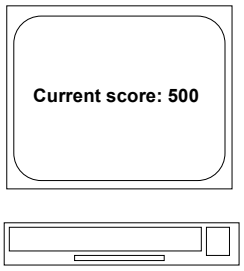


Experimental Task



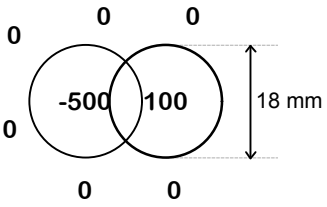
The screen is hit later than 700 ms after target display: -700 points.

Experimental Task



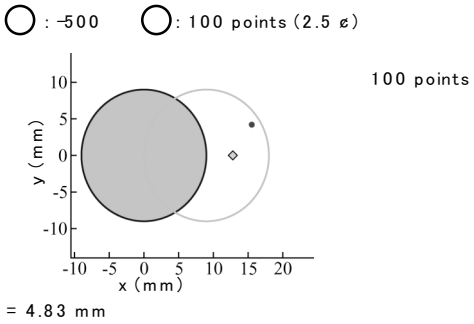
End of trial

Choice among Movement Strategies



What should Paulina do?

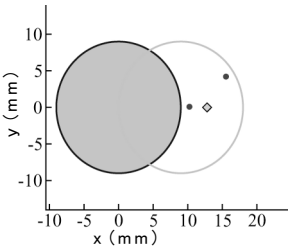
Thought Experiment



σ = 4.83 mm

Thought Experiment

: −500 : 100 points (2.5 ¢)

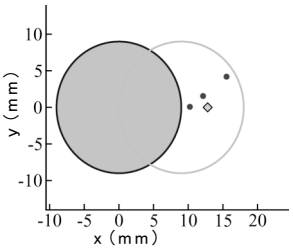


100 points
100 points
200 points

σ = 4.83 mm

Thought Experiment

: −500 : 100 points (2.5 ¢)

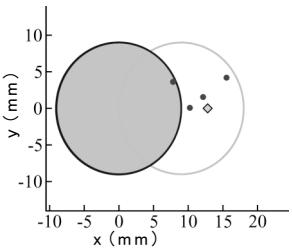


100 points
100 points
100 points
300 points

σ = 4.83 mm

Thought Experiment

: −500 : 100 points (2.5 ¢)

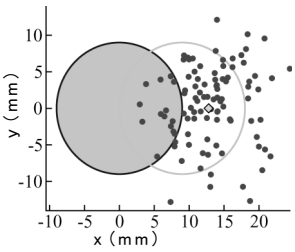


100 points
100 points
100 points
−400 points
−100 points

σ = 4.83 mm

Thought Experiment

: −500 : 100 points (2.5 ¢)

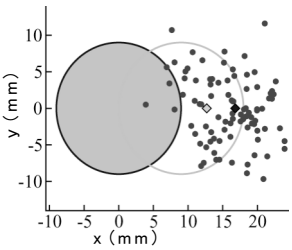


100 points
100 points
100 points
−400 points
.
.
.
−0.3 pts. per trial

σ = 4.83 mm

Thought Experiment

: −500 : 100 points (2.5 ¢)

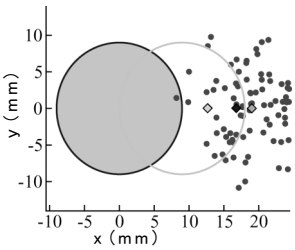


−0.3 pts. per trial
30.7 pts. per trial

σ = 4.83 mm

Thought Experiment

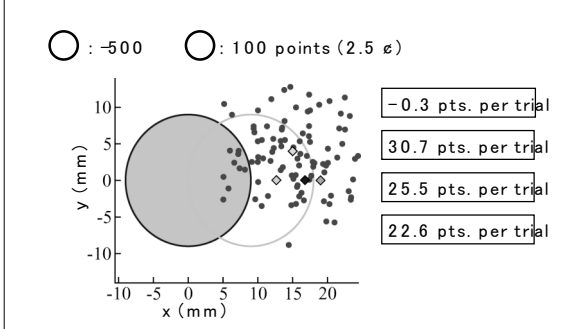
: −500 : 100 points (2.5 ¢)



−0.3 pts. per trial
30.7 pts. per trial
25.5 pts. per trial

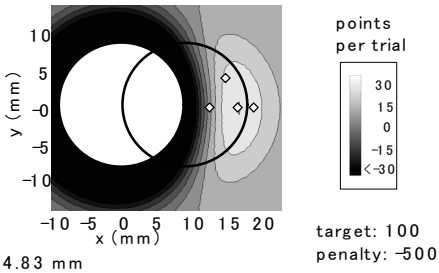
σ = 4.83 mm

Thought Experiment



σ = 4.83 mm

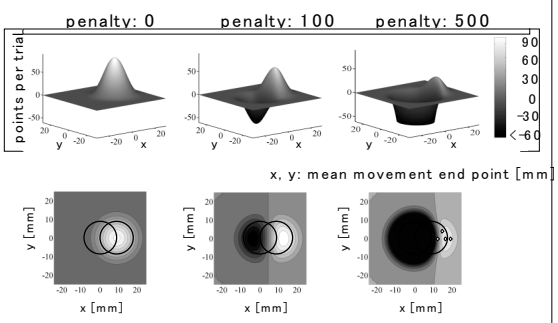
Expected gain as function of mean movement end point (x,y):



target: 100
penalty: -500

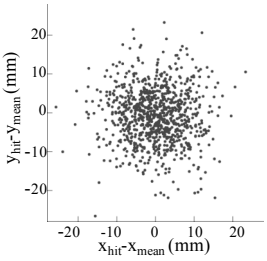
σ = 4.83 mm

Thought Experiment

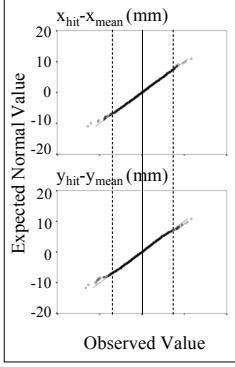


σ = 4.83 mm

Distribution of movement end points

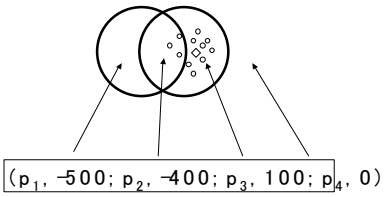


Q-Q Plot



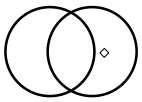
Subject S4, σ = 3.62 mm,
72x15 = 1080 end points

Movement Planning as Decision Making



(p_1, -500; p_2, -400; p_3, 100; p_4, 0)

Movement Planning as Decision Making



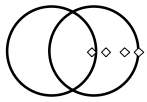
σ = 4 mm

Lottery:

(1.3%, -500; 30.3%, -400; 60.9%, 100; 7.5%, 0)

Movement Planning as Decision Making

optimal aim point: lottery with maximum expected gain



σ = 4 mm

(6.6%, −500; 52.3%, −400; 37.0%, 100; 4.0%, 0)

(1.3%, −500; 30.3%, −400; 60.9%, 100; 7.5%, 0)

(0%, −500; 4.6%, −400; 62.6%, 100; 32.8%, 0)

(0%, −500; 0.7%, −400; 37.6%, 100; 61.7%, 0)

What do we expect?

What do we expect?

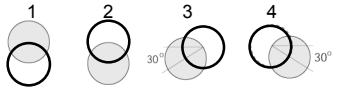
Abject failure

Outline

- *decision making under risk*
- ⇨ *movement planning under risk*
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*
- *conclusion*

Test of the model: Experiment 1

4 stimulus configurations: (varied within block)



R = 9 mm

2 penalty conditions:
0 and -500 points (varied between blocks)

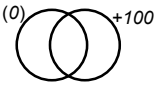
5 "practiced movers"
1 session of data collection: 360 trials
24 data points per condition

Trommershäuser, Maloney, Landy (2003) *JOSA A*, **20**, 1419-1433.

General Methods: Training

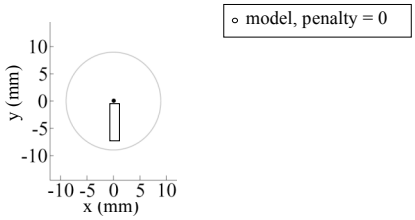
For all experiments:

- *All subjects practice the task for 360 trials or more until their variance stabilizes.*
- *The timeout limit is gradually decreased to 700 ms during training.*
- *There are no penalties during training (the concept is never mentioned).*
- *We verify that each subject's movement variance has stabilized.*
- *They are told only to make money.*



Results: Experiment 1

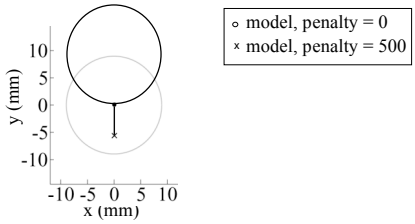
Model prediction:



Subject S5, σ = 2.99 mm

Results: Experiment 1

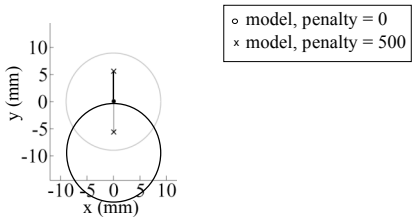
Model prediction: configuration 1



Subject S5, σ = 2.99 mm

Results: Experiment 1

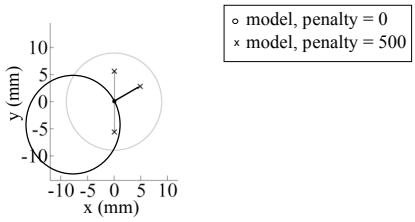
Model prediction: configuration 2



Subject S5, σ = 2.99 mm

Results: Experiment 1

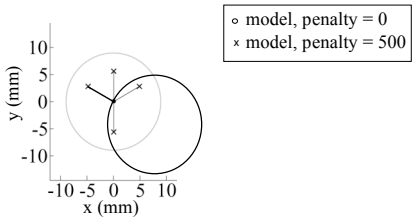
Model prediction: configuration 3



Subject S5, σ = 2.99 mm

Results: Experiment 1

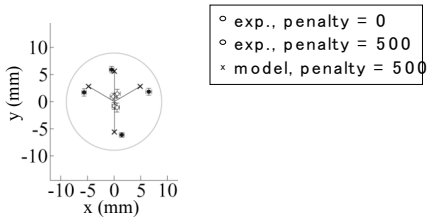
Model prediction: configuration 4



Subject S5, σ = 2.99 mm

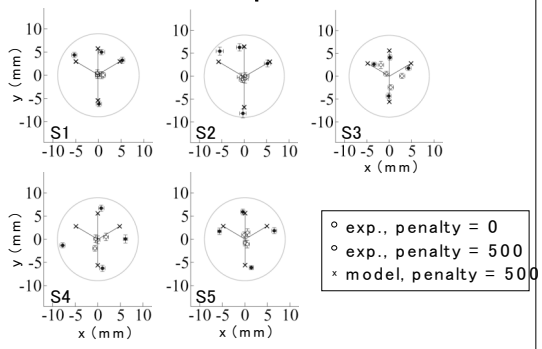
Results: Experiment 1

Comparison with experiment



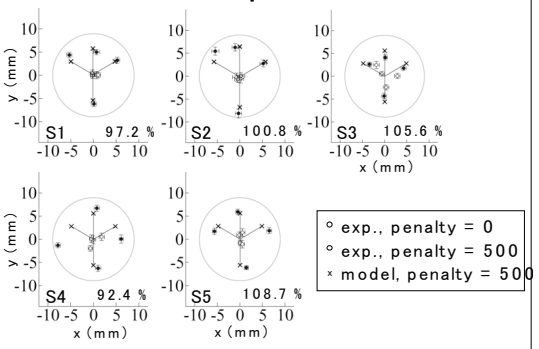
Subject S5, σ = 2.99 mm

Results: Experiment 1



(Data corrected for constant pointing bias.)

Results: Experiment 1



(Data corrected for constant pointing bias.)

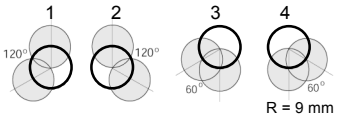
Outline

- *decision making under risk*
- *movement planning under risk*
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*
- *conclusion*

Test of the model: Experiment 2

Movement endpoints in response to more complex stimulus configurations.

4 "more complex" configurations: (varied within block)



R = 9 mm

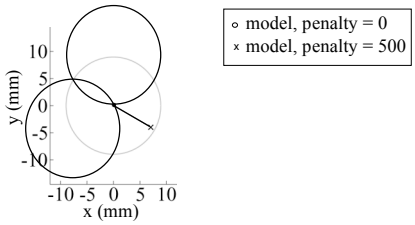
2 penalty conditions:
0 and -500 points (varied between blocks)

5 "practiced movers"
1 session of data collection: 360 trials
24 data points per condition

Trommershäuser, Maloney, Landy (2003) *JOSA A*, **20**, 1419-1433.

Results: Experiment 2

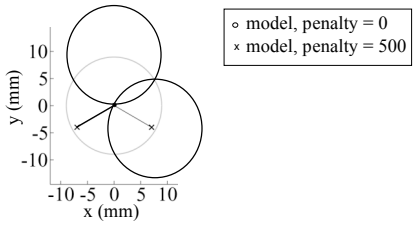
Model prediction: configuration 1



Subject S5, σ = 2.99 mm

Results: Experiment 2

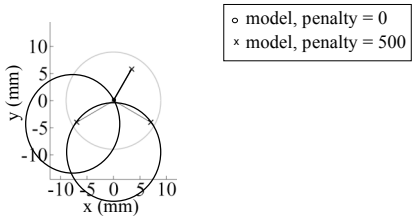
Model prediction: configuration 2



Subject S5, σ = 2.99 mm

Results: Experiment 2

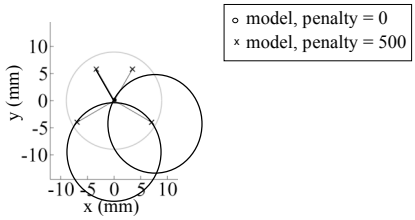
Model prediction: configuration 3



Subject S5, σ = 2.99 mm

Results: Experiment 2

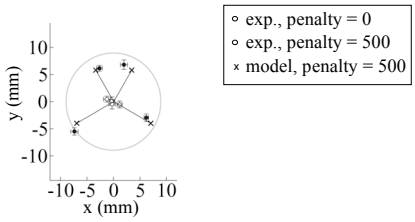
Model prediction: configuration 4



Subject S5, σ = 2.99 mm

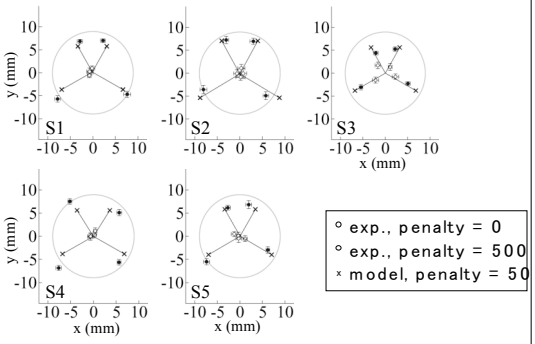
Results: Experiment 2

Comparison with experiment

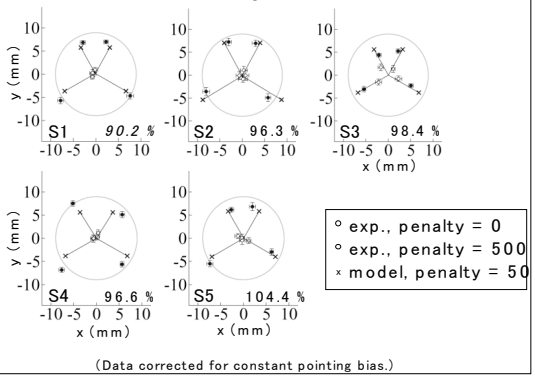


Subject S5, σ = 2.99 mm

Results: Experiment 2



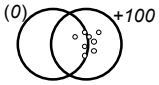
Results: Experiment 2



(Data corrected for constant pointing bias.)

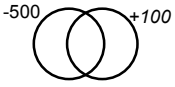
Learning?

Training: Learn to minimize variance, bias – no penalty
Learn one's own variability



Aim for center
Of green

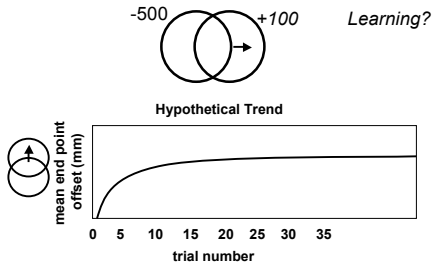
Experiment:



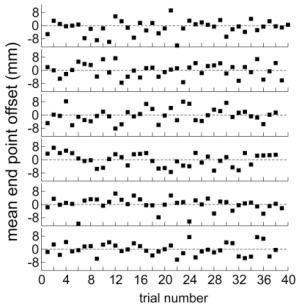
Learning?

Learning?

Experiment:



Learning?



Exp. 1
S01

No trends corresponding to learning in experimental trials

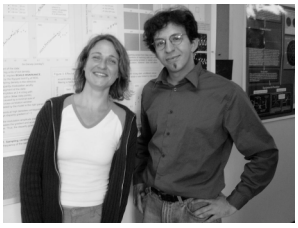
What if we *changed* a subject's motor variability?

Outline

- *decision making under risk*
- *movement planning under risk*
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*
- *conclusion*

Experiment 3

Changes in movement endpoints in response to simulated changes in motor variability
(Sergei Gepshtein, Marty Banks, Berkeley).



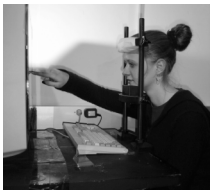
Trommershäuser, Gepshtein, Maloney, Landy & Banks(2005). *J. Neuroscience, **25**, 7169-7178.*

Experiment 3 omitted

Summary

Subjects rapidly adapt to novel motor uncertainties (Expt. 3).

People are good at movement planning.



Trommershäuser, Maloney, Landy (2003) *Spatial Vision*, **16**, 255-275.
Trommershäuser, Maloney, Landy (2003) *JOSA A*, **20**, 1419-1433.
Trommershäuser, Gepshtein, Maloney, Landy & Banks (2005), *J. Neuroscience* **25**, 7169-7178

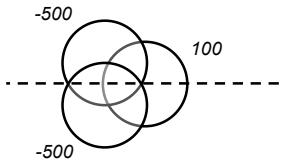
Experiment 4

Asymmetric Reward Configurations

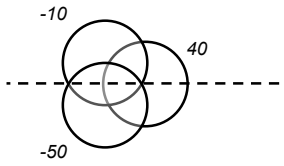
Shi-Wei Wu

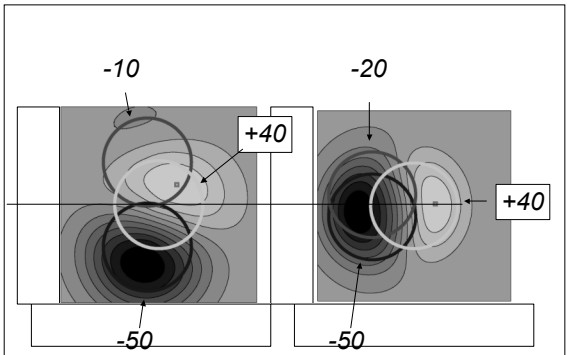
*Wu, Trommershäuser, Maloney & Landy (2006), JOV, **6**, 53-63.*

Geometric Symmetry: Heuristic?

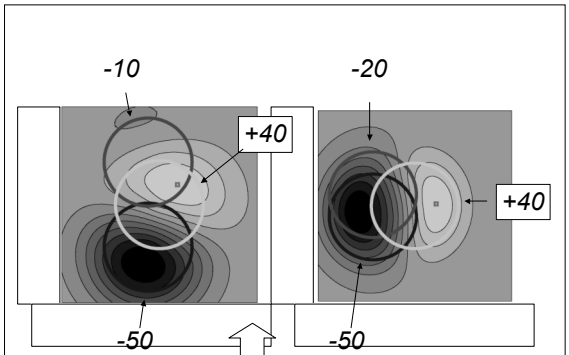


Geometric Symmetry: Heuristic?





σ = 5.75 mm



σ = 5.75 mm

Movement Planning

Earlier work

*Trommershäuser, Maloney **&** Landy (2003)**,** JOSA A, **20**, 1419-1433.*
*Trommershäuser, Maloney **&** Landy (2003)**,** Spatial Vision, **16**, 255-275.*
*Trommershäuser, Gepshtein, Maloney**,** Landy & Banks, (2005), J. Neuroscience **25**, 7169-7178.*
*Wu, Trommershäuser, Maloney & Landy (2006), JOV, **6**, 53-63.*
*Maloney**,** Trommershäuser & Landy (2007), chapter. Oxford, in press.*
*Trommershäuser, Mattis, Maloney **&** Landy (2006), Exp. Brain Res., in press.*
*Trommershäuser, Landy & Maloney (2006)**,** Psych. Science, in press.*

planning with spatial movement uncertainty

Movement Planning

Earlier work

*Trommershäuser, Maloney **&** Landy (2003)**,** JOSA A, **20**, 1419-1433.*
*Trommershäuser, Maloney **&** Landy (2003)**,** Spatial Vision, **16**, 255-275.*
*Trommershäuser, Gepshtein, Maloney**,** Landy & Banks, (2005), J. Neuroscience **25**, 7169-7178.*
*Wu, Trommershäuser, Maloney & Landy (2006), JOV, **6**, 53-63.*
*Maloney**,** Trommershäuser & Landy (2007), chapter. Oxford, in press.*
*Trommershäuser, Mattis, Maloney **&** Landy (2006), Exp. Brain Res., in press.*
*Trommershäuser, Landy & Maloney (2006)**,** Psych. Science, in press.*

planning with spatial movement uncertainty

planning with temporal movement uncertainty

Movement Planning

Earlier work

*Trommershäuser, Maloney **&** Landy (2003)**,** JOSA A, **20**, 1419-1433.*
*Trommershäuser, Maloney **&** Landy (2003)**,** Spatial Vision, **16**, 255-275.*
*Trommershäuser, Gepshtein, Maloney**,** Landy & Banks, (2005), J. Neuro, **25**, 7169-7178.*
*Wu, Trommershäuser, Maloney & Landy (2006), JOV, **6**, 53-63.*
*Maloney**,** Trommershäuser & Landy (2007), chapter. Oxford.*
*Trommershäuser, Mattis, Maloney **&** Landy (2006), Exp. Brain Res., in press.*

planning with spatial movement uncertainty

planning with temporal movement uncertainty

Outline

- *decision making under risk*
- *movement planning under risk*
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - ⇨ *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*
- *conclusion*

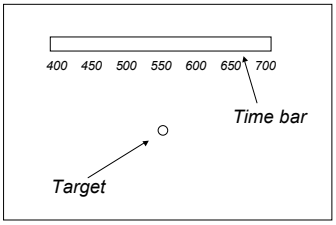
Experiment 5

Timing with Asymmetric Gain/Loss

Todd Hudson

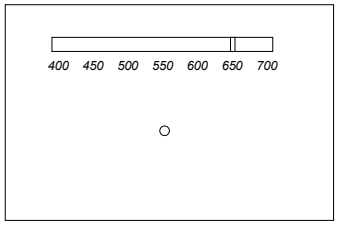
*Wu, Trommershäuser, Maloney & Landy (2006), JOV, **6**, 53-63.*

Experiment 5:

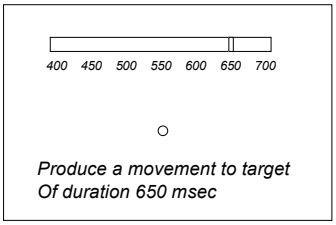


Hudson, Landy & Maloney, VSS 2006.

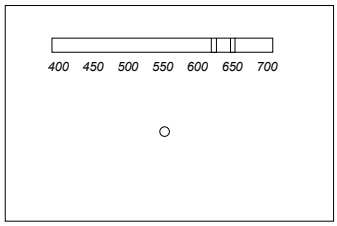
Experiment 5: Practice



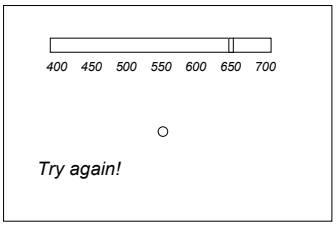
Experiment 5: Practice



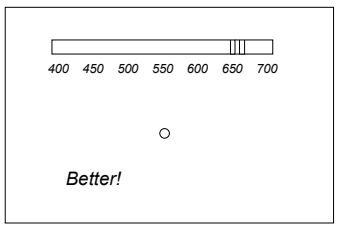
Experiment 5: Practice

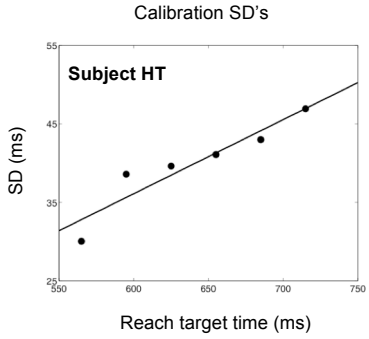


Experiment 5: Practice

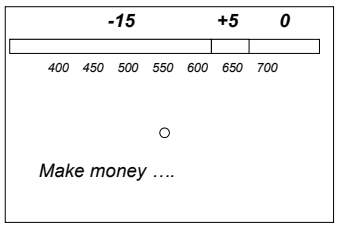


Experiment 5: Practice



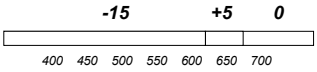


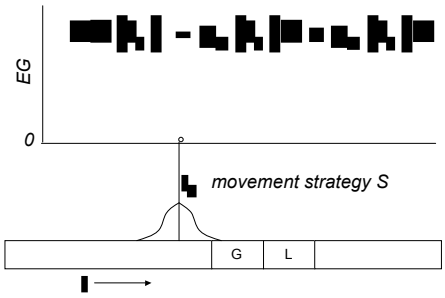
Experiment 5: The Task

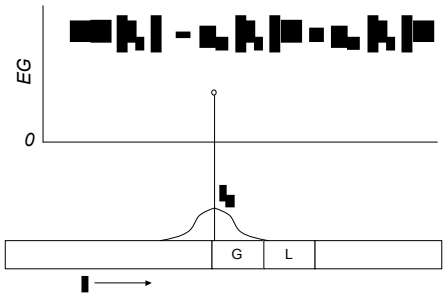


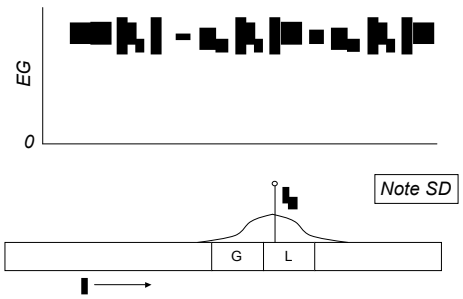
Experiment 5: The Task

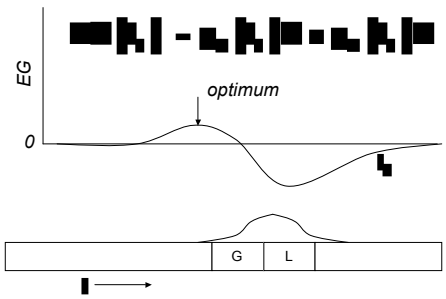
How to maximize expected gain?





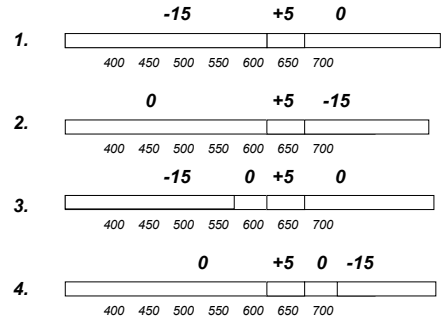


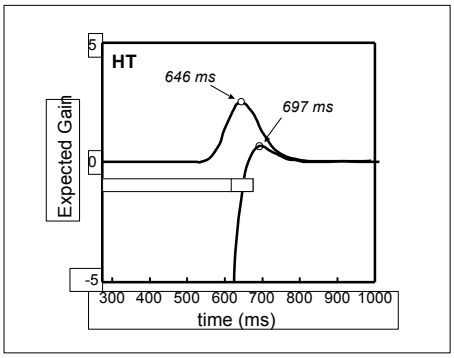


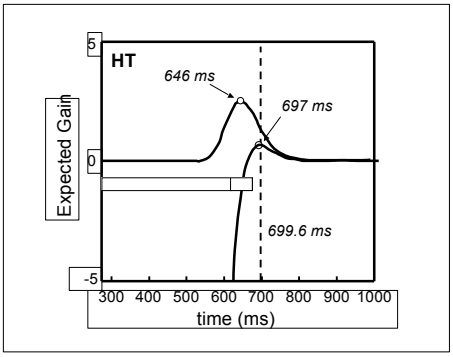


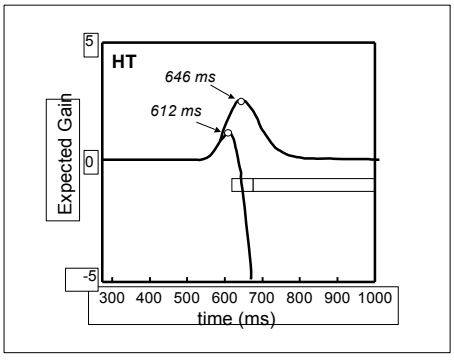
Main Experiment

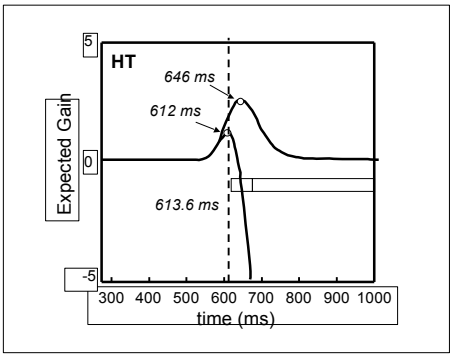
Configurations

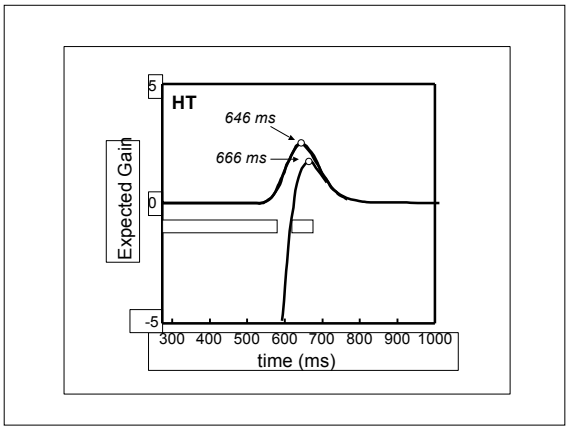


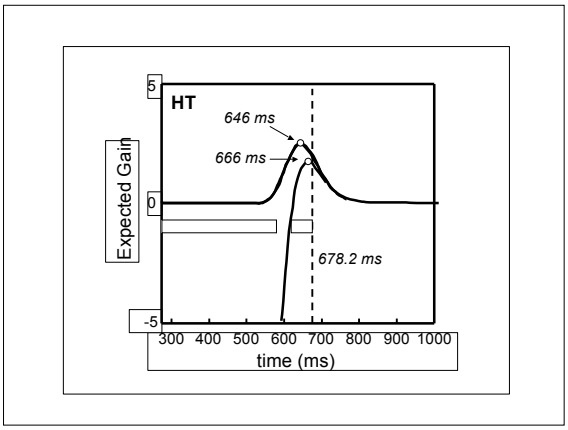


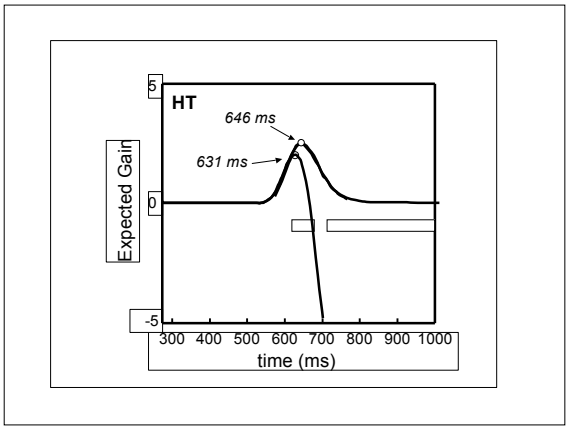


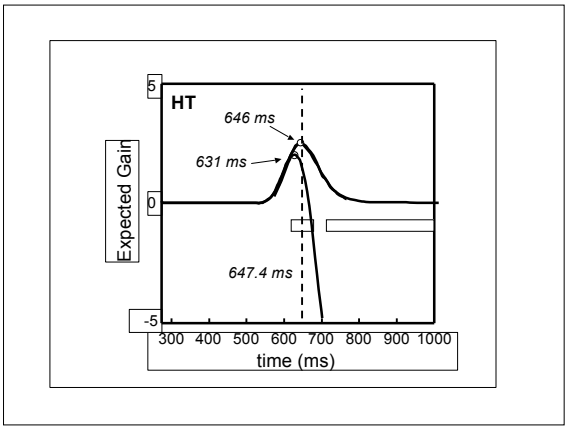


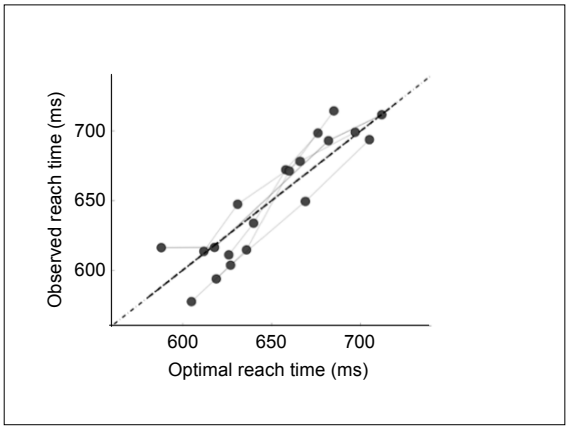












Summary: Experiment 5

Subjects chose movements whose mean time came close to maximizing expected gain.
No patterned deviations.

Experiment 6

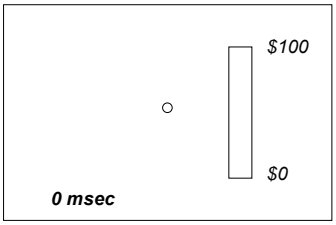
Speed-Accuracy Tradeoffs

Mark Dean

Shih-Wei Wu

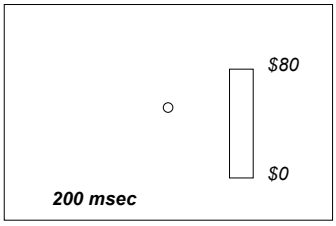
Dean, Wu, & Maloney (2006), JOV, in press.

Experiment 6: Idea



Dean, Wu & Maloney, VSS 2006.

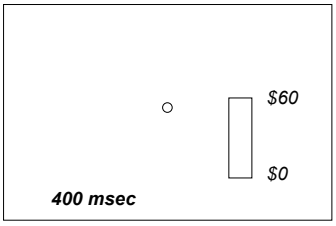
Experiment 6: Idea



Mark Dean

Shih-Wei Wu

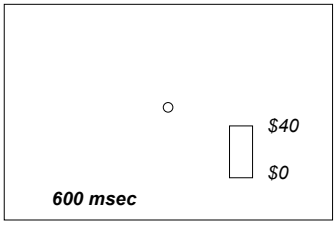
Experiment 6: Idea



Mark Dean

Shih-Wei Wu

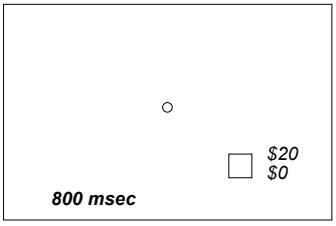
Experiment 6: Idea



Mark Dean

Shih-Wei Wu

Experiment 6: Idea

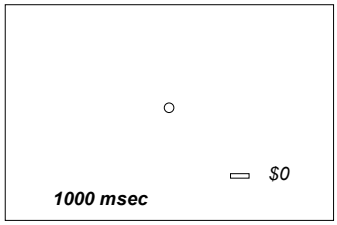


Mark Dean

Shih-Wei Wu

Experiment 6: Idea

Mark Dean



Shih-Wei Wu

Experiment 6

Do we compensate for our own speed-accuracy tradeoffs?

Mark Dean

Shih-Wei Wu

Methods

Eight naïve subjects

Training session (measure SAT)

4 Time-limits: 400, 600, 800, 1000 ms
Block: 20 warm-up, 60 formal training trials
Target value: 100 points (0.5 cents)

Methods

Choice session

2 linear reward schedules (blocked):
Fast vs. slow
Block: 20 warm-up, 80 choice trials
Initial target value: 100 points

Methods

Sixteen naïve subjects

1. Training session (measure SAT)

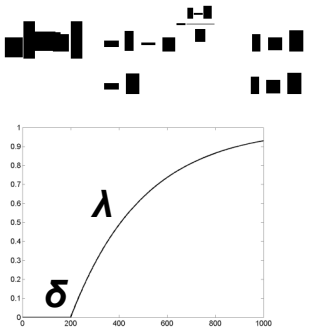
4 Time-limits: 400, 600, 800, 1000 ms
Block: 20 warm-up, 60 formal training trials
Target value: 100 points (0.5 cents)

Methods

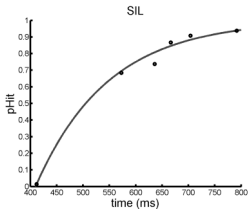
2. Choice session

2 linear reward schedules (blocked):
Fast vs. slow*
Block: 20 warm-up, 80 choice trials
Initial target value: 100 points

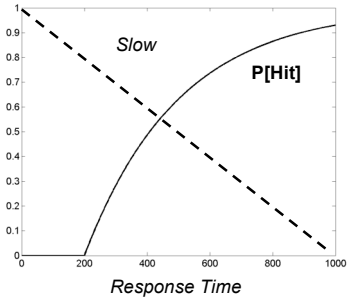
Exponential SAT



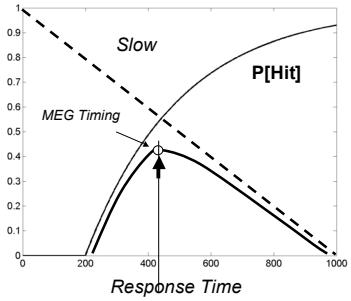
Probability fit



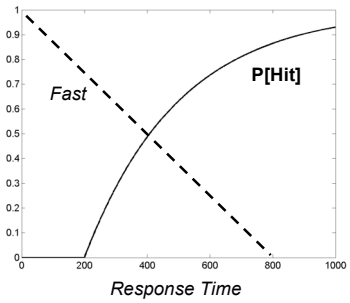
Expected Gain



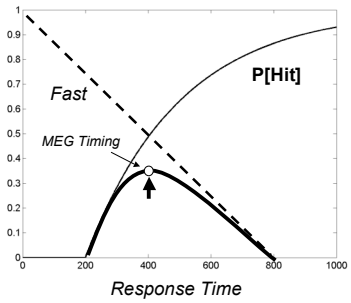
Expected Gain



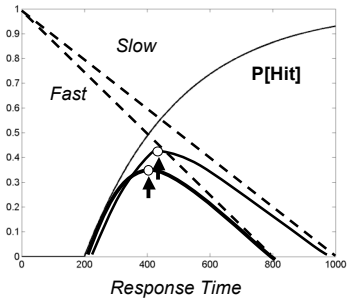
Expected Gain



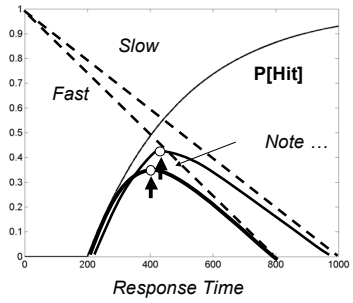
Expected Gain



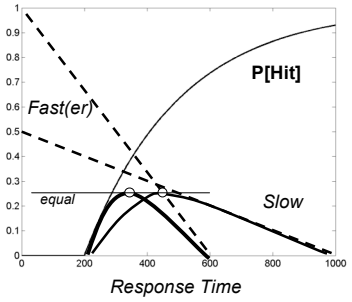
Reward Structure 1

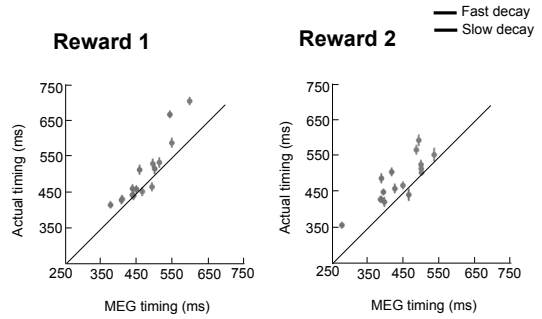


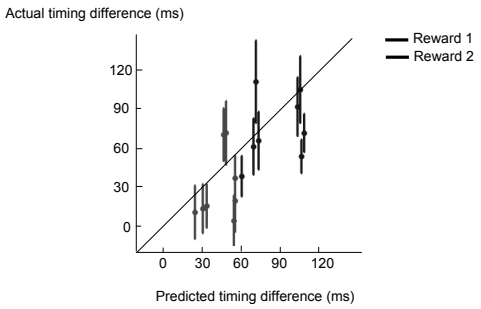
Reward Structure 1



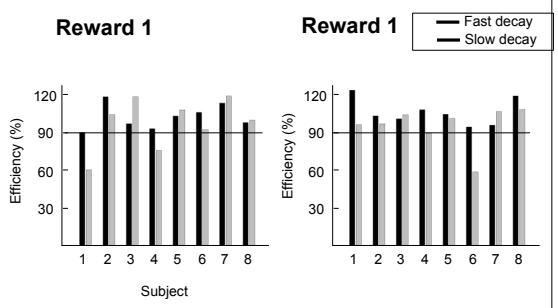
Reward Structure 2







Efficiency = [redacted]



Summary: Experiment 6

In both conditions subjects timing was close to predicted optimal.

Small but patterned deviations from optimal.

Six out of eight subjects had efficiencies above 90% for both slow and fast conditions.

Outline

- *decision making under risk*
- *movement planning under risk*
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- ⇨ *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*
- *conclusion*

"Cognitive Illusions"

Kahneman& Tversky

Human decision making is a distortion of optimal decision making.

This is ***not*** what we find for movement planning under risk.

WHY?

Our experiments differs from typical decision making experiments:

- *Many trials with cumulative winnings*
  - *Samuelson (1963); Coombs & Meyer (1969)*
  - *Redelmeier & Tversky (1992); Thaler, Tversky, Kahneman et al (1997); Benartzi & Thaler (1999)*
- *"House money effect"*
  - *Thaler & Johnson (1990)*
- *Small winnings/losses on any single trial*
  - *Holt & Laury (2002)*
  - *Camerer (1992)*
- *Probabilities are* implicit
  - *"decisions from experience" Hertwig, Barron, Weber & Erev (2004)*

Outline

- *decision making under risk*
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  - *Expt. 1 spatial uncertainty*
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  - *Expt. 6*
- ⇨ *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*
- *conclusion*

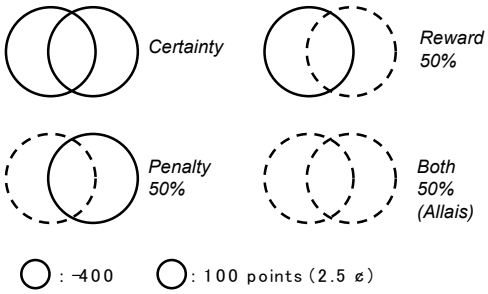
Experiment 7

Comparison of performance with implicit probabilities only and with both implicit and explicit probabilities.

Julia Trommershäuser
Paulina Trzcinka

Maloney, Trommershäuser, Trzcinka, & Landy, VSS 2004
Trommershäuser, Trzcinka, Maloney & Landy *(in prep.)*

Explicit Probability Targets



Conclusion

With implicit probability, all but one subject were indistinguishable from MEG.

With explicit probability, all but one subject deviated markedly in one or more conditions from MEG.

Maloney, Trommershäuser, Landy (2007) In W. Gray (ed) Oxford University Press.

Experiment 8

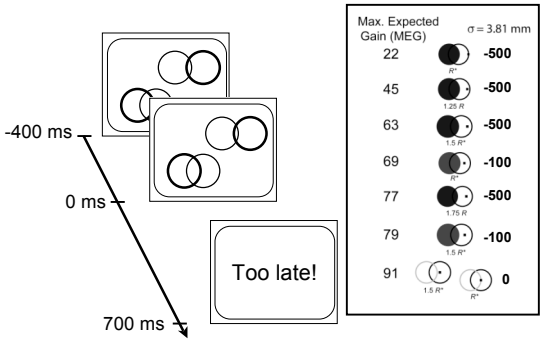
Speeded Choice

Julia Trommershäuser

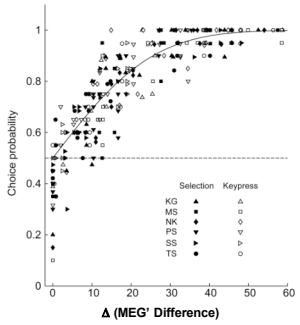
Michael Landy

Trommershäuser, Landy & Maloney (2006), Psych. Sci. In press.

Sensory-Motor Choices



Exp.: Human vs. Optimal Strategies; Sensory-Motor Choices



Outline

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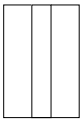
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - ⇨ *Expt. 9*
- *conclusion*

Experiment 9: Idea

Shih-Wei Wu

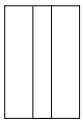


Goal Design a motor task precisely equivalent to choices among lotteries

Maloney, Wu, Dal Martello, VSS 2006.

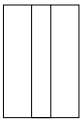
Experiment 9: Idea

Practice hitting the target for several hundred trials.



Maloney, Wu, Dal Martello, VSS 2006.

Experiment 9: Idea

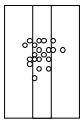


Small reward for hitting the blue regions.
Larger reward for yellow.

Maloney, Wu, Dal Martello, VSS 2006.

Experiment 9: Idea

We measure your motor uncertainty.



We can adjust the widths of the yellow and blue stripes to control the probability that you will hit them.

Maloney, Wu, Dal Martello, VSS 2006.

Experiment 9: Idea

Experimental Session

Which target would you prefer to hit? No movement!!

Maloney, Wu, Dal Martello, VSS 2006.

Experiment 9: Idea

Experimental Session

A: (*0.20, $24; 0.70,$20*) B: (*0.95, $20*)

Maloney, Wu, Dal Martello, VSS 2006.

We can construct pairs of motor lotteries equivalent to lotteries in classical form. We can compare performance in motor and classical tasks.

A: (*0.20, $24; 0.70,$20*) B: (*0.95, $20*)

Maloney, Wu, Dal Martello, VSS 2006.

Testing for non-linearities in probability

Independence Axiom

Alais (1953)
Wu & Gonzalez (1998)

Independence Axiom

1953

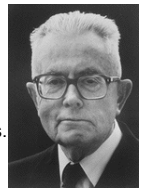
Independence Axiom

Adding 0.5U($20) to all lotteries should not affect preference if EU theory holds.

Allais Paradox

It does. Human subjects violate EU theory.

Non-linear distortions of probability



Maurice Allais

Independence Axiom

1953

Independence Axiom

Adding 0.5U($20) to all lotteries should not affect preference if EU theory holds.

Allais Paradox

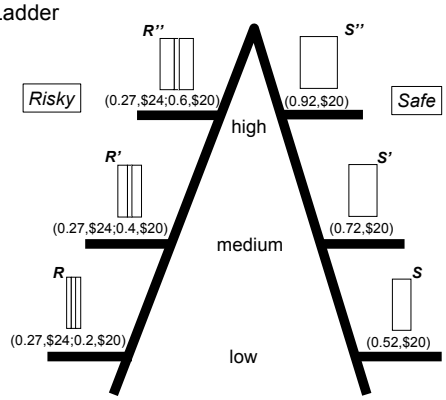
It does. Human subjects violate EU theory.

Non-linear distortions of probability

Maurice Allais

But, in movement planning?

Ladder



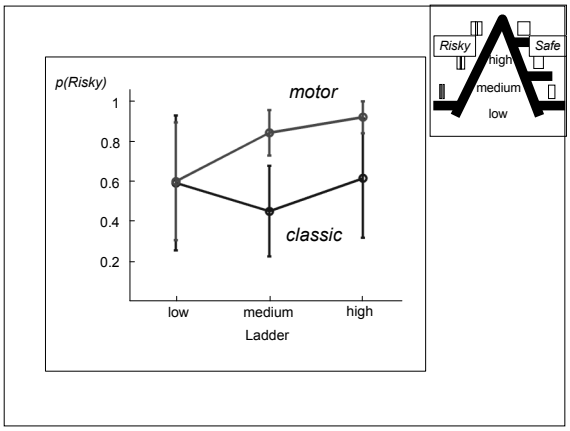
Methods

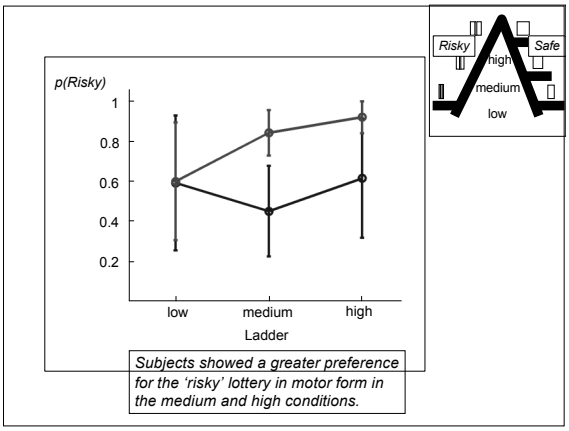
1. Training: 320 trials 8 naïve subjects

2. Judge 24 lottery pairs (3 ladders)
   motor form
   Judge same lottery pairs
   classical form (p, $V; q, $W)

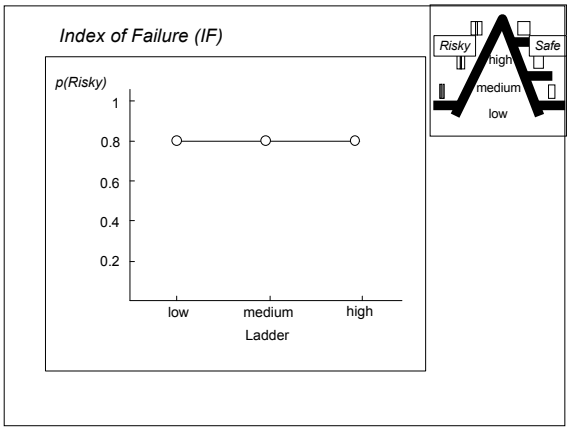
3. Subjects estimate frequency of success at hitting target for seven lotteries.

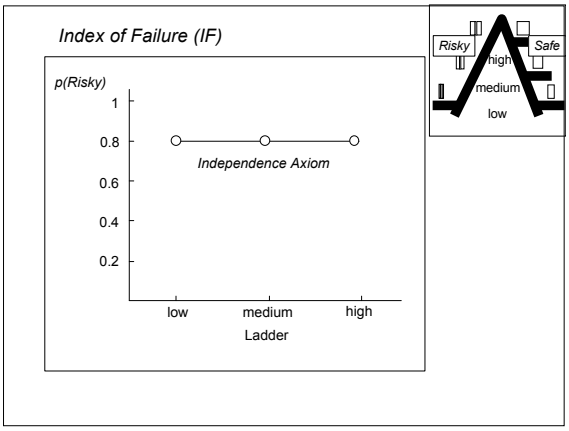
Results

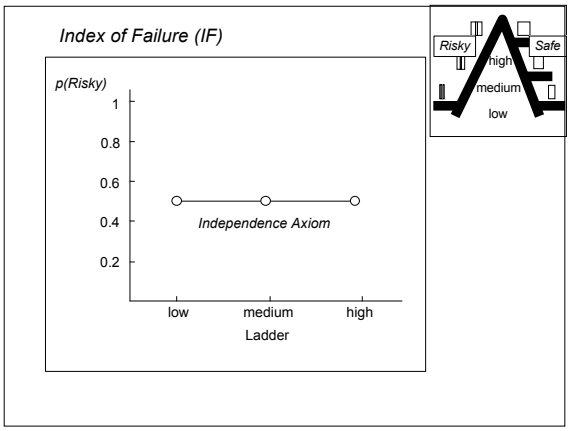


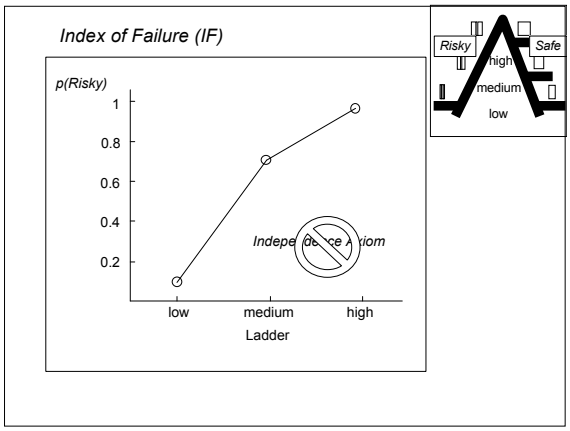


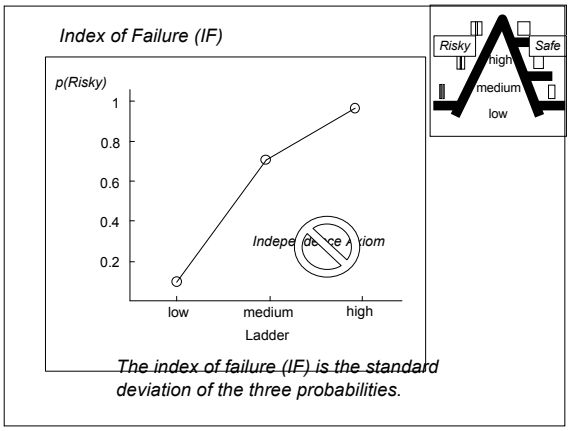
Subjects showed a greater preference for the 'risky' lottery in motor form in the medium and high conditions.



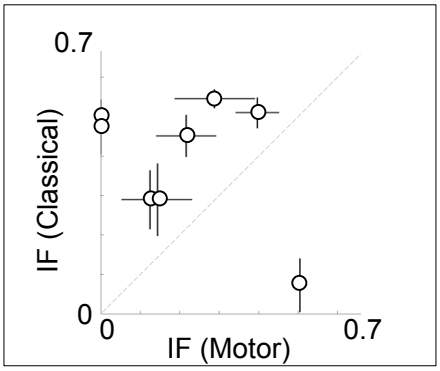








The index of failure (IF) is the standard deviation of the three probabilities.

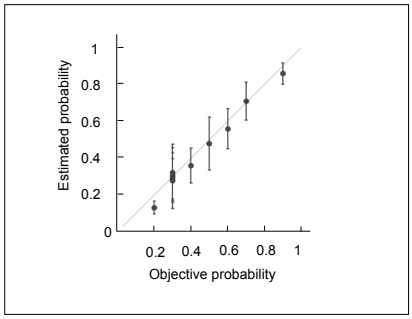


Seven out of eight subjects had a lower IF (tendency to violate the Independence Axiom) with lotteries in motor form.

Seven out of eight subjects had a lower IF (tendency to violate the Independence Axiom) with lotteries in motor form.

Overconfidence Hypothesis

Perhaps they are simply overestimating their probability of success in the motor lotteries?



Conclusion: Experiment 9

Subjects use the same probability information differently when it is implicit in their own motor performance than when it is explicitly given.

Decision making performance in motor tasks is better than in matched classical decision tasks.

Conclusion: Experiment 8

Subjects use the same probability information differently when it is implicit in their own motor performance than when it is explicitly given.

Decision making performance in motor tasks is better (in one respect) than in matched classical decision tasks.

Outline

- *decision making under risk*
- *movement planning under risk*
  - *Expt. 1 spatial uncertainty*
  - *Expt. 2*
  - *Expt. 3*
  - *Expt. 4*
  - *Expt. 5 temporal uncertainty*
  - *Expt. 6*
- *decision making and movement planning*
  - *Expt. 7*
  - *Expt. 8*
  - *Expt. 9*

⇨ *conclusion*

Summary

Subjects cope well with a wide range of arbitrary gain functions in space and time (but not all).

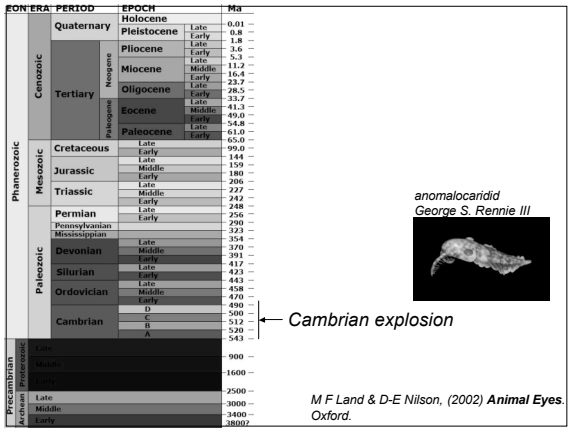
Subjects effectively take into account their own motor variability in planning movements.

No evidence for learning.

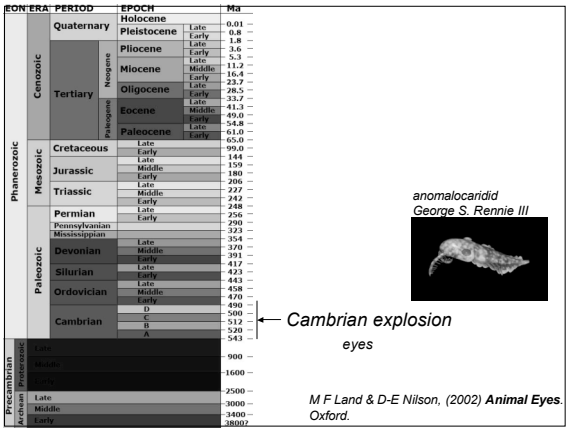
Subjects come very close to maximizing expected gain by choice of movement strategy.

When we compare movement planning to equivalent decision making tasks, subjects are closer to MEG in movement planning.

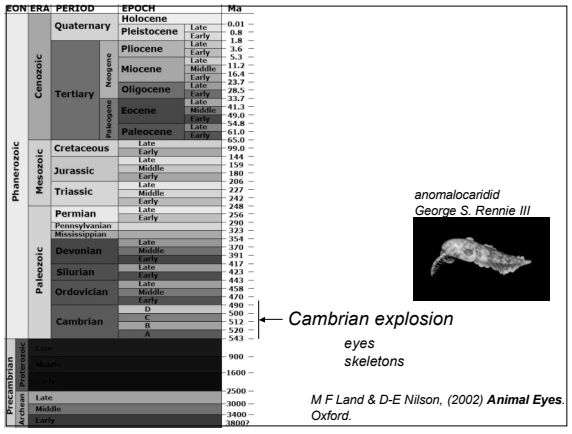
Why?



M F Land & D-E Nilson, (2002) ***Animal Eyes****. Oxford.*



M F Land & D-E Nilson, (2002) ***Animal Eyes****. Oxford.*



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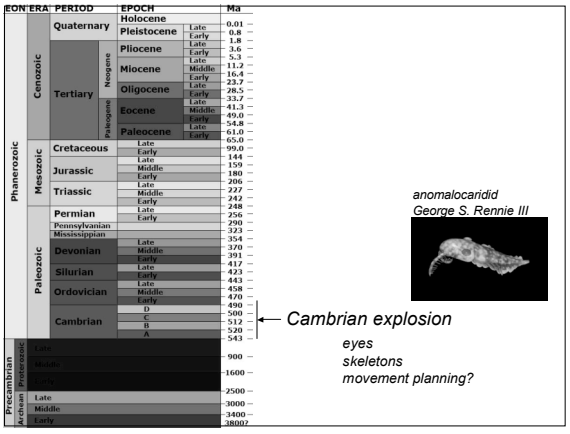

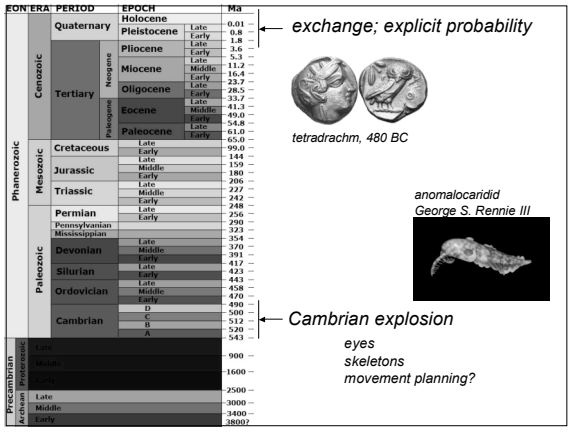

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http://www.psych.nyu.edu/maloney/index.html