Bayesian Accounts of the Central Tendency of Judgment

Pascal Mamassian

Laboratoire des Systèmes Perceptifs

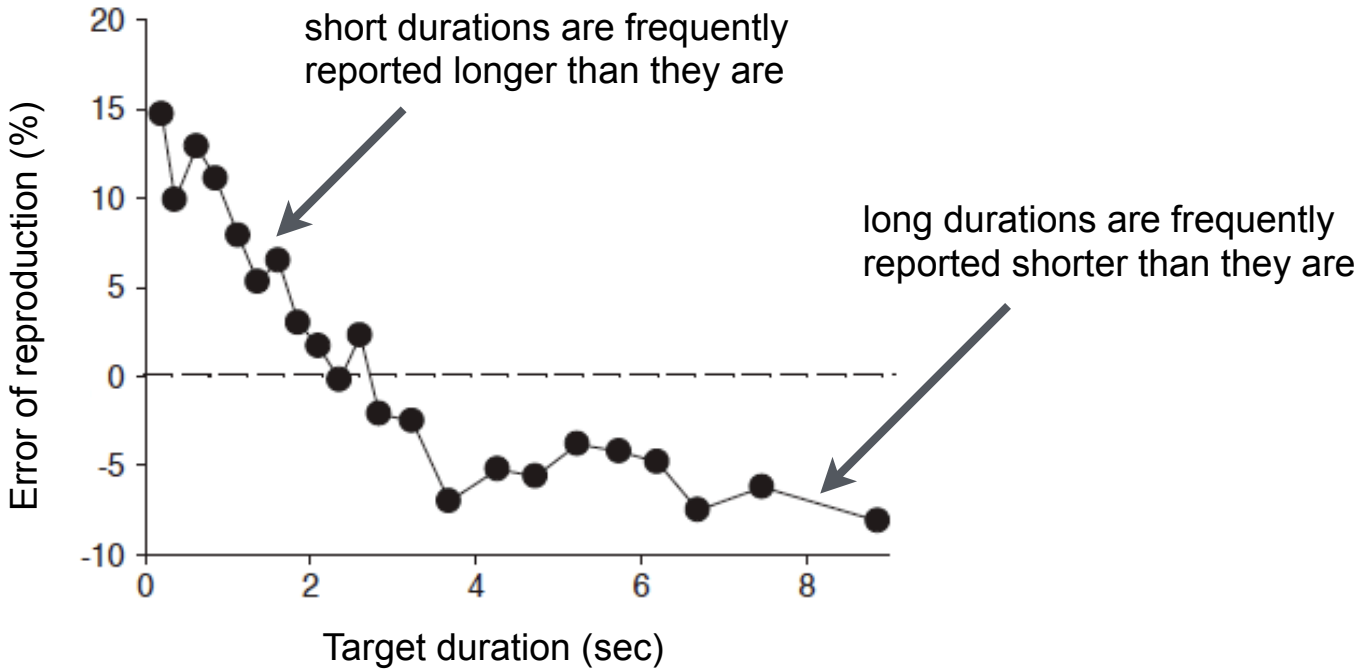
CNRS & Ecole Normale Supérieure

Biases in perceived duration

- Vierordt's law (1868):

short durations in a series are perceived longer than they really are,

and long durations in that series are perceived shorter.



Vierordt, K. von (1868)
Der Zeitsinn nach Versuchen [The time sense according to experiments]
Tübingen, Germany: Laupp

Biases in perceived duration

- Vierordt's law (1868):
short durations in a series are perceived longer than they really are,
and long durations in that series are perceived shorter.

- Hollingworth's central tendency of judgment (1910):
an element in a series tends to be perceived like the median of the series.

THE CENTRAL TENDENCY OF JUDGMENT

Just as our experience with a race, class, or social group results in the conception of a *type* which shall in some way represent the central tendency of the group, and from which the separate members shall deviate the least, so in an experiment on sensible discrimination we become adapted to the median value of the series, tend to expect it, to assimilate all other values toward it, and to greater or less degree to substitute it for them.

H. L. HOLLINGWORTH.

Hollingworth, H. L. (1910)
The central tendency of judgment
Journal of Philosophy, Psychology and Scientific Methods, 7(17), 461–469

Biases in perceived duration

- Vierordt's law (1868):
short durations in a series are perceived longer than they really are,
and long durations in that series are perceived shorter.

- Hollingworth's central tendency of judgment (1910):
an element in a series tends to be perceived like the median of the series.

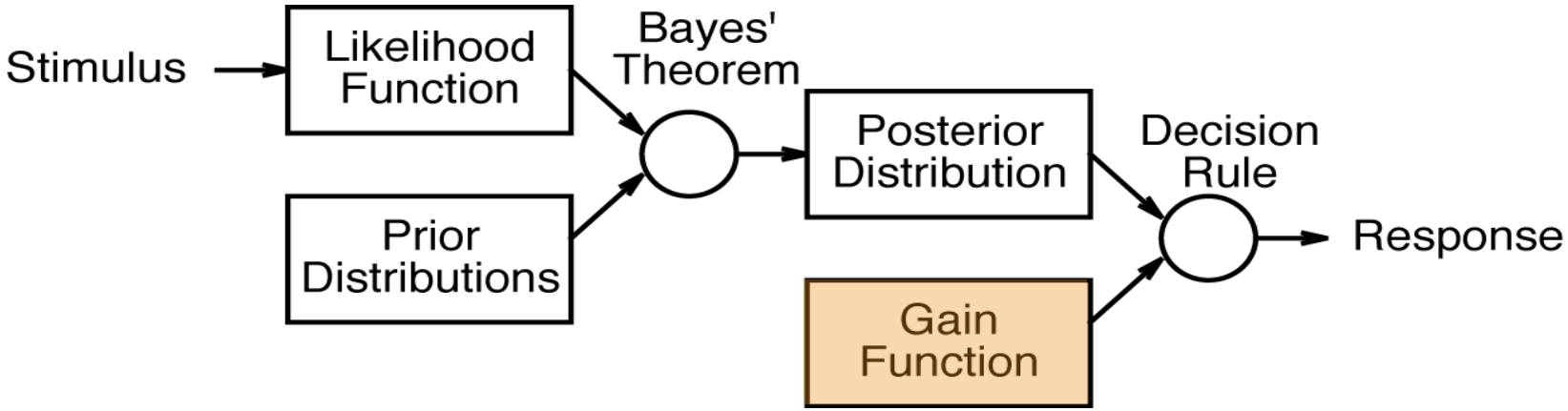
- Allan's time-order error (1977):
the second event in a pair is perceived longer (negative TOE) or shorter (positive TOE) than the first one.

- Issue: are these biases the results of:
  - intrinsic properties of duration (Weber's law)?
  - an update of the prior to expect the next stimulus?
  - the use of a specific cost function?

Bayesian framework

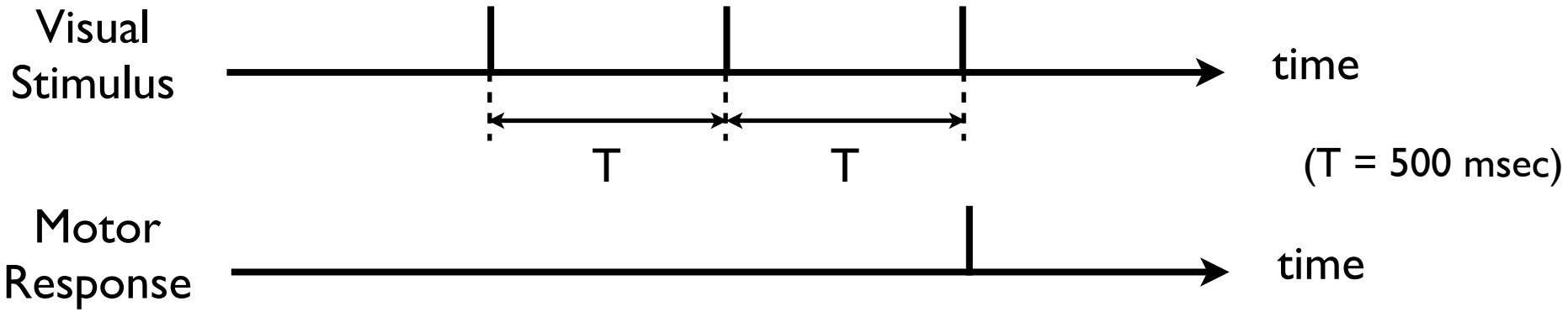
According to the Bayesian framework, a perception can be seen as the resolution of an inference problem. For instance in vision:

What is the most probable world scene that is responsible for the retinal image?



Mamassian, P., Landy, M. S. & Maloney, M. S. (2002)
Bayesian modelling of visual perception
In R. Rao, B. Olshausen & M. Lewicki (Eds.)
Probabilistic Models of the Brain. Cambridge, MA: MIT Press

Methods



Stimulus:

3 pairs of dots forming a hexagon, presented sequentially

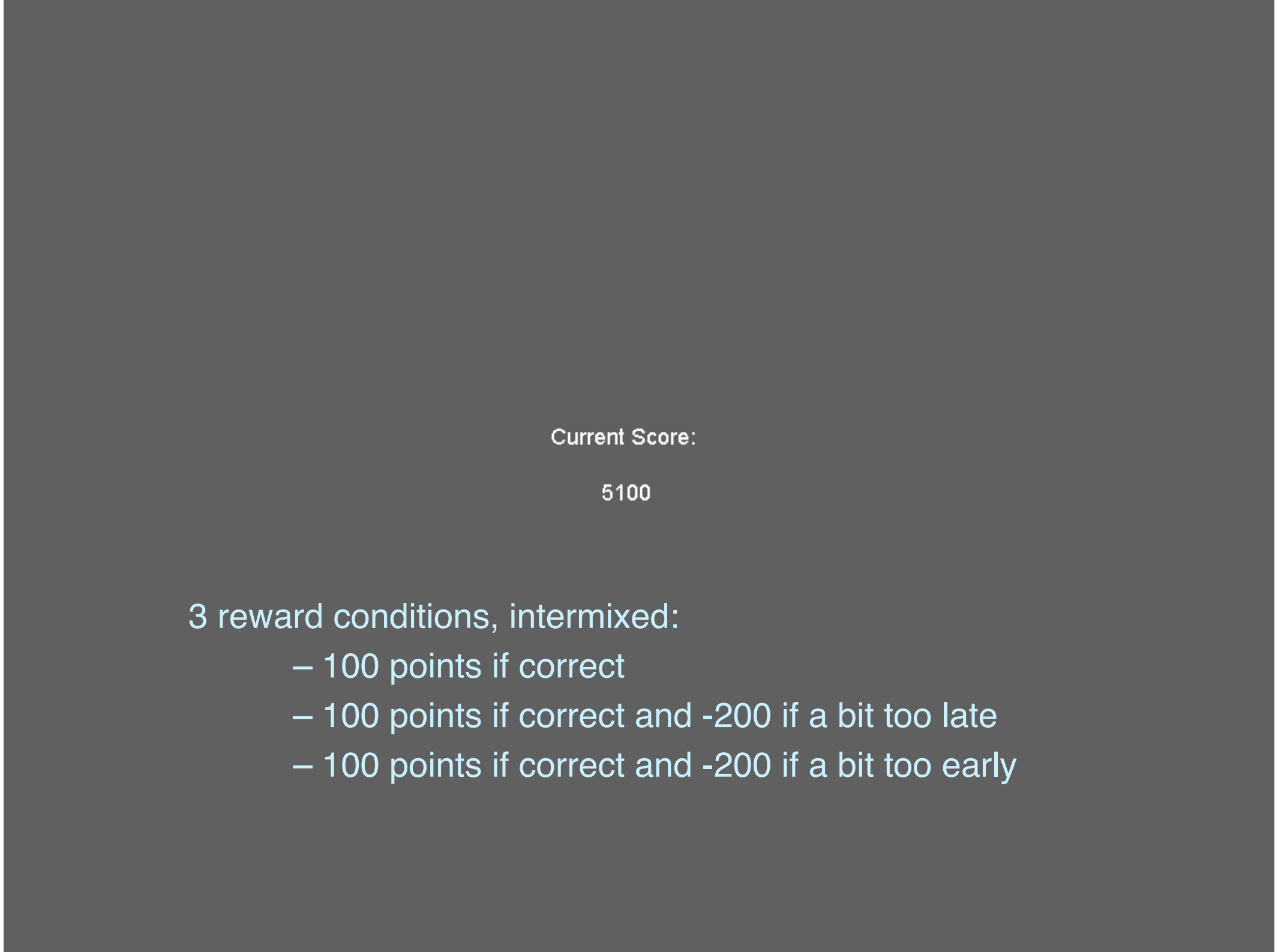
Task:

anticipate the occurrence of the 3rd pair of dots

Reward:

100 points if timing occurs within a pre-defined interval


+100



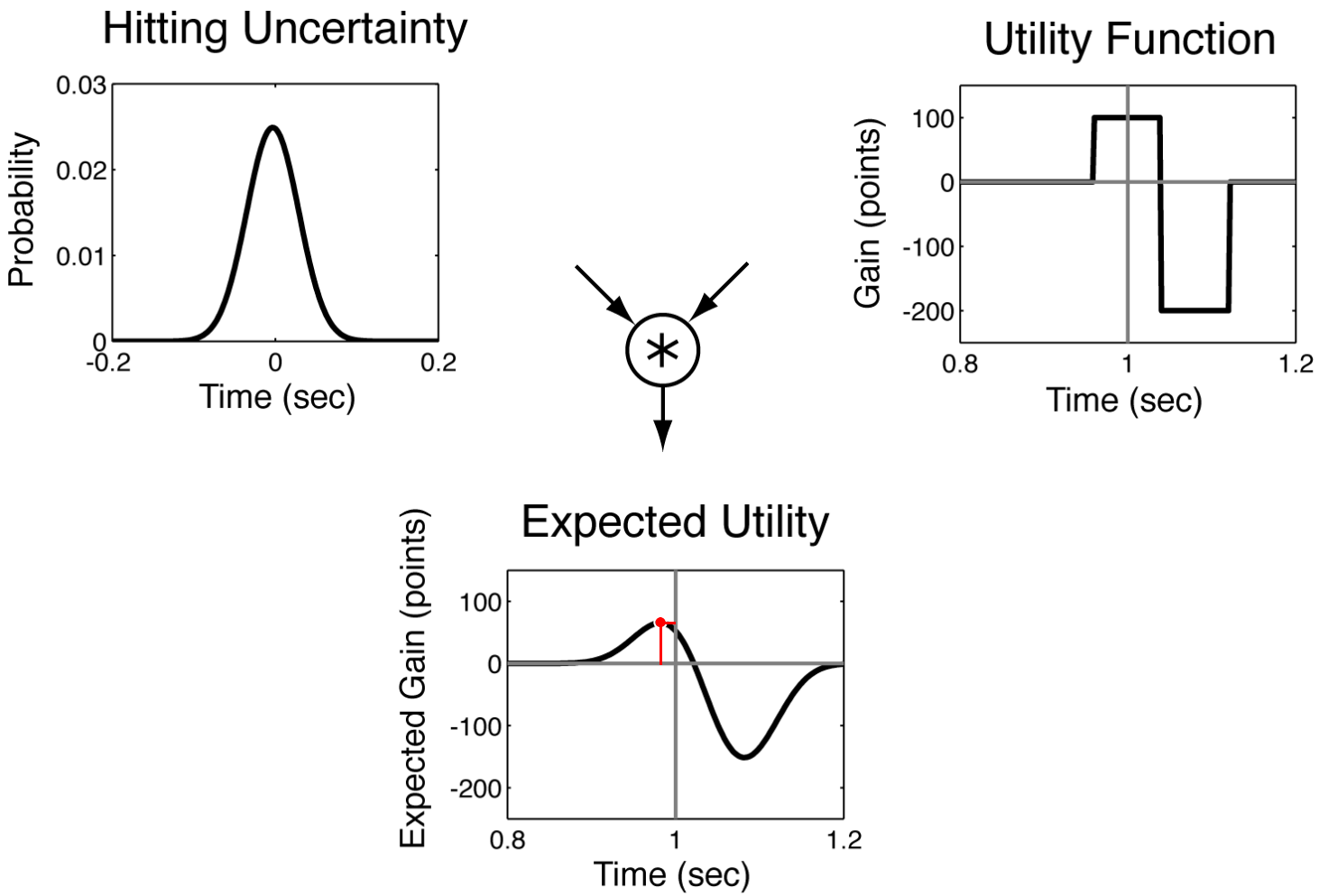
3 reward conditions, intermixed:

- 100 points if correct
- 100 points if correct and -200 if a bit too late
- 100 points if correct and -200 if a bit too early

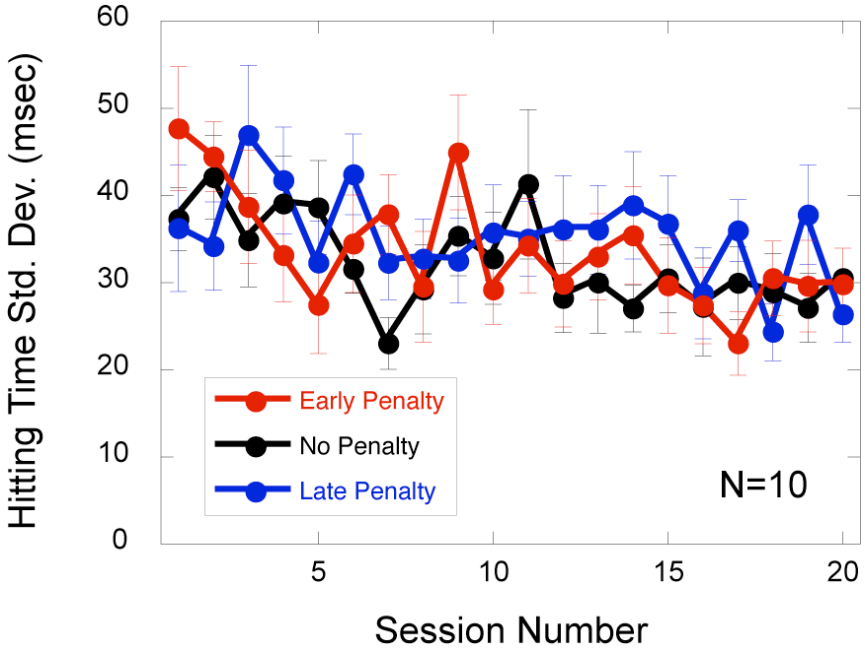
early penalty condition

late penalty condition

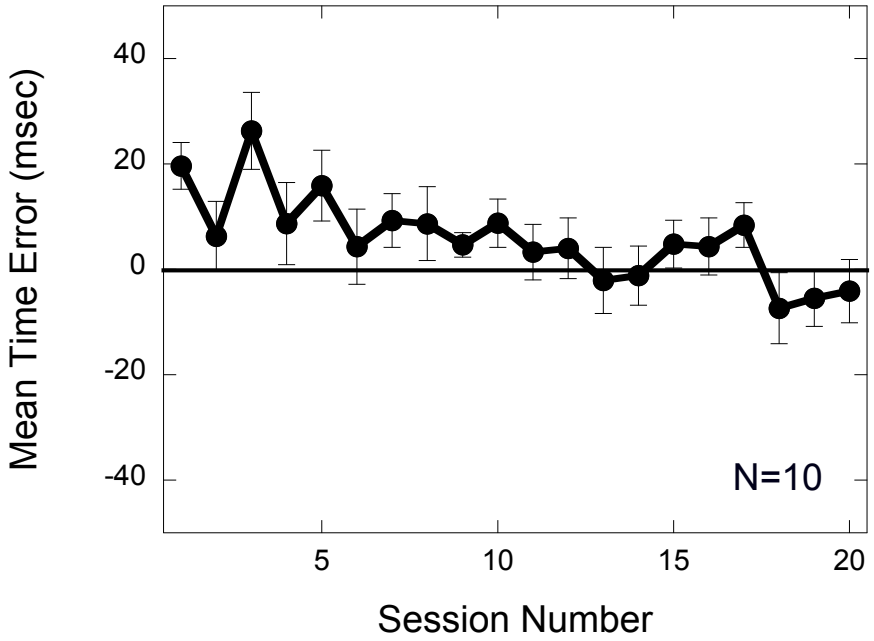
What is the expected behaviour?



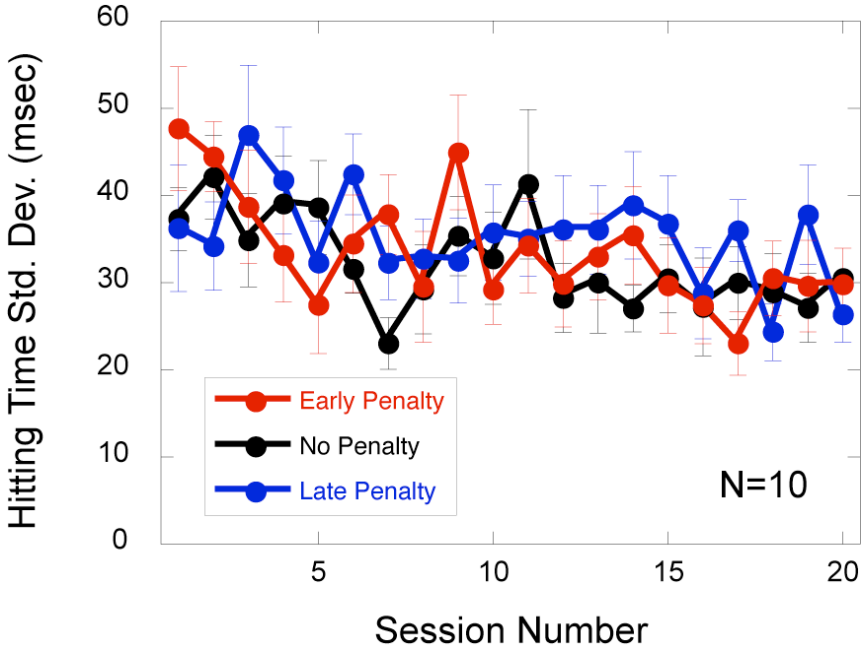
Variability



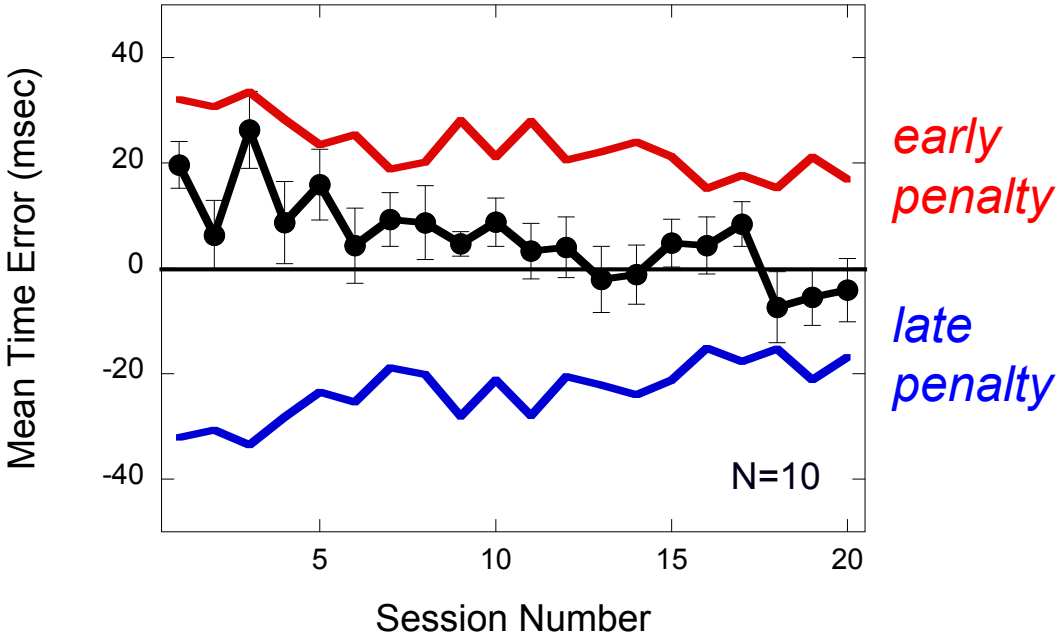
Bias



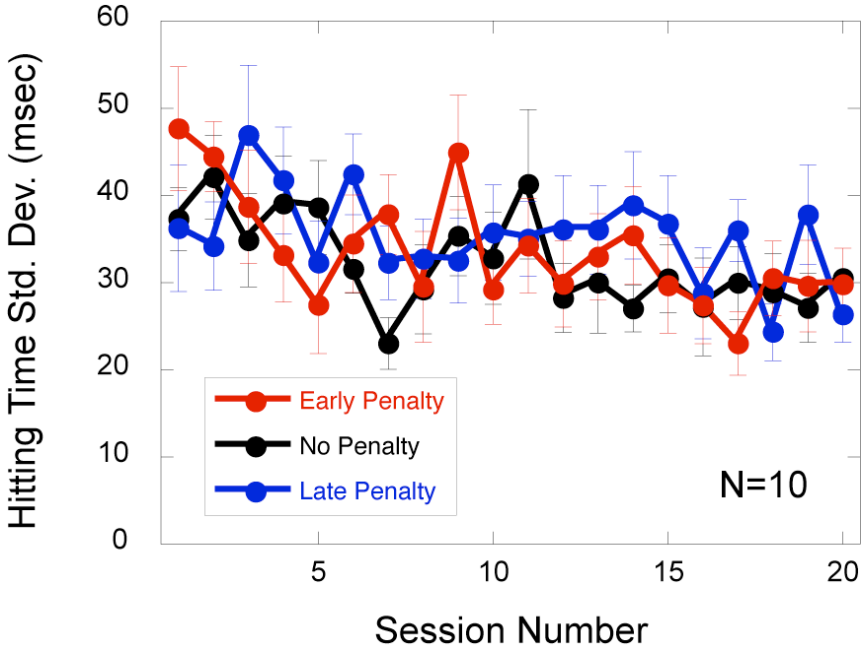
Variability



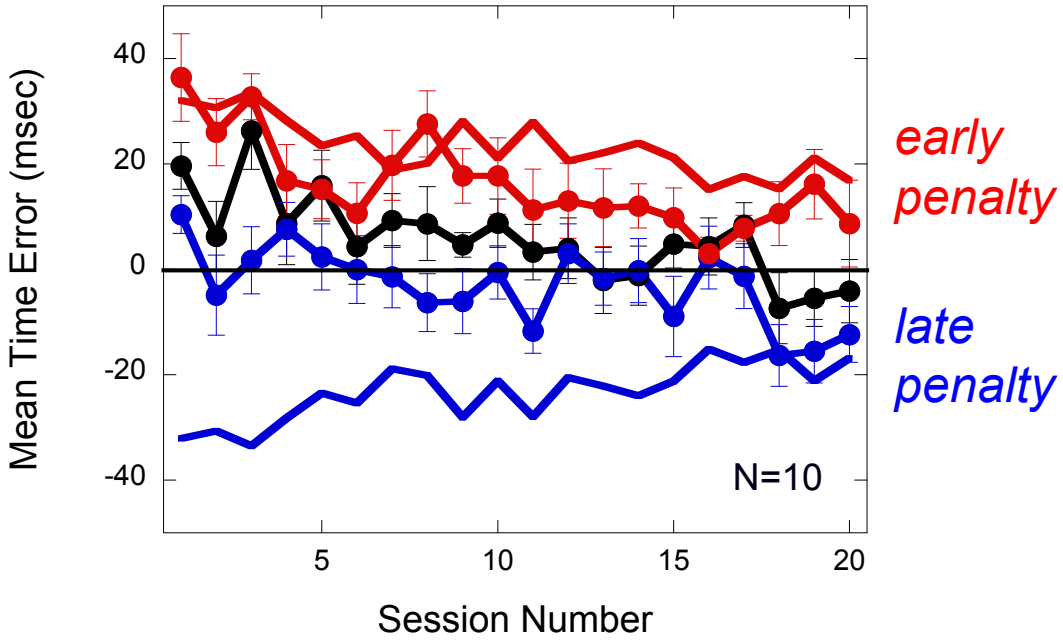
Bias



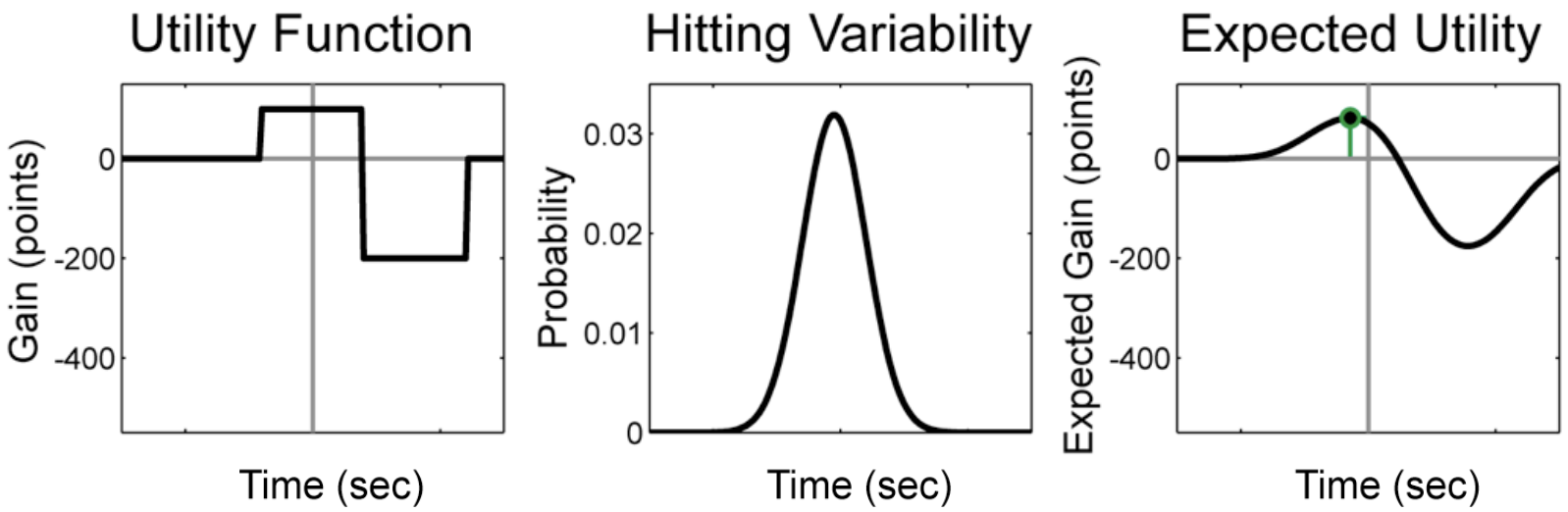
Variability



Bias



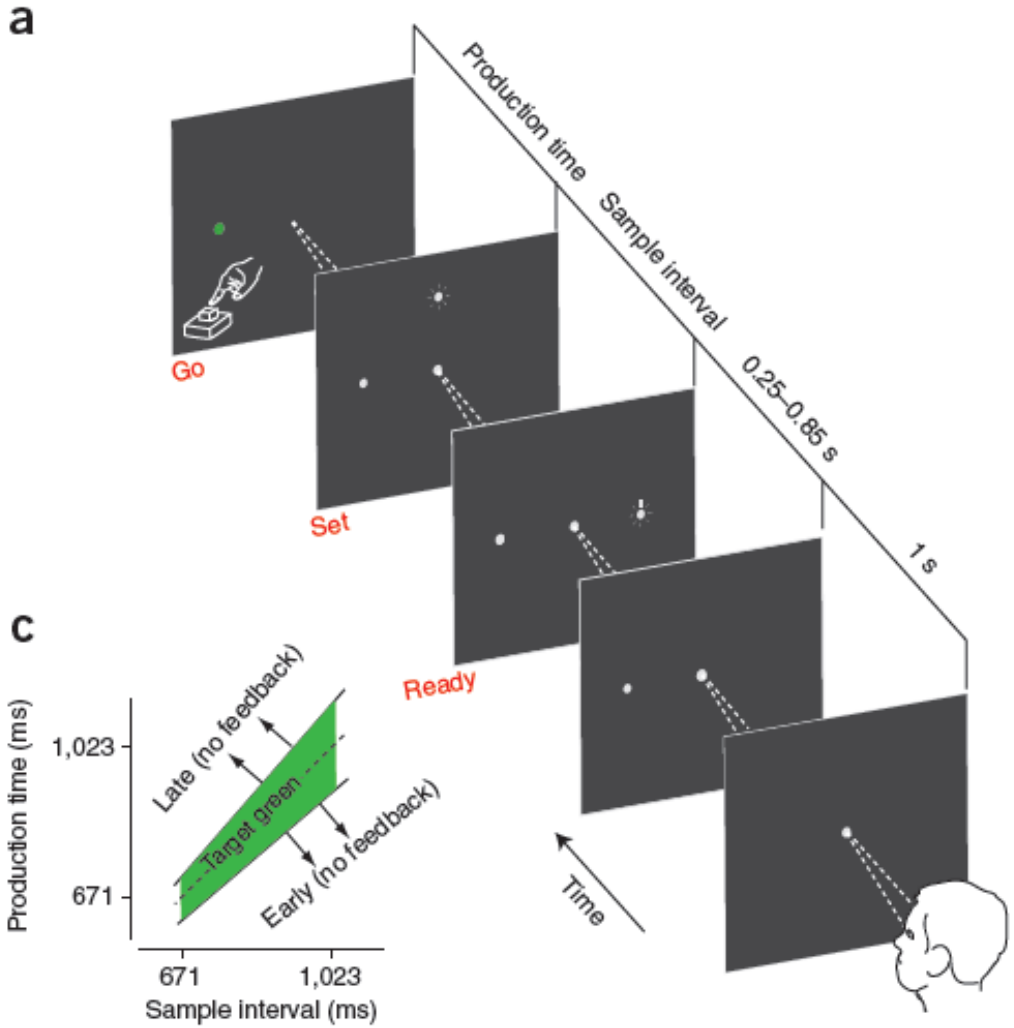
Mamassian, P. (2008)
Overconfidence in an objective anticipatory motor task
Psychological Science, 19, 601-606


Utility Function
Gain (points)
0
-200
-400
Time (sec)
Hitting Variability
Probability
0.03
0.02
0.01
0
Time (sec)
Expected Utility
Expected Gain (points)
0
-200
-400
Time (sec)

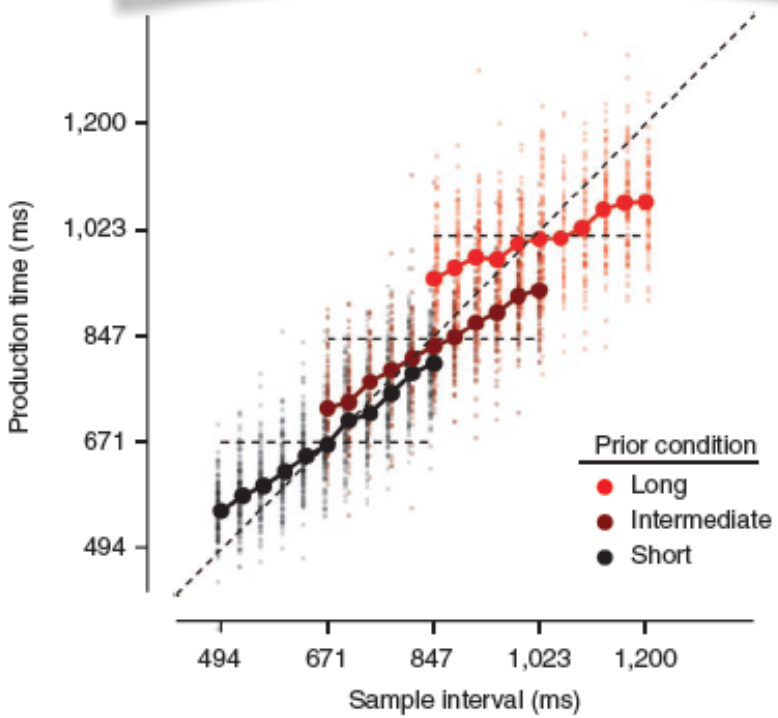
Interim summary

- Participants are initially biased to over-estimate the duration of the interval (positive time-order error), but they can easily learn to cancel this bias.

- Participants also behave in an over-confident manner, either under-estimating the internal variability or under-estimating the cost of making an error.



This is the Central Tendency of Judgment



Jazayeri, M. & Shadlen, M. N. (2010)
Temporal context calibrates interval timing
Nature Neuroscience, 13, 1020-1026

How common are these Central Tendencies of Judgment?

In other words, how reproducible are these effects?

RESEARCH ARTICLE

PSYCHOLOGY

Estimating the reproducibility of psychological science

Open Science Collaboration*†

Reproducibility is a defining feature of science, but the extent to which it characterizes current research is unknown. We conducted replications of 100 experimental and correlational studies published in three psychology journals using high-powered designs and original materials when available. Replication effects were half the magnitude of original effects, representing a substantial decline. Ninety-seven percent of original studies had statistically significant results. Thirty-six percent of replications had statistically significant results; 47% of original effect sizes were in the 95% confidence interval of the replication effect size; 39% of effects were subjectively rated to have replicated the original result; and if no bias in original results is assumed, combining original and replication results left 68% with statistically significant effects. Correlational tests suggest that replication success was better predicted by the strength of original evidence than by characteristics of the original and replication teams.

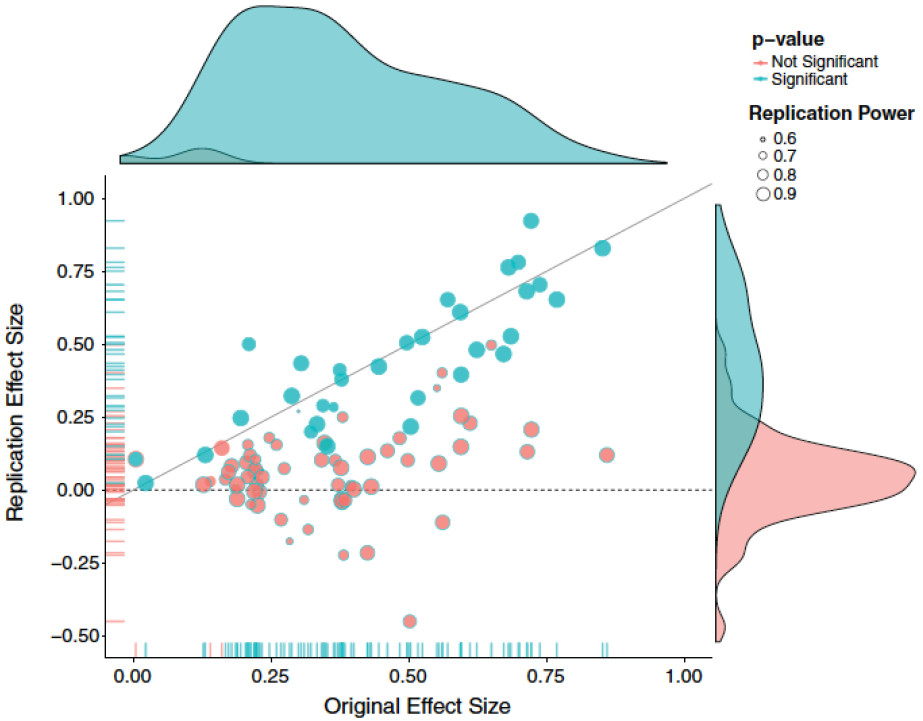
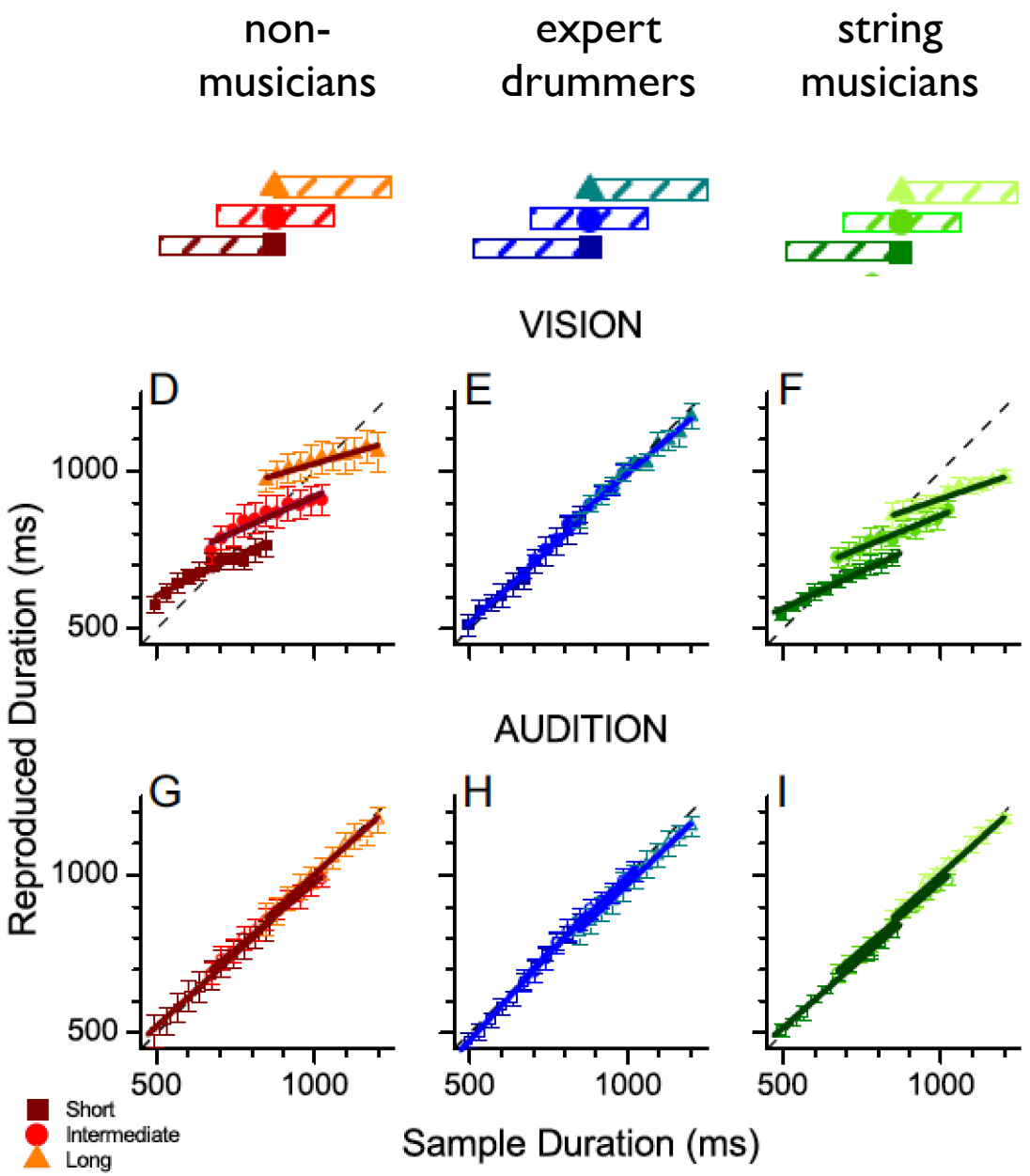
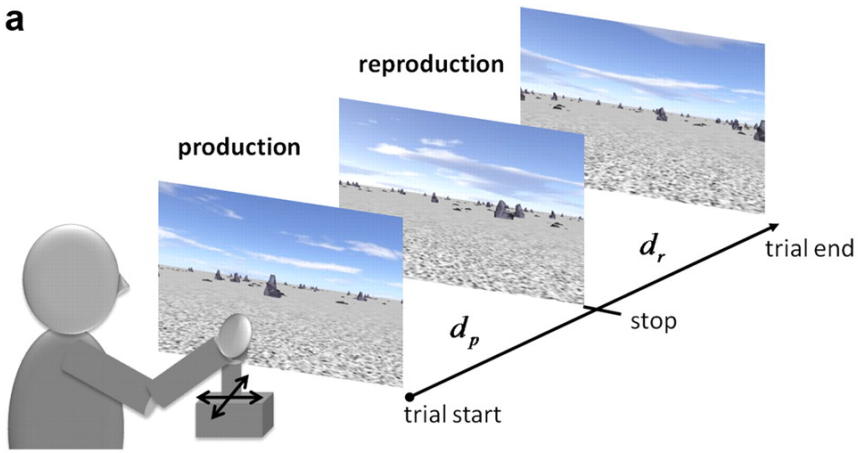


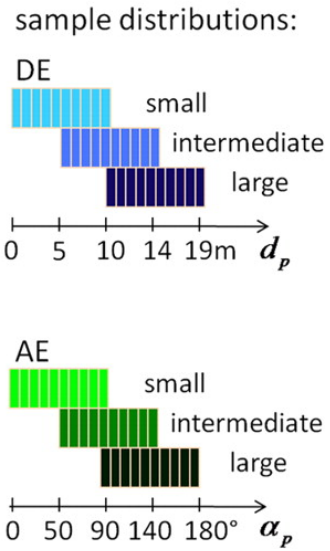
Fig. 3. Original study effect size versus replication effect size (correlation coefficients). Diagonal line represents replication effect size equal to original effect size. Dotted line represents replication effect size of 0. Points below the dotted line were effects in the opposite direction of the original. Density plots are separated by significant (blue) and nonsignificant (red) effects.

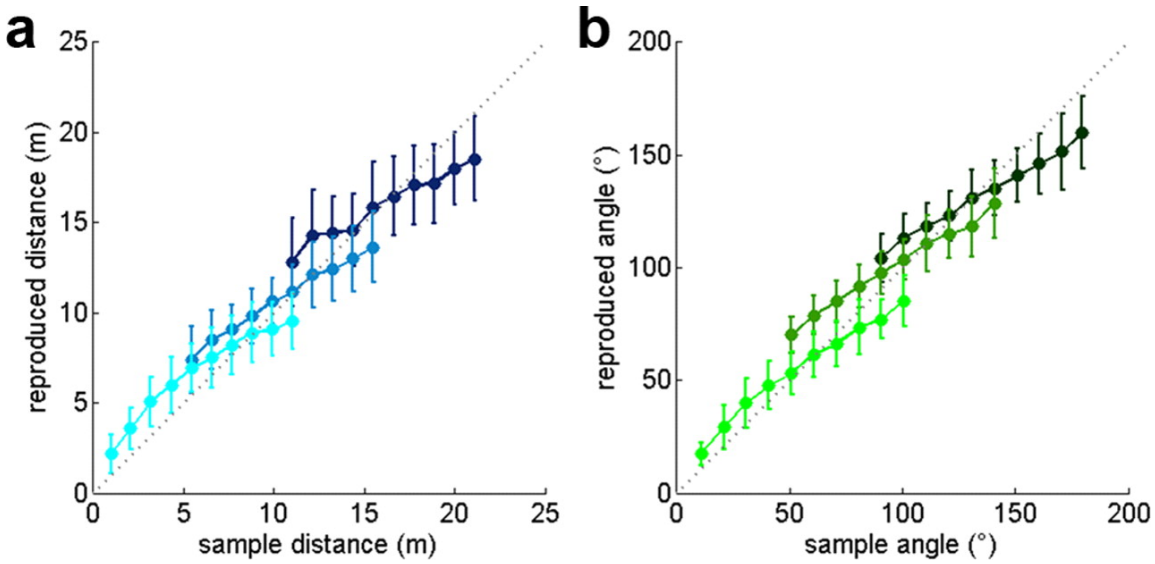
Open Science Collaboration (2015)
Estimating the reproducibility of psychological science
Science, 349(6251), 943



Cicchini, G. M., Arrighi, R., Cecchetti, L., Giusti, M., & Burr, D. C. (2012)
Optimal encoding of interval timing in expert percussionists
The Journal of Neuroscience, 32(3), 1056-1060

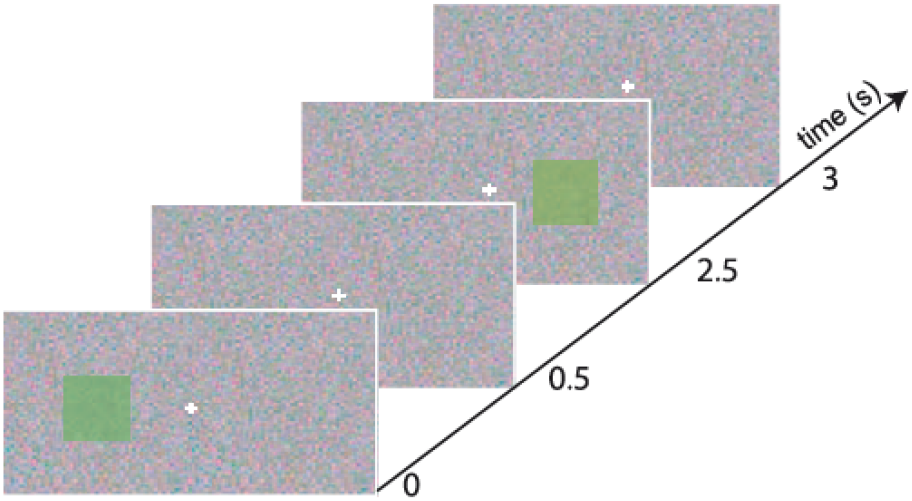


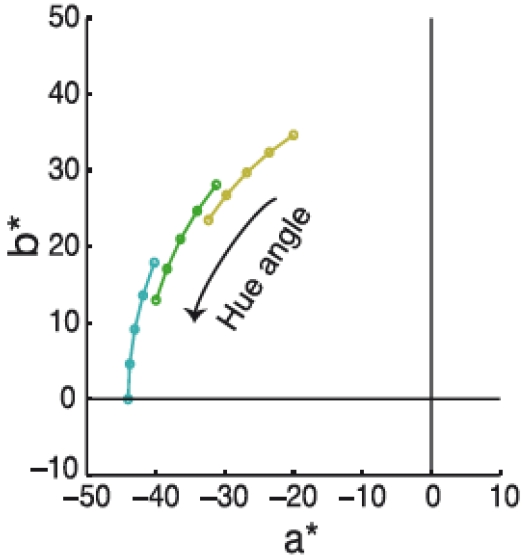


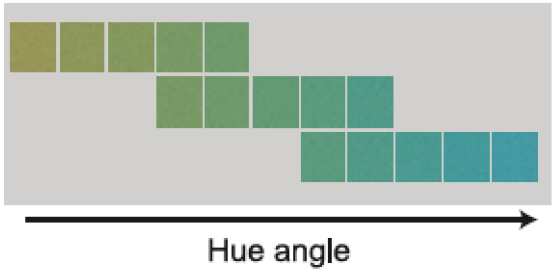


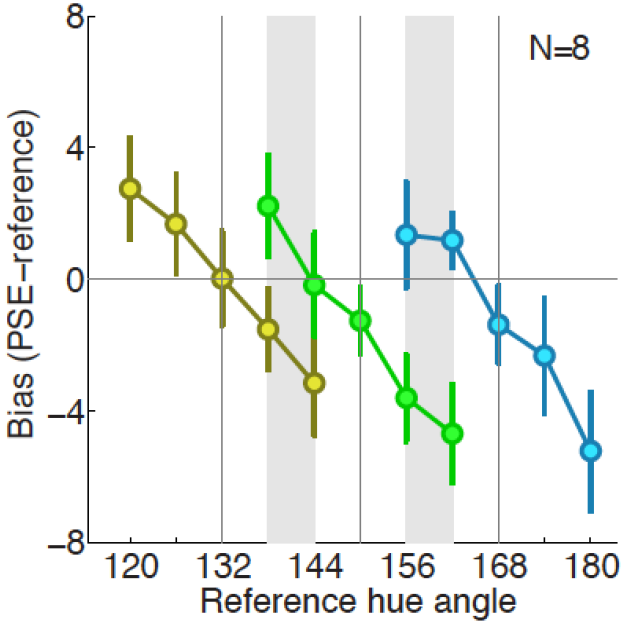
Petzschner, F. H. & Glasauer, S. (2011)
Iterative Bayesian estimation as an explanation for range and regression effects: A study on human path integration
The Journal of Neuroscience, 31(47), 17220-17229

Task: Which center patch appears bluer (group 1) / yellower (group 2)?

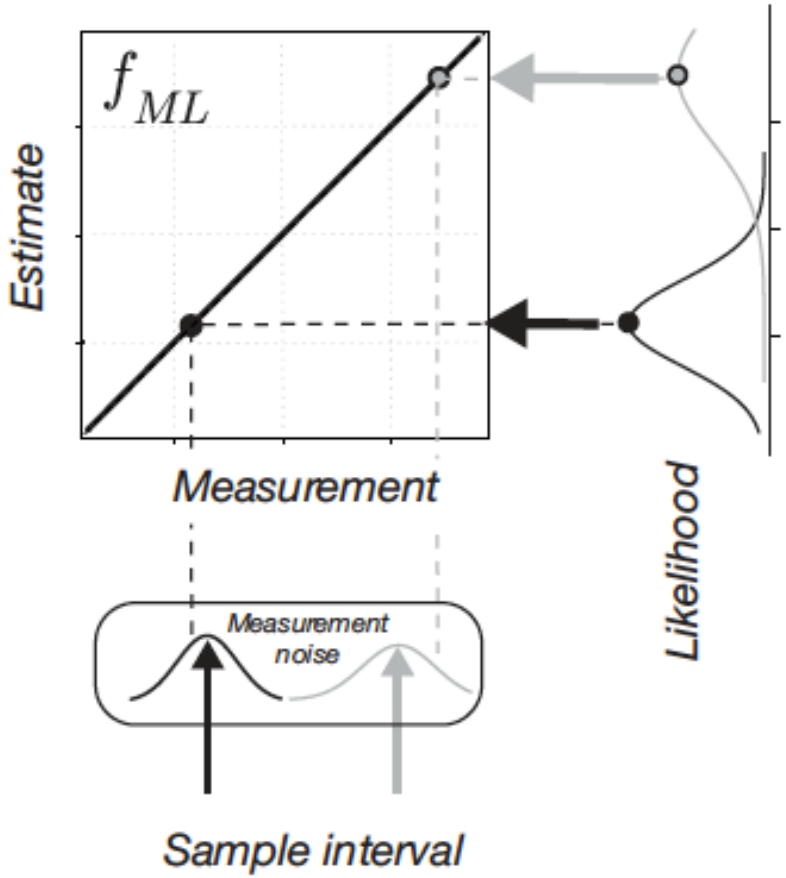






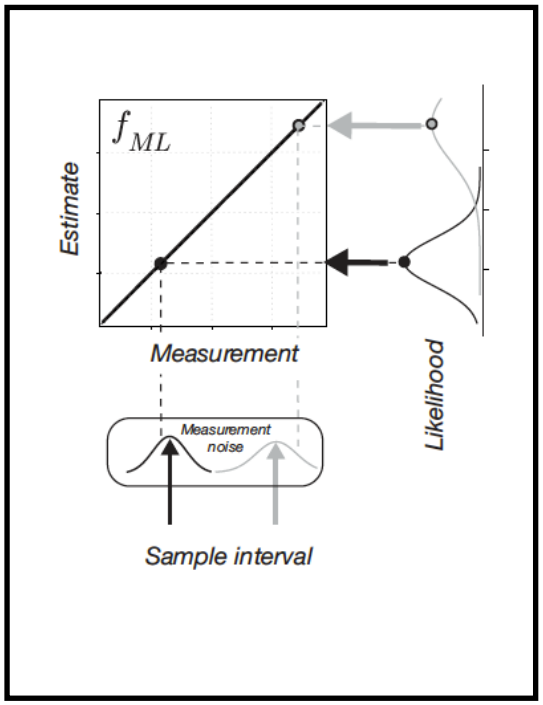


Olkkonen, M., McCarthy, P. F., & Allred, S. R. (2014)
The central tendency bias in color perception: Effects of internal and external noise
Journal of Vision, 14(11):5, 1-15

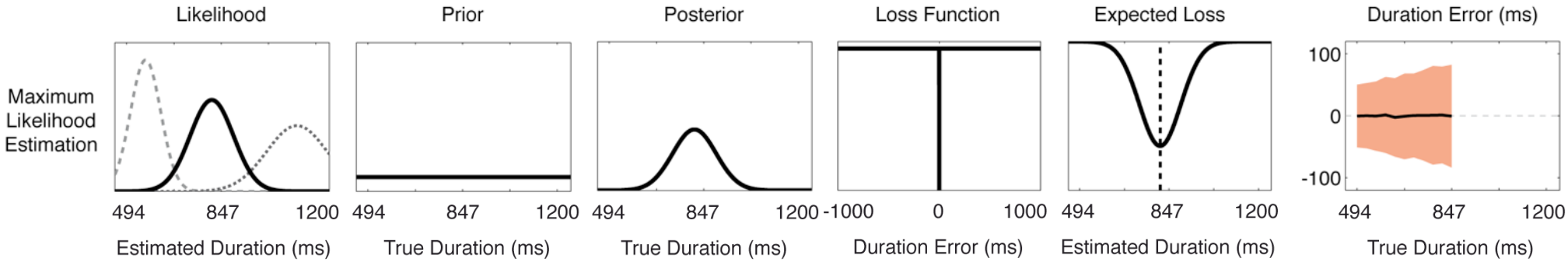


Jazayeri, M. & Shadlen, M. N. (2010)
Temporal context calibrates interval timing
Nature Neuroscience, 13, 1020-1026

Maximum Likelihood Estimation

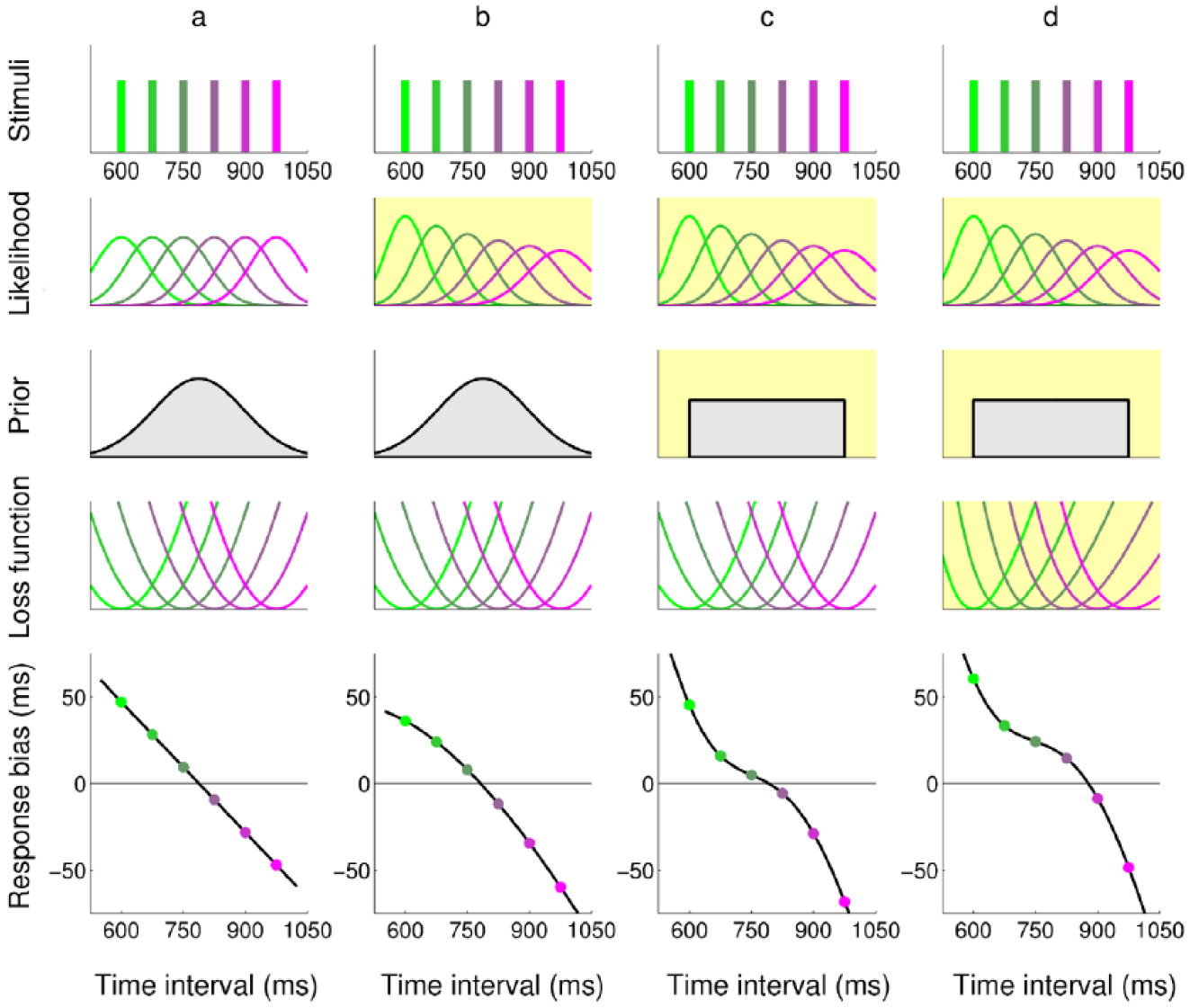


Jazayeri, M. & Shadlen, M. N. (2010)
Temporal context calibrates interval timing
Nature Neuroscience, 13, 1020-1026



Mamassian, P. & Landy, M. S. (2010)
It's that time again [News & Views]
Nature Neuroscience, 13, 914-916

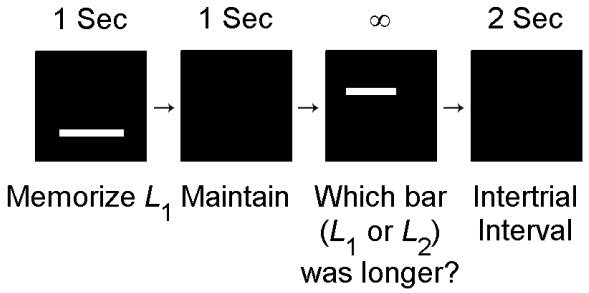
Next step: comparing different models



Acerbi, L., Wolpert, D. M., & Vijayakumar, S. (2012)
Internal representations of temporal statistics and feedback calibrate motor-sensory interval timing
PLoS Computational Biology, 8(11):e1002771

Estimating each Bayesian component separately

A



Ashourian, P. & Loewenstein, Y. (2011)
Bayesian inference underlies the contraction bias in delayed comparison tasks
PLoS ONE 6(5): e19551

How is the prior learned?

- Most likely in an iterative way
  (Petzschner & Glasauer, 2011, J Neurosc; Bausenhart, Dyjas & Ulrich, 2014, Acta Psych).

How is the prior learned?

- Most likely in an iterative way
  (Petzschner & Glasauer, 2011, J Neurosc; Bausenhart, Dyjas & Ulrich, 2014, Acta Psych).

- This will introduce sequential effects
  (e.g. Cross, 1973, Percept Psychophys; periodically rediscovered, e.g. Fisher & Whitney, 2014, Nat Neuro).

Perception & Psychophysics
1973, Vol. 14, No. 3, 547-552

Sequential dependencies and regression in psychophysical judgments*

DAVID V. CROSS
State University of New York at Stony Brook, Stony Brook, New York 11790

A tendency for judgments of stimulus magnitude to be biased in the direction of the value of the immediately preceding stimulus is found in magnitude estimations of loudness. This produces a bias in the empirical psychophysical function that results in underestimation of the exponent of the unbiased function presumed to relate number and stimulus intensity, $N = aS^n$.

Discussion

- Participants exhibit a regression to the mean of a set in judging perceived duration (Vierordt's law; Central Tendency of Judgment). This regression is larger for longer durations.

- The regression to the mean can be explained by a Bayesian model that includes specific properties of the likelihood (Weber's law), prior (knowledge of the set), and cost function (quadratic).

- There is no unique solution for the combination of these three properties.

- One workaround is to try and estimate each Bayesian component separately, and test the model in a different context (Bayesian transfer: Maloney & Mamassian, 2009, Vis Neurosc).