TECHNISCHE UNIVERSITÄT DRESDEN

Department of Psychology, Chair of Neuroimaging

Models of perceptual decision making

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DRESDEN concept
Exzellenz aus Wissenschaft und Kultur

Overview

1 Perceptual decision making: Experiments

2 The drift-diffusion model

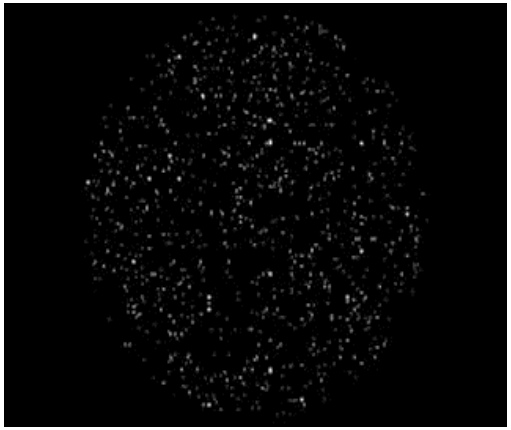
3 Bayesian version of the drift-diffusion model

4 Model comparison

5 Summary

Overview

Random dot motion task



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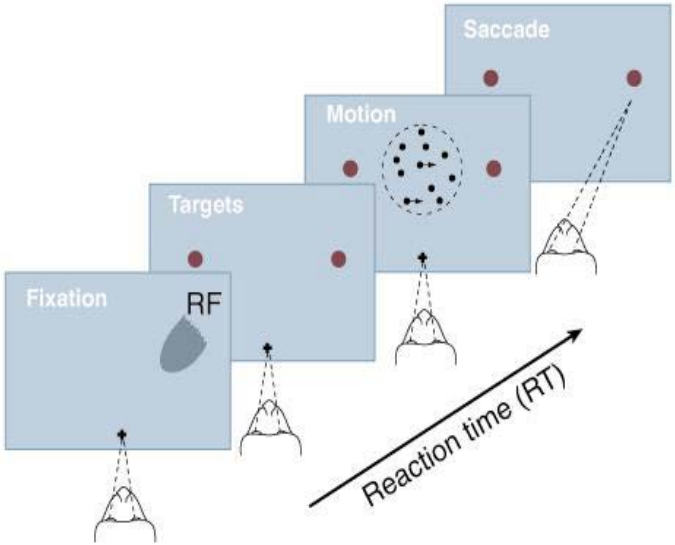

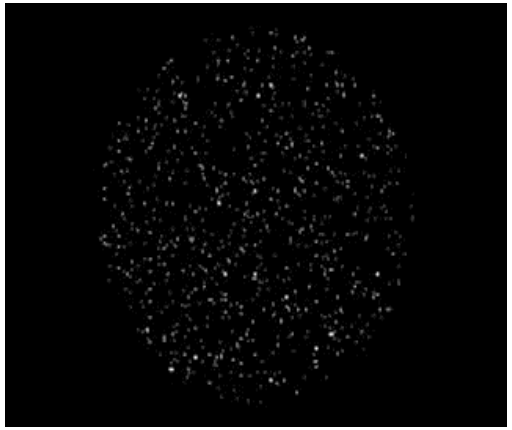

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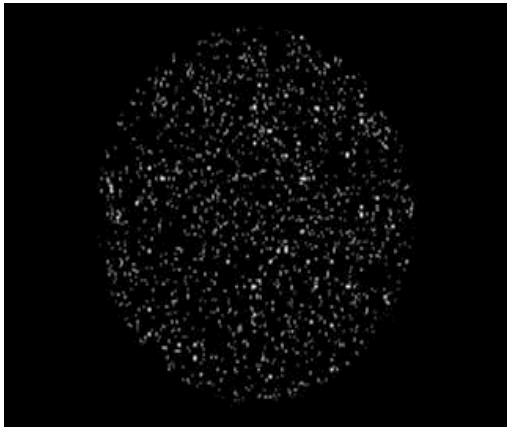

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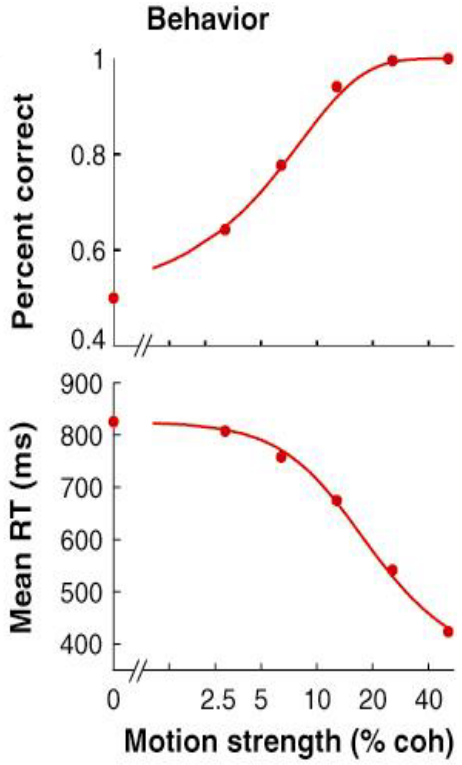
Gold & Shadlen, Annu Rev Neurosci, 2007; http://monkeybiz.stanford.edu/research.html

Behaviour



Behaviour depends on difficulty level, i.e., coherence of moving dots

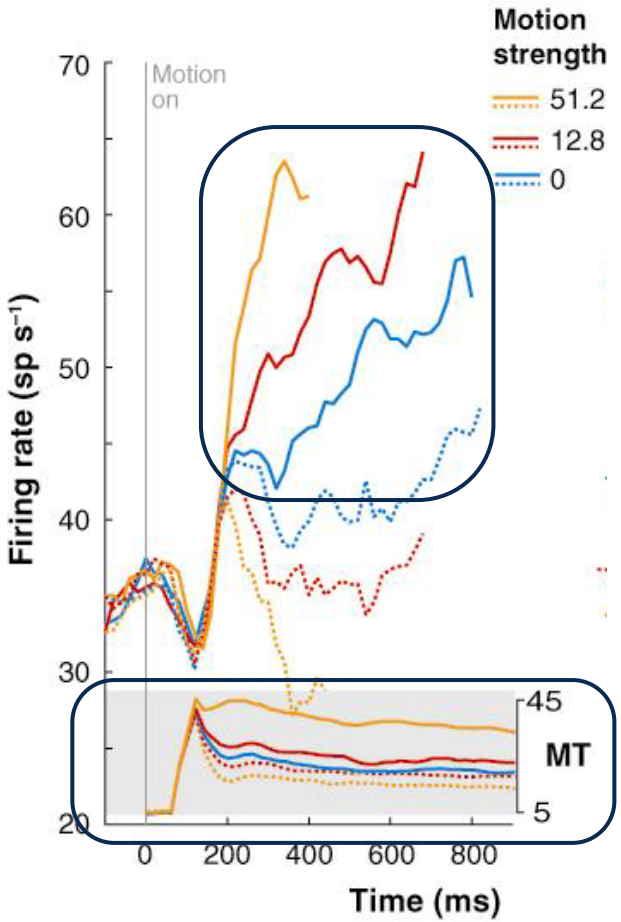
When task easier:

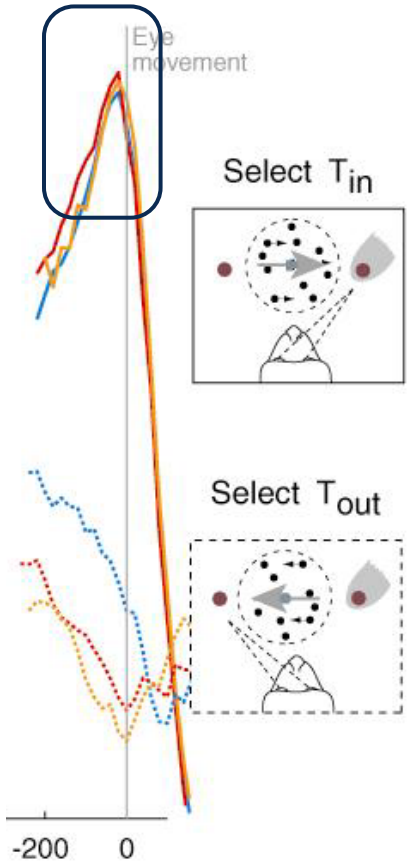
Better performance

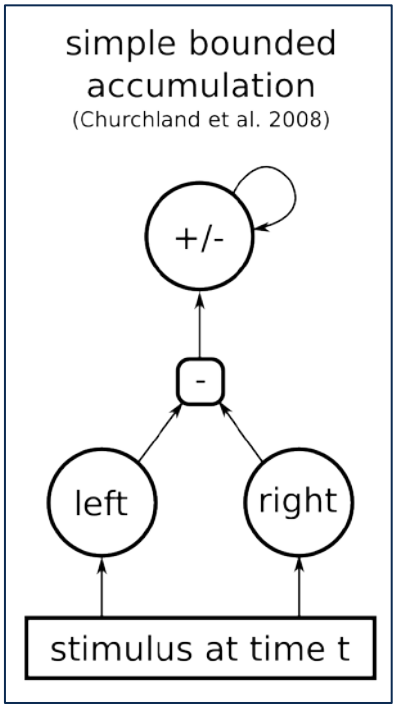
Faster reaction times

Gold & Shadlen, Annu Rev Neurosci, 2007

Neuronal findings



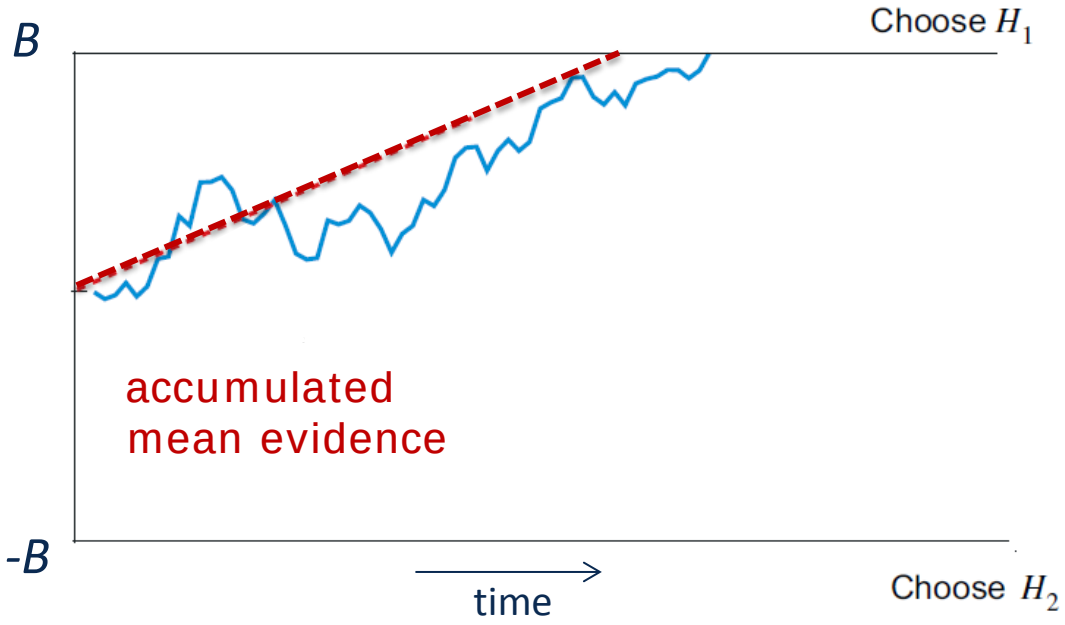




Gold & Shadlen, Annu Rev Neurosci, 2007

Overview

Drift-diffusion model (DDM)



Continuous:

$$dy = vdt + sdW$$

Discrete:

$$y_t - y_{t-\Delta t} = v\Delta t + \sqrt{\Delta t}s\varepsilon_t$$

Decision made when:

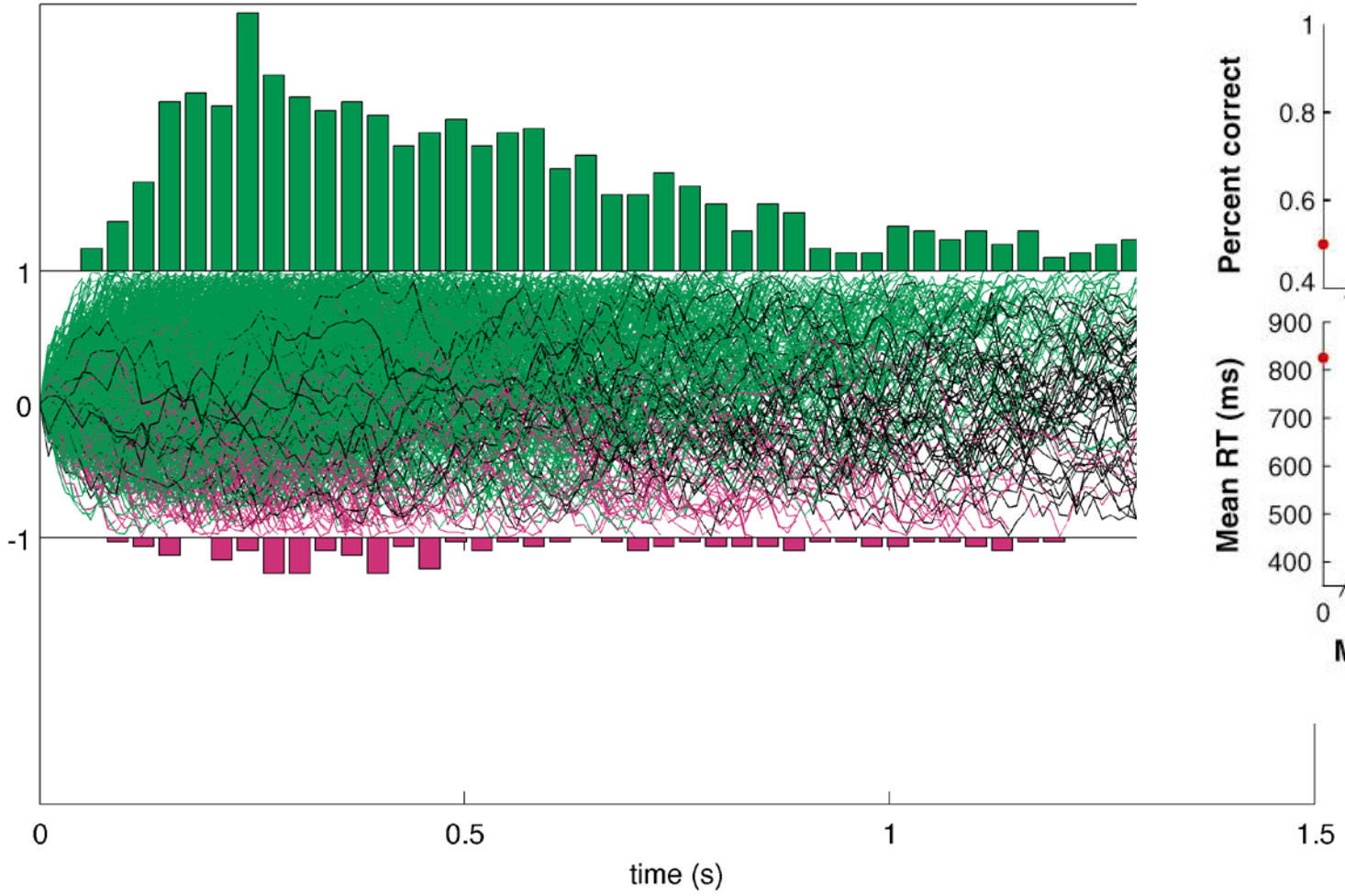
$$|y_t| \geq B$$

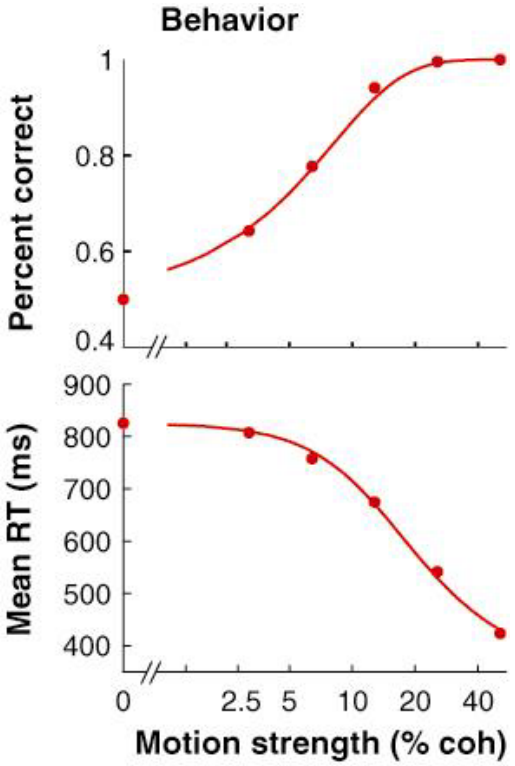
Noise → variance in RT

Noise → errors

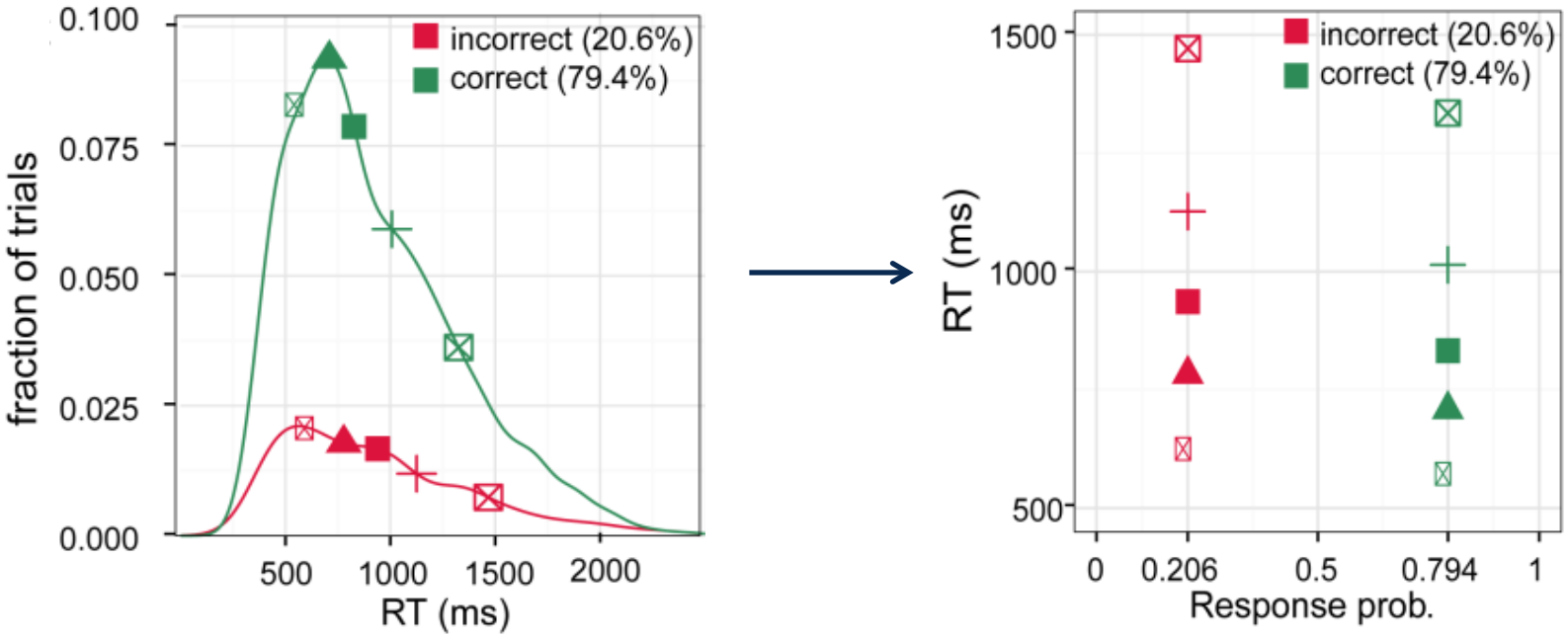
Ratcliff (1978); Bogacz et al. (2006)

Model for reaction times and performance





DDM: Reduction of data



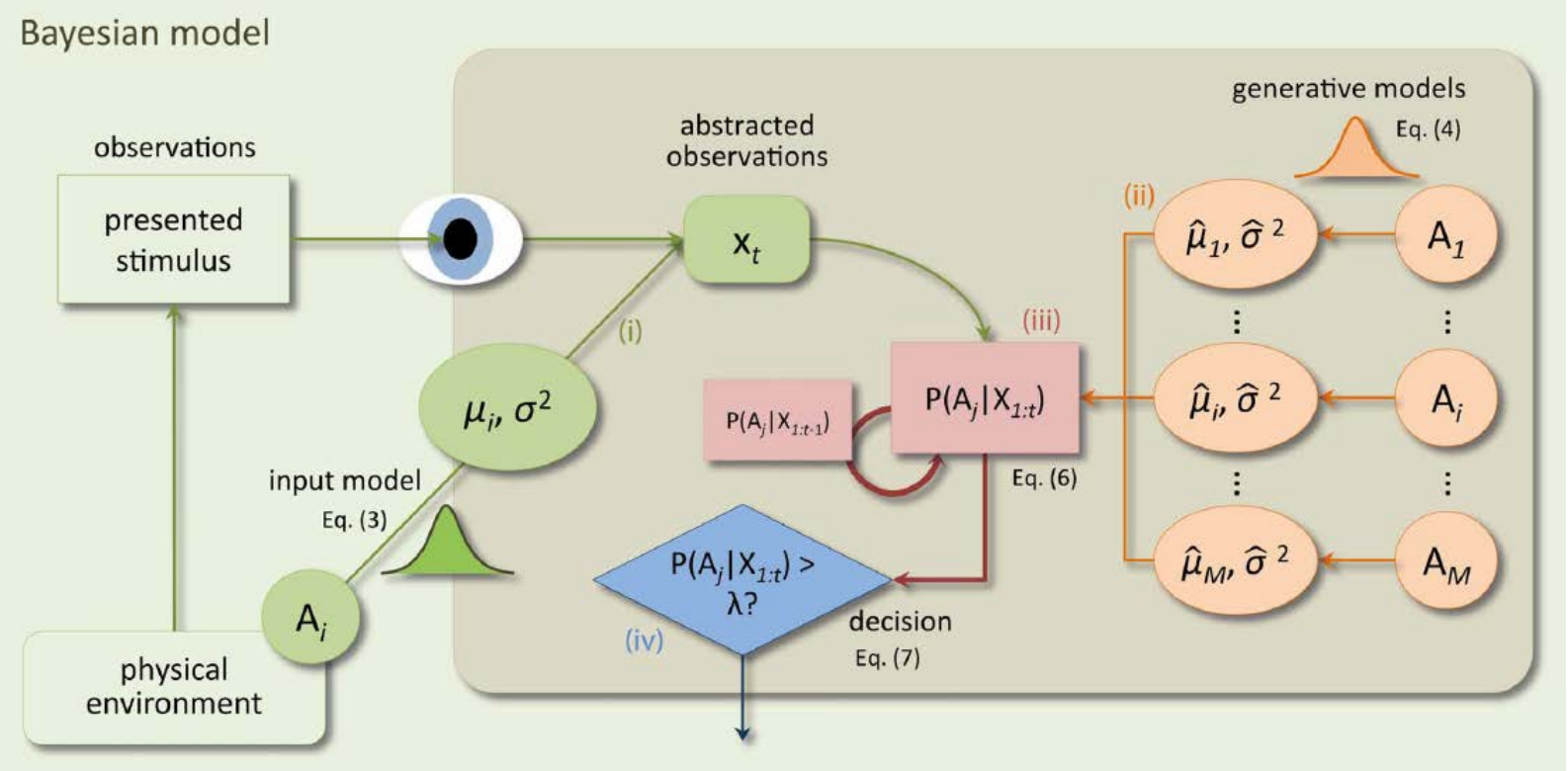
Behavioural measures:
Single trials with one RT and one choice.
RTs can be plotted as histogram.

DDM reduces data to typically five RT quantiles per choice and one performance percentage.

Typically, the quantile data are fitted, as opposed to single trial reaction times or the histogram.

Overview

Bayesian version of drift-diffusion model



Idea: Re-formulate the drift-diffusion model as a Bayesian model based on a generative model.

Advantage: Recast as a predictive coding model and can use Bayesian machinery now.

Bitzer et al., Frontiers in Human Neuroscience, 2014

Equivalence of DDM and Bayesian version

The reformulation of the DDM as Bayesian inference provides some interesting insights into the mechanism.

For example, the drift rate *v* of the DDM is inversely related to the squared uncertainty of the decision maker (i.e. the internal noise estimate).

$$v = \frac{2}{r^2 dt^2}$$

This is interesting because it indicates that the strength of the evidence input to the DDM is related to an estimate of how noisy the the sensory input is.

What else, except for insights, is the equivalence of the DDM to Bayesian inference good for?

Bitzer et al., Frontiers in Human Neuroscience, 2014

Overview

Single trial modelling

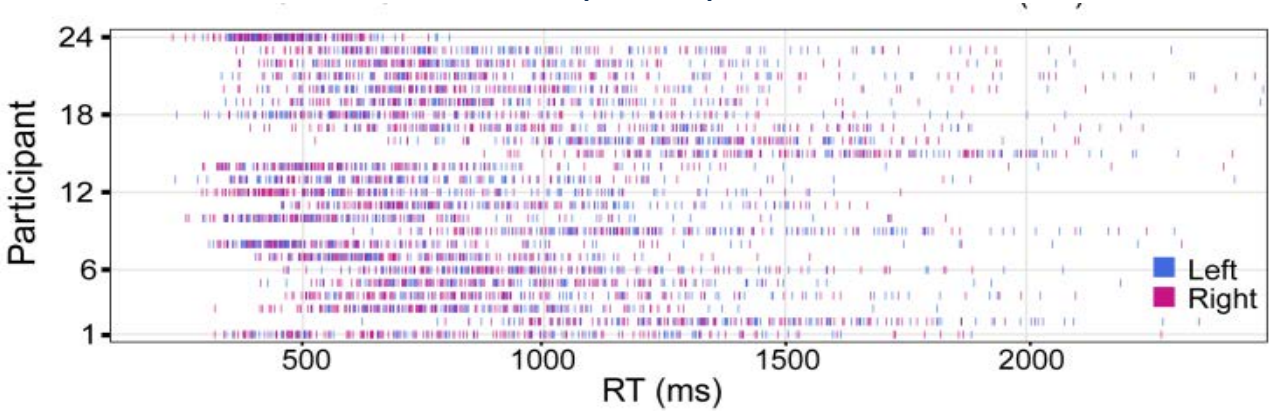
Idea: Provide trial-wise sensory input seen by participant to Bayesian model.

Which is the better model?

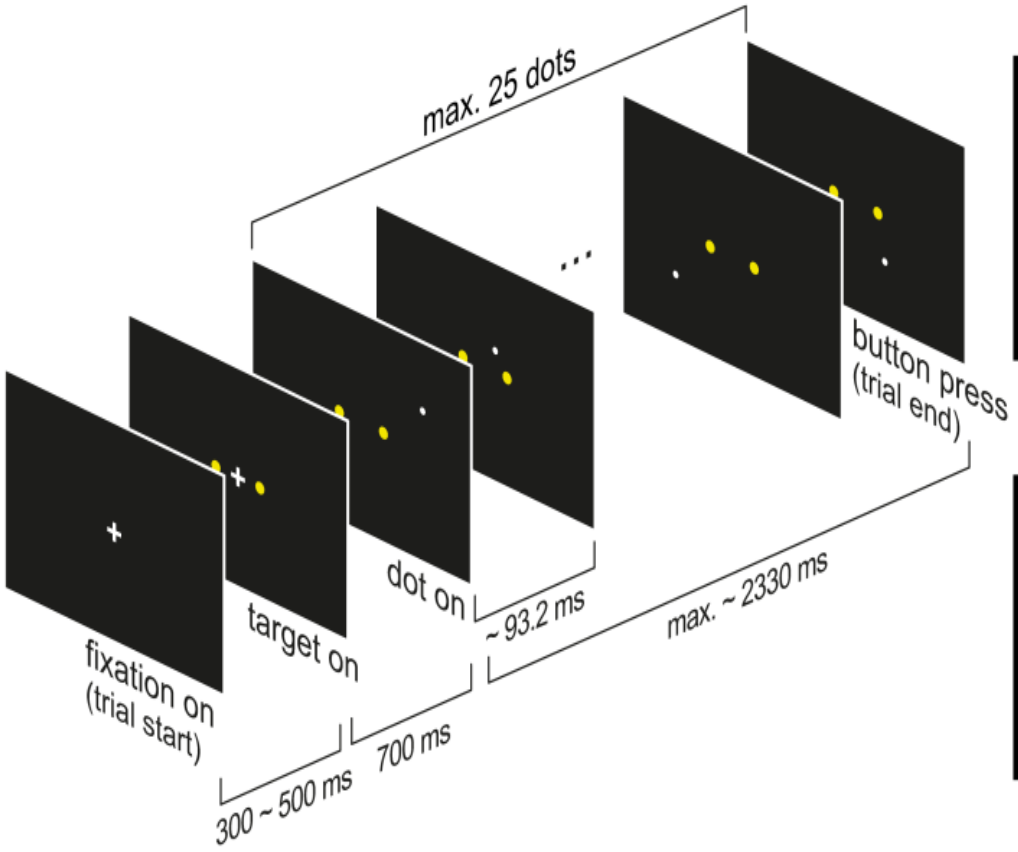
1. A DDM-equivalent model which uses random input?

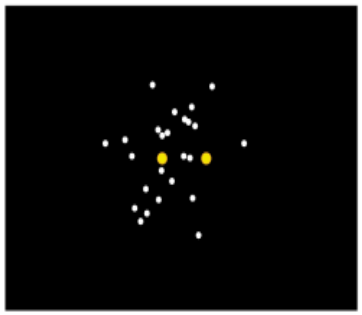
2. Or a model that sees exactly the same input as participants?

Behavioural data: 24 participants with 800 trials each.

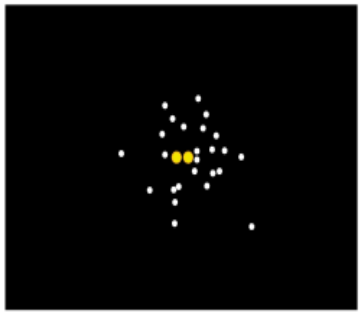


Single dot tracking task

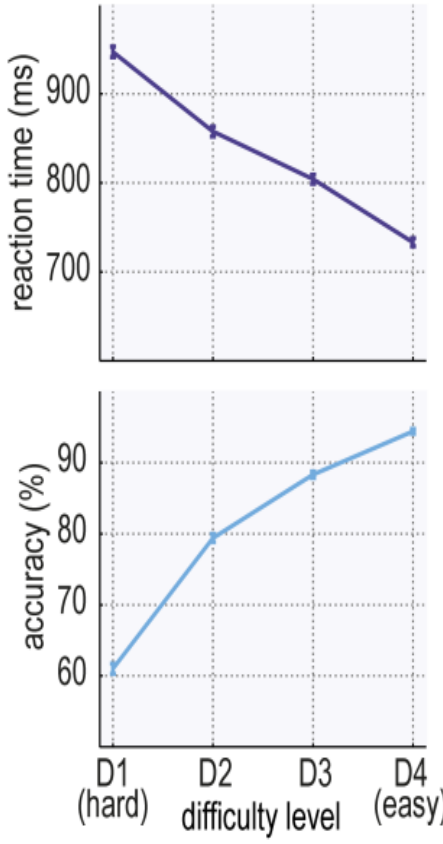




easy trial (target: left)



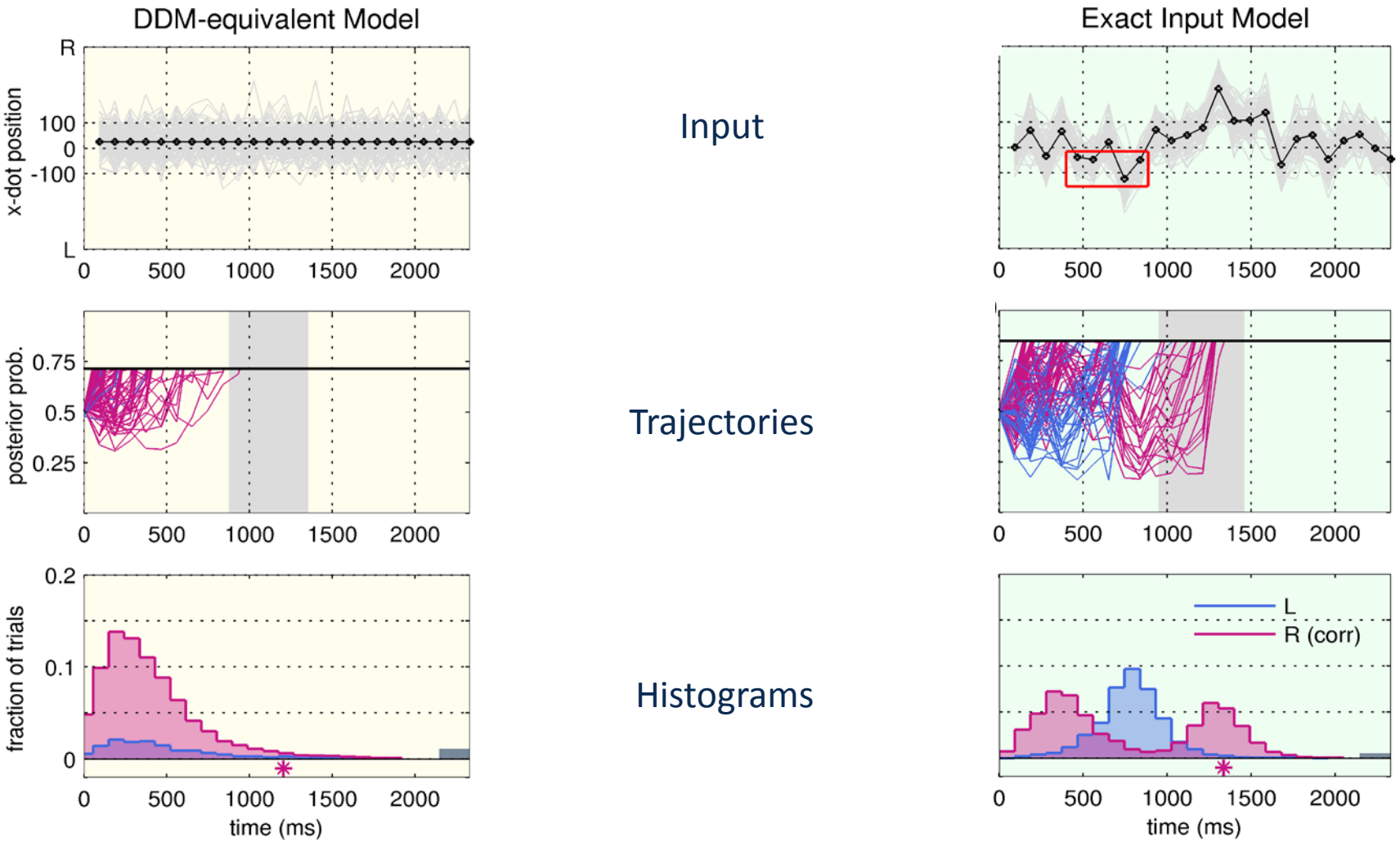
hard trial (target: right)



→ Poster #1457, Tuesday afternoon

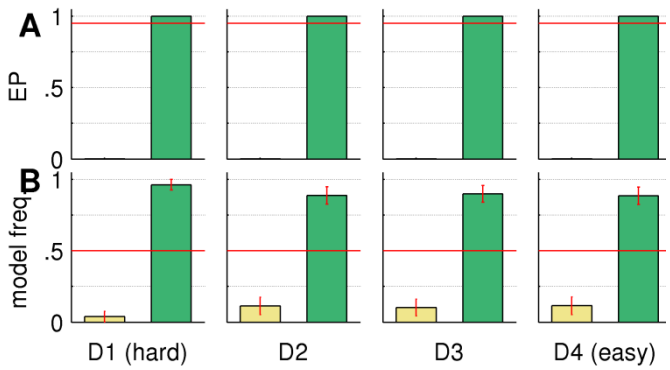
Park et al., under review

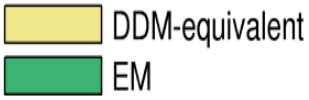
Model predictions



Park et al., under review

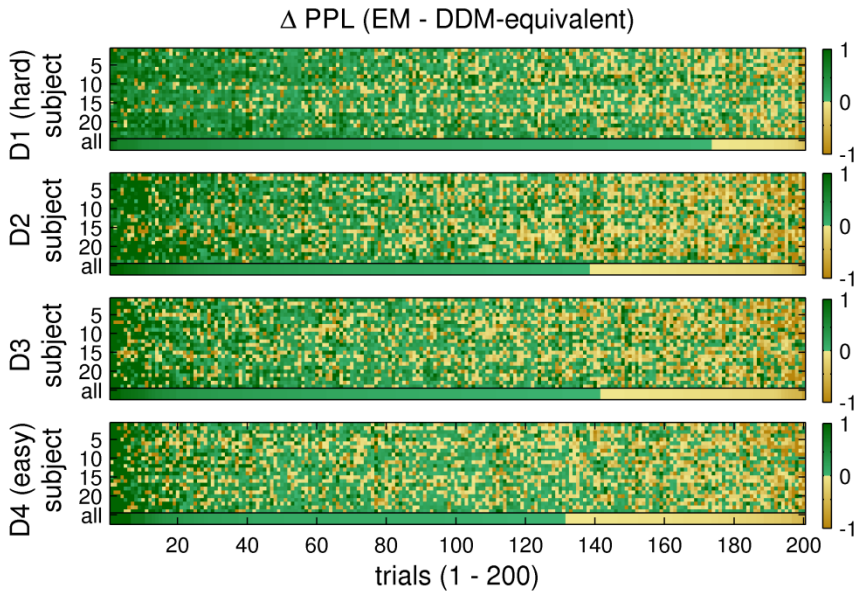
Model comparison





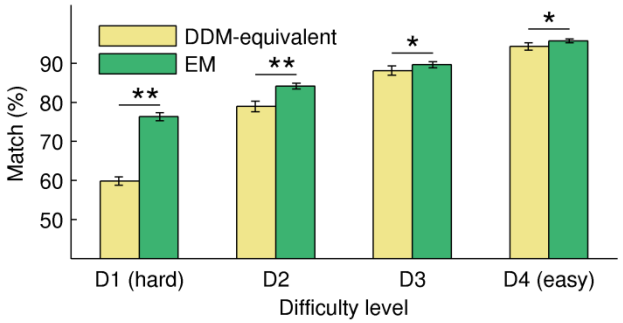
Exact input model (EM)
is the better model.

Posterior predictive log-likelihood (PPL)

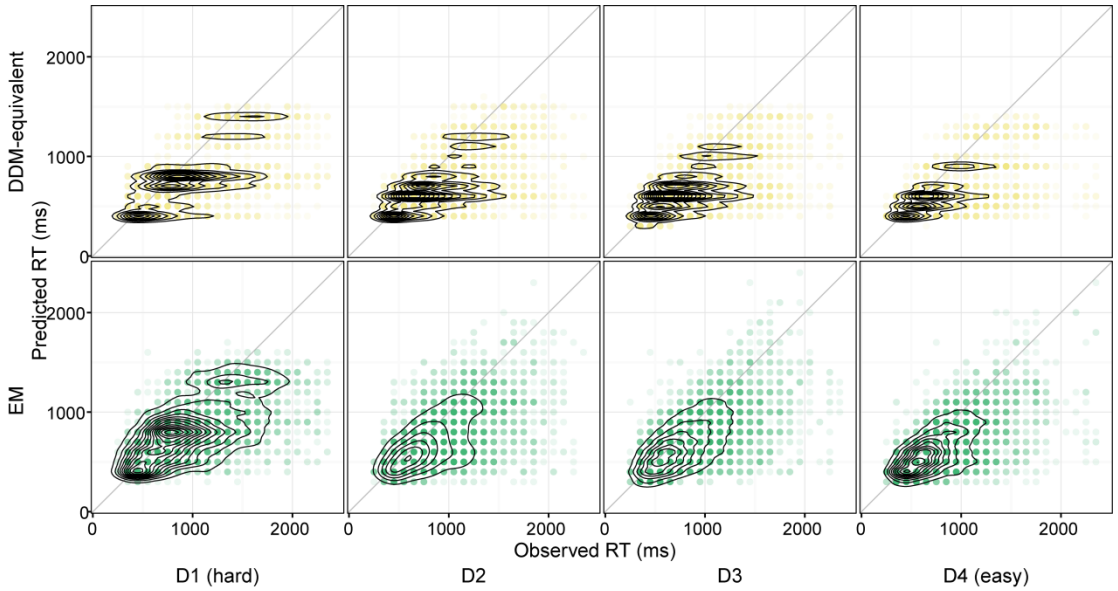


Park et al., under review

Point predictions



Exact input model predicts both single trial choices and RTs better than DDM-equivalent model.

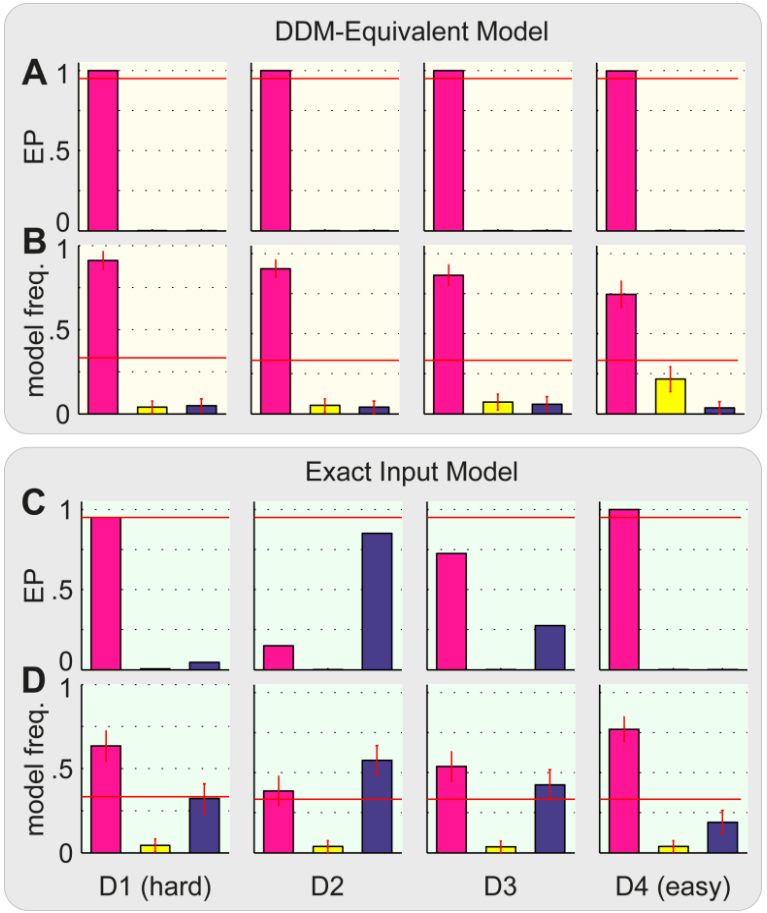


Urgency gating

Test different models using Bayesian model comparison:

The ‚urgency gating' hypothesis states that the participant can make quick decisions towards the end of a trial by reducing the threshold.

Here, we find evidence for such a mechanism by using the exact input model but not the DDM-equivalent model.

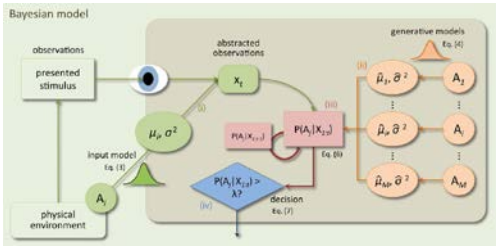


Standard
Leakage
Urgency gating

Park et al., under review

Overview

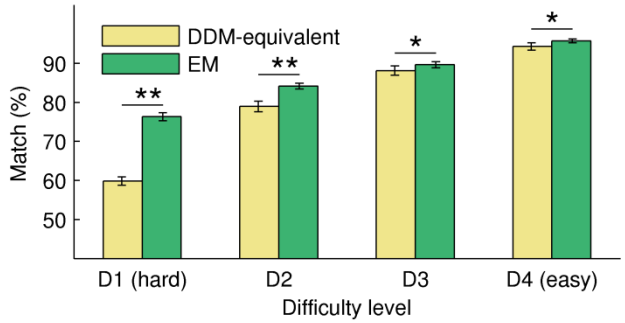
Summary



The drift-diffusion model is a well-established model which has been around in its present form since 1978.

We have shown that the DDM equations are equivalent to a Bayesian model based on a simple generative model.

This equivalence is useful because the Bayesian model can be easily extended to add useful and powerful features.



Acknowledgments

Thanks to

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