Quantifying The Benefits Of Modeling Decision Making Over Measuring Speed And Accuracy Alone.

Tom Stafford, Angelo Pirrone
Parallelisation: Mike Croucher
Shiny app: Anna Krystalli

These slides: goo.gl/FbuJEb

Psychonomics Amsterdam, Berlagezaal,
Thursday 10th May 2018, 14:00 - 14:20

The Speed-Accuracy Trade Off

Fast but inaccurate vs Slow but accurate

- Individual differences: definitely
- Group differences: likely
- RT and accuracy contain different information on the decision process (Palmer, Huk & Shadlen, 2005; Stone, 2014)

Palmer, J., Huk, A. C., & Shadlen, M. N. (2005). The effect of stimulus strength on the speed and accuracy of a perceptual decision. Journal of Vision, 5 (5), 1–1.
Stone, J. V. (2014). Using reaction times and binary responses to estimate psychophysical performance: An information theoretic analysis. Frontiers in Neuroscience, 8, 35.

The Speed-Accuracy Trade Off (SATO)

Popular (but bad) solutions

1. Ignore either speed or accuracy

    e.g. psychophysics

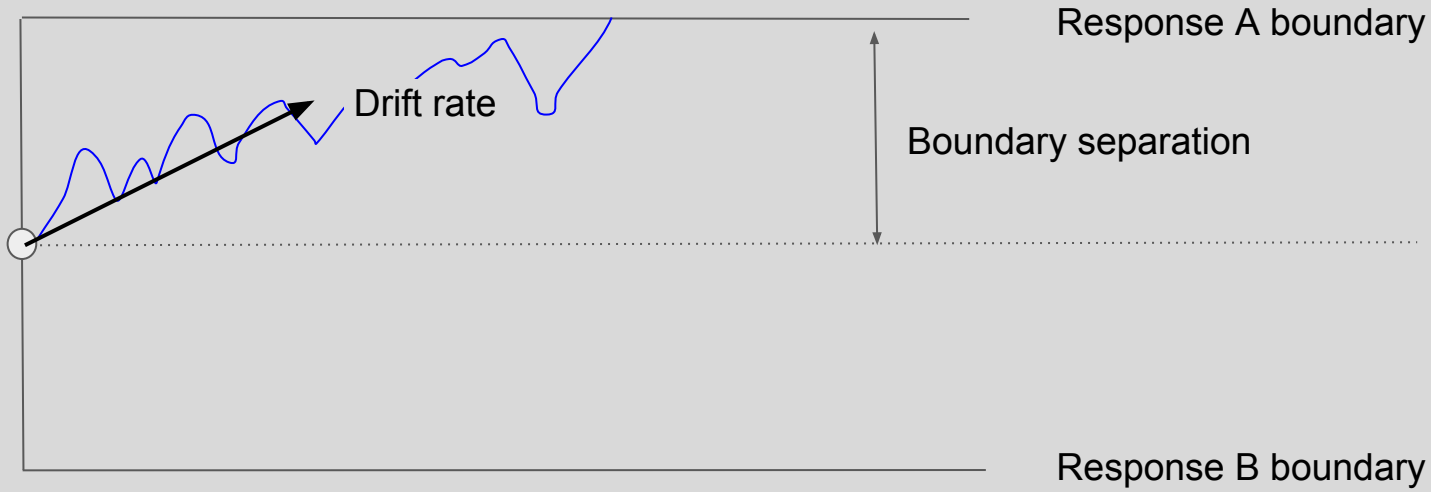
2. Ignore one after failing to find a significant difference on the other

3. Linearly combine

    e.g. ANOVA models, inefficiency scores (RT/accuracy)

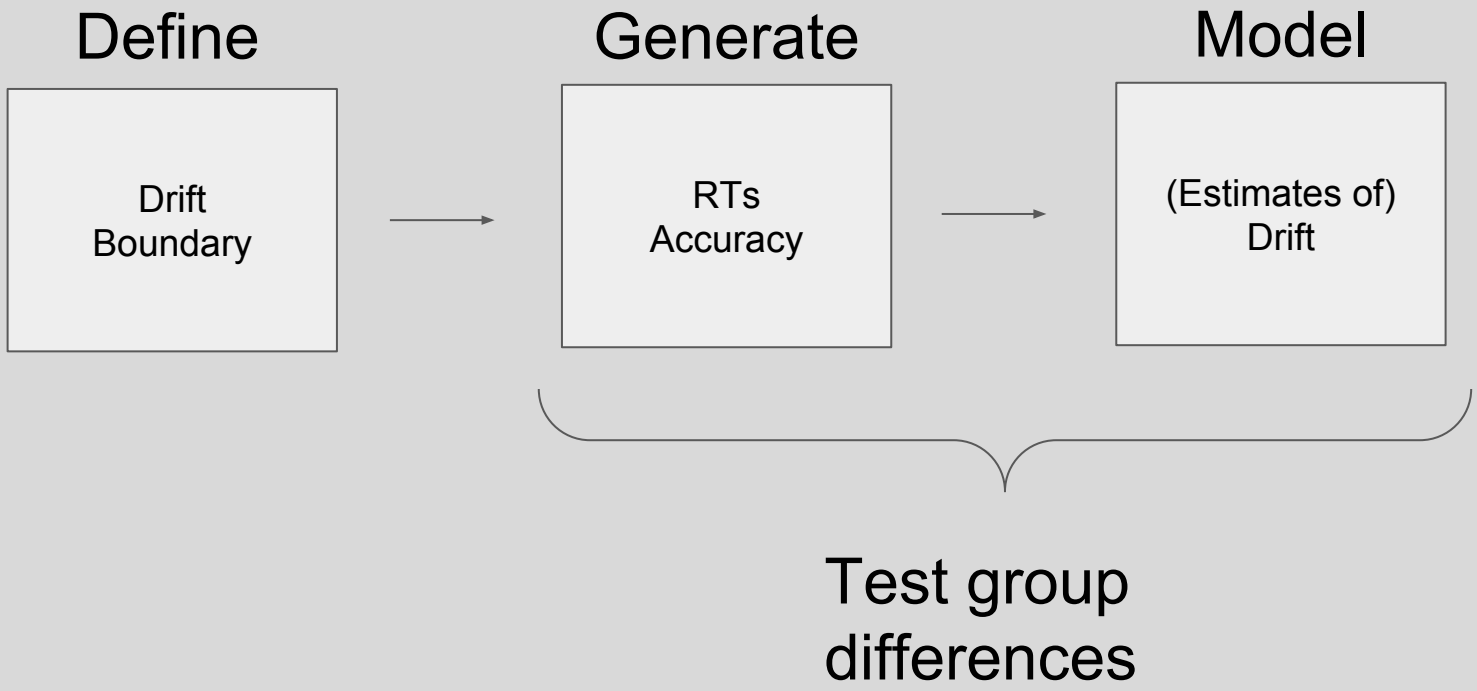
Bruyer, R., & Brysbaert, M. (2011). Combining speed and accuracy in cognitive psychology: Is the inverse efficiency score (ies) a better dependent variable than the mean reaction time (rt) and the percentage of errors (pe)? Psychologica Belgica, 51 (1), 5–13.
Townsend, J.T., & Ashby, F.G. (1983). Stochastic modeling of elementary psychological processes. Cambridge: Cambridge University Press

Decision models



Ratcliff, R. (1978). A theory of memory retrieval. *Psychological review, 85*(2), 59-108
Smith, P. L., and Ratcliff, R.(2004) Psychology and neurobiology of simple decisions. *Trends in neurosciences 27*(3), 161-168.

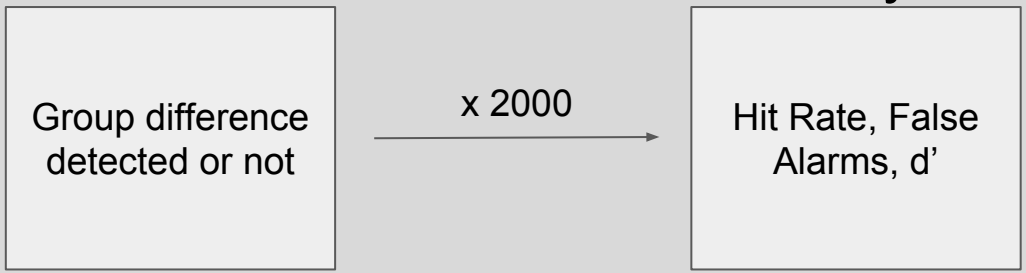
Simulation strategy...simulate & test group differences



Simulation strategy...repeat many times

Simulated expt and parameter recovery

Sensitivity measures for drift, RT and Accuracy



Technical Details

Code available here : github.com/tomstafford/ddm_sims

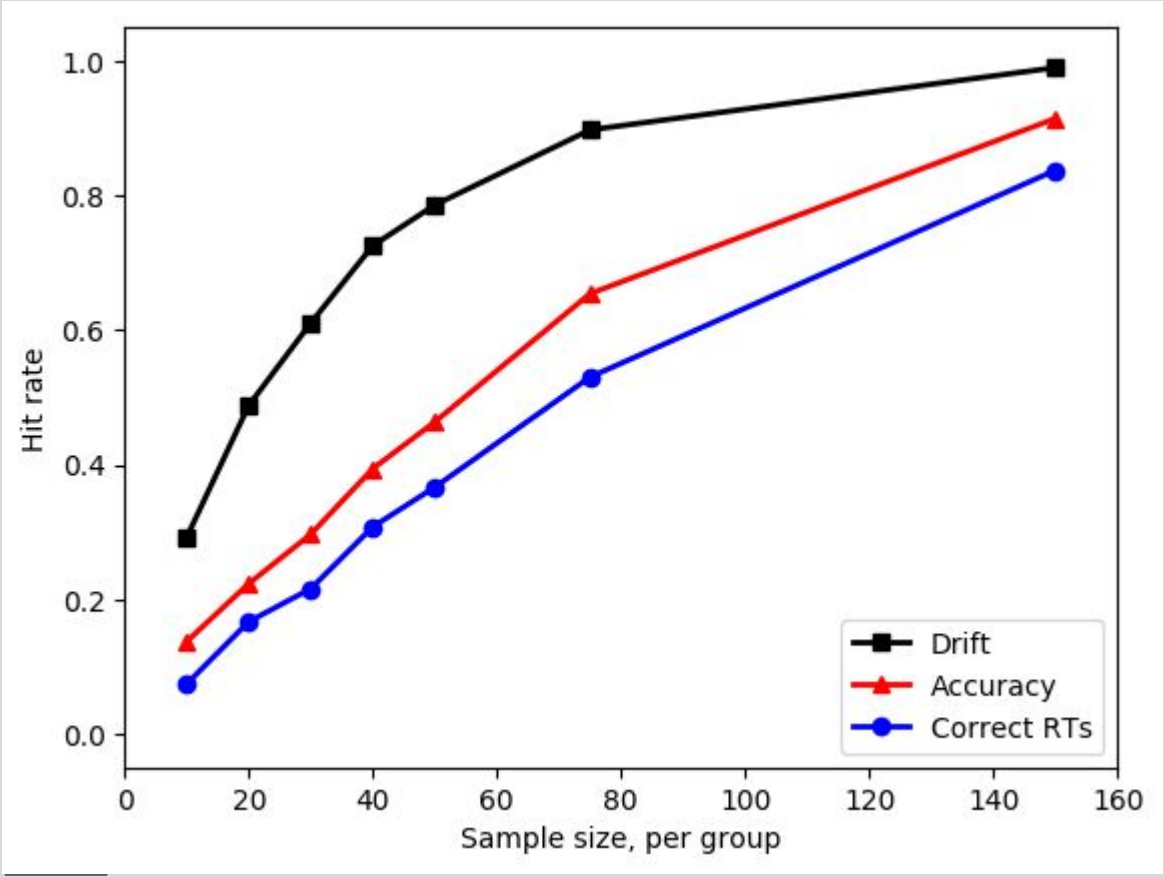
Decision modelling using HDDM (Wiecki, Sofer & Frank, 2013)

Parallelisation implemented by Mike Croucher, Co-founder Research Software Engineering at University of Sheffield (now Director of Research Computing, University of Leeds) - thanks Mike!

Results qualitatively similar if done using fast-dm (Voss & Voss, 2007)

Voss, A., & Voss, J. (2007). Fast-dm: A Free Program for Efficient Diffusion Model Analysis. *Behavioral Research Methods, 39,* 767-775
http://www.psychologie.uni-heidelberg.de/ae/meth/fast-dm/index.htm
Wiecki, T. V., Sofer, I., & Frank, M. J. (2013). HDDM: Hierarchical bayesian estimation of the drift-diffusion model in python. Frontiers in Neuroinformatics, 7, 14.

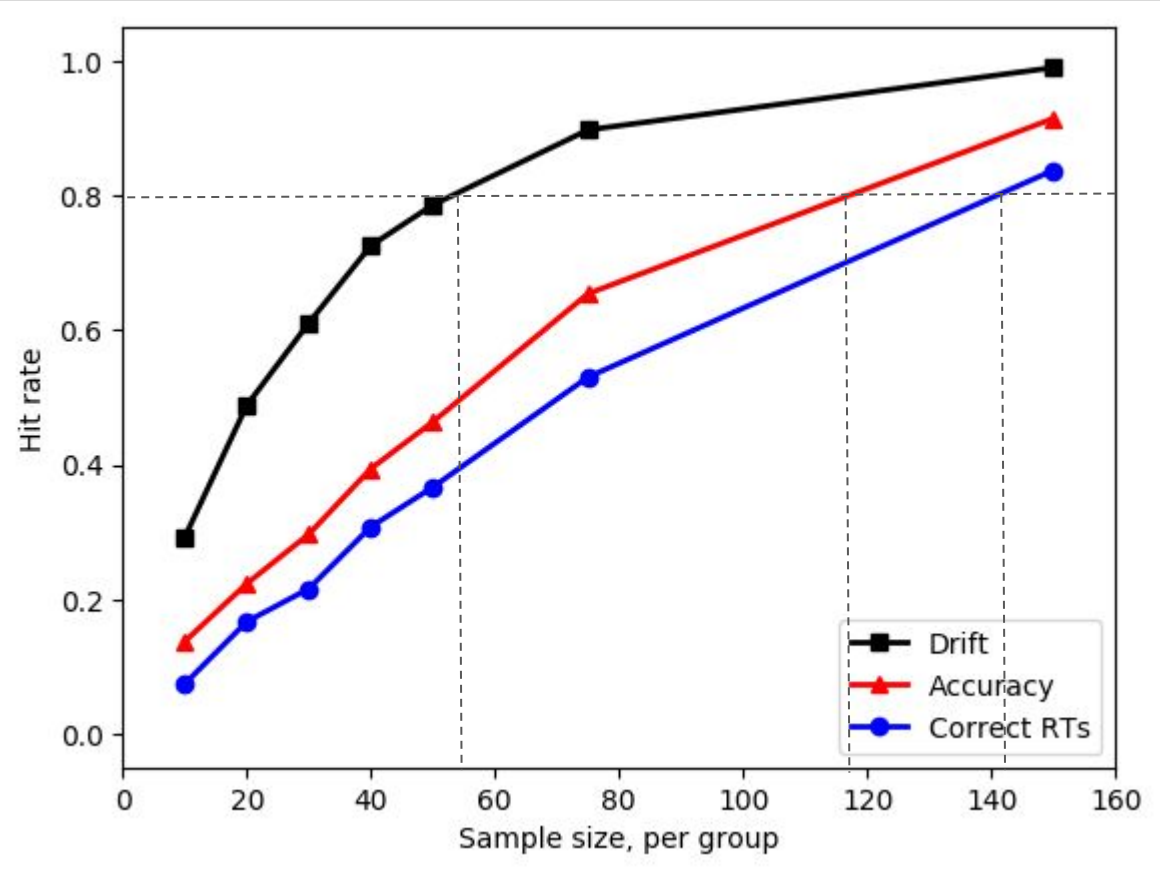
Results



Hit Rate

No Sato

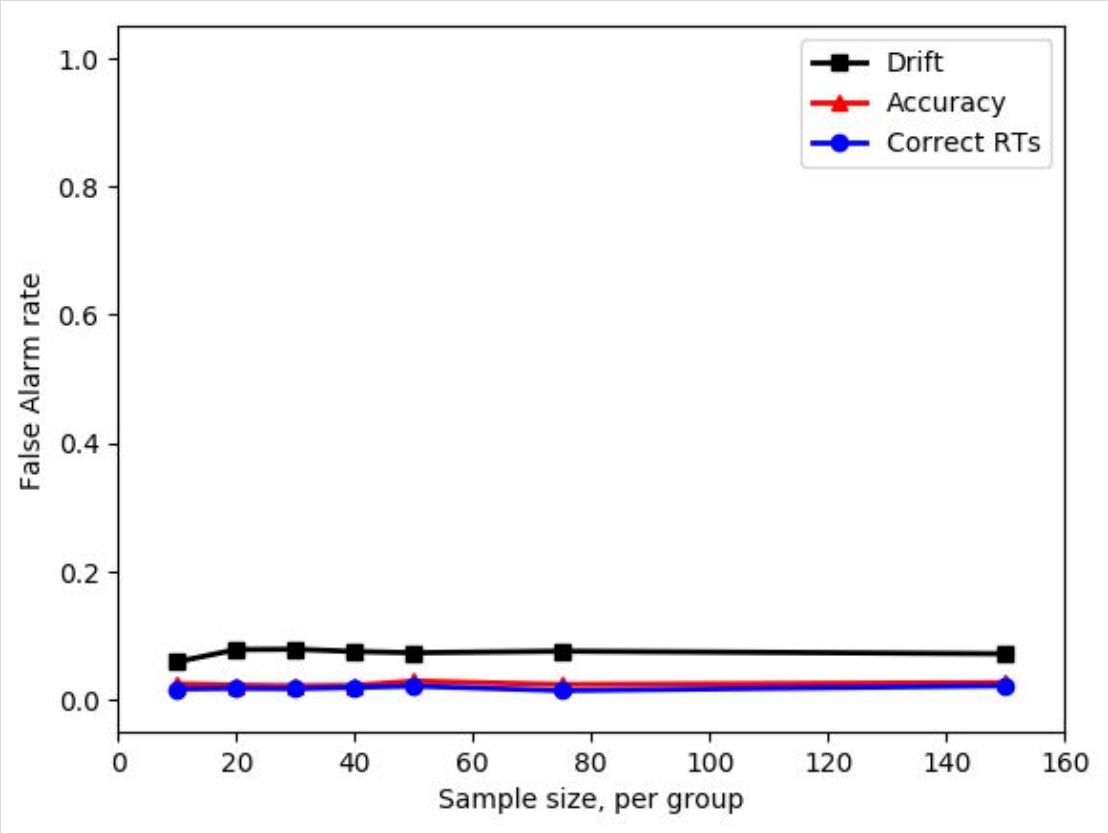
Parameters:
drift: 1 vs 1.1
boundary: 2 vs 2
intersubj var = 0.05
trials/ppt = 40



ppts/group for 80% power:

RT: ~140
Acc: ~115
Drift: ~55

trials/ppt = 40



False Alarms

No Sato

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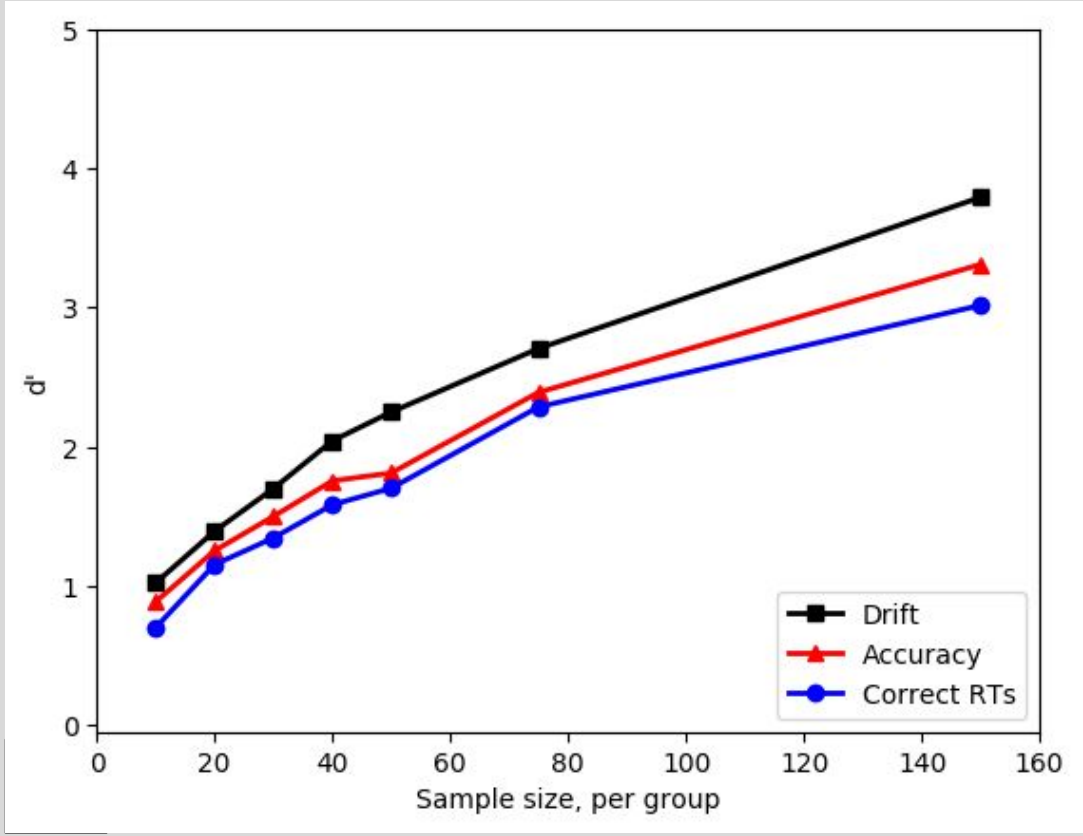

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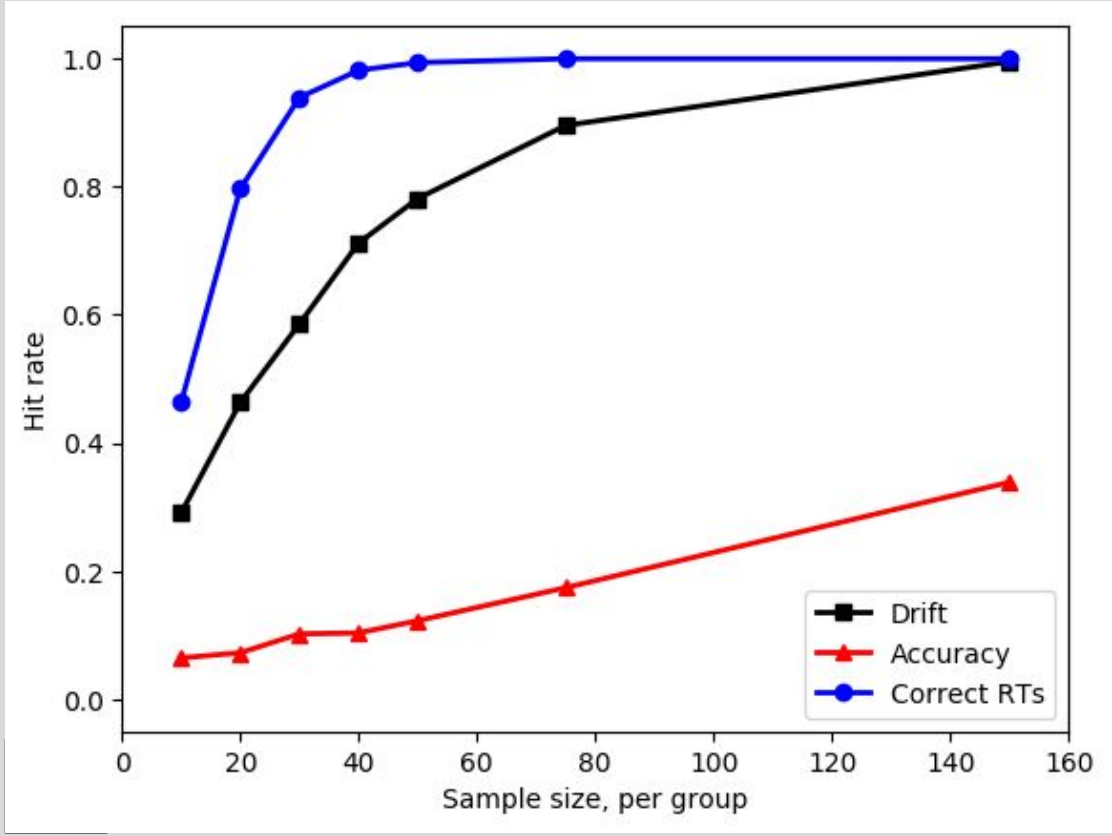
No Sato

Parameters:
drift: 1 vs 1.1
boundary: 2 vs 2
intersubj var = 0.05
trials/ppt = 40

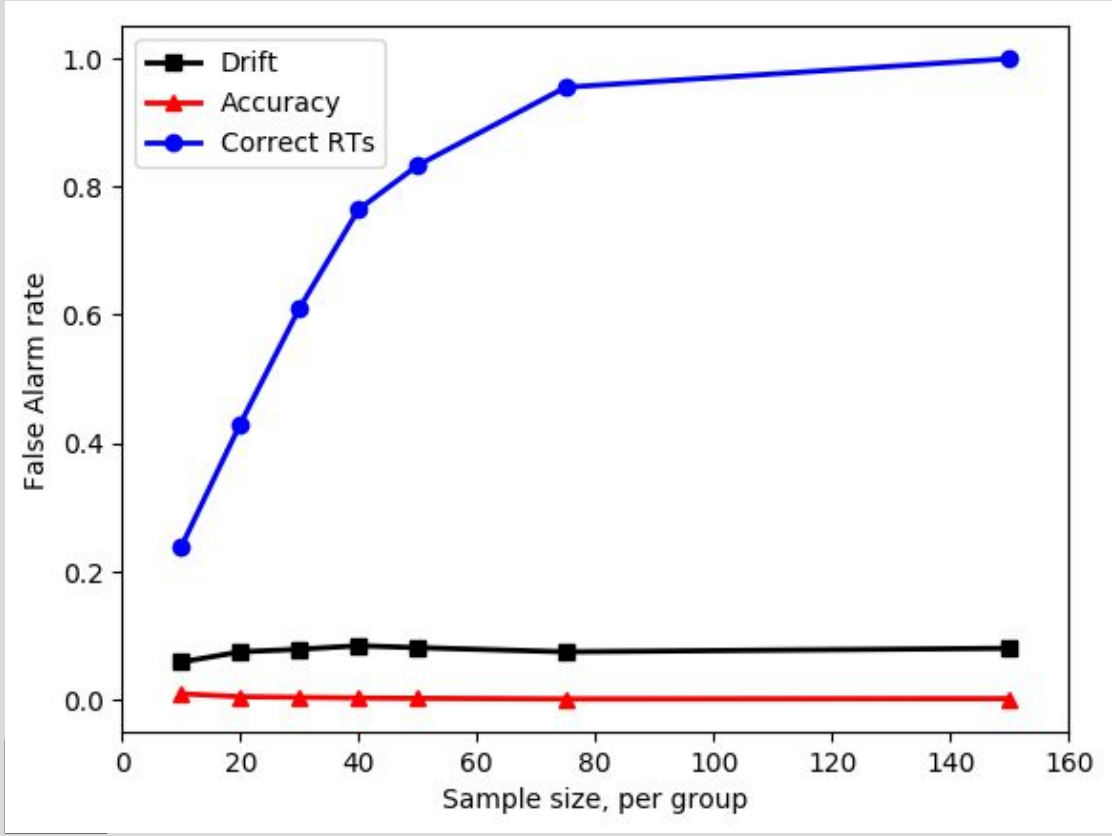
With Speed-Accuracy Trade Off
(i.e. between group boundary shift)



Hit Rate

With Sato

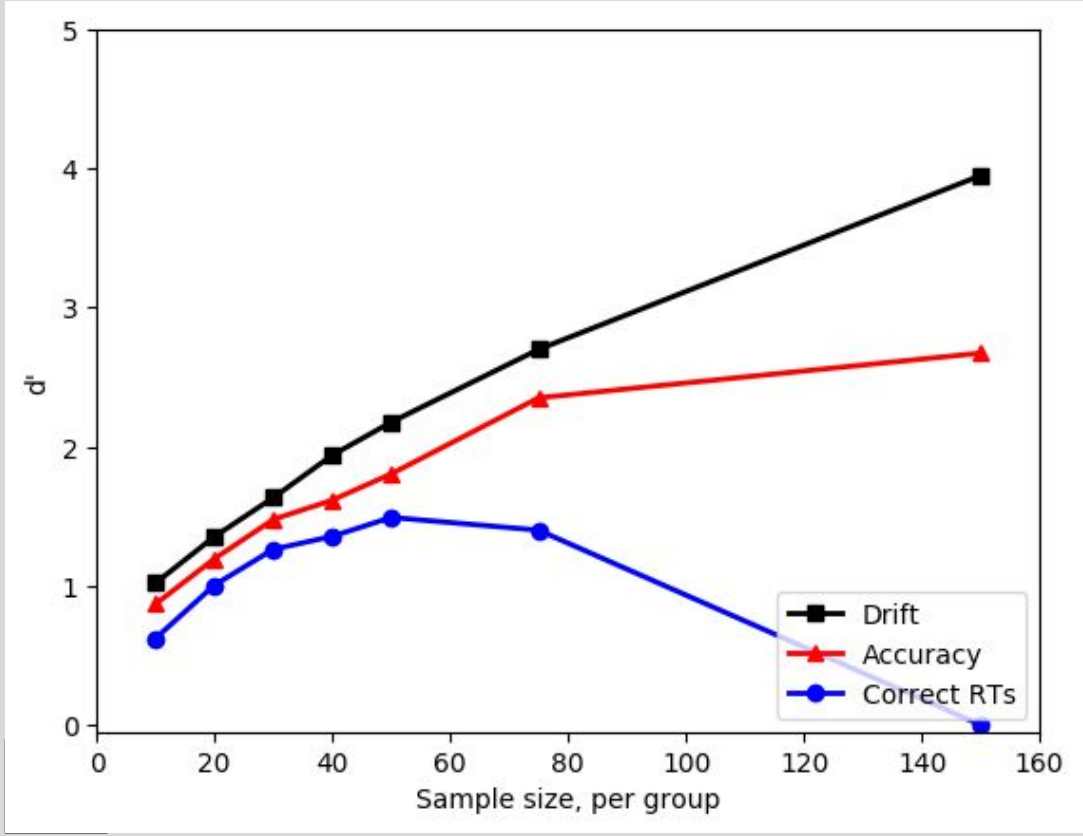
Parameters:
drift: 1 vs 1.1
boundary: 2 vs 1.9
intersubj var = 0.05
trials/ppt = 40



False Alarms

With Sato

Parameters:
drift: 1 vs 1.1
boundary: 2 vs 1.9
intersubj var = 0.05
trials/ppt = 40

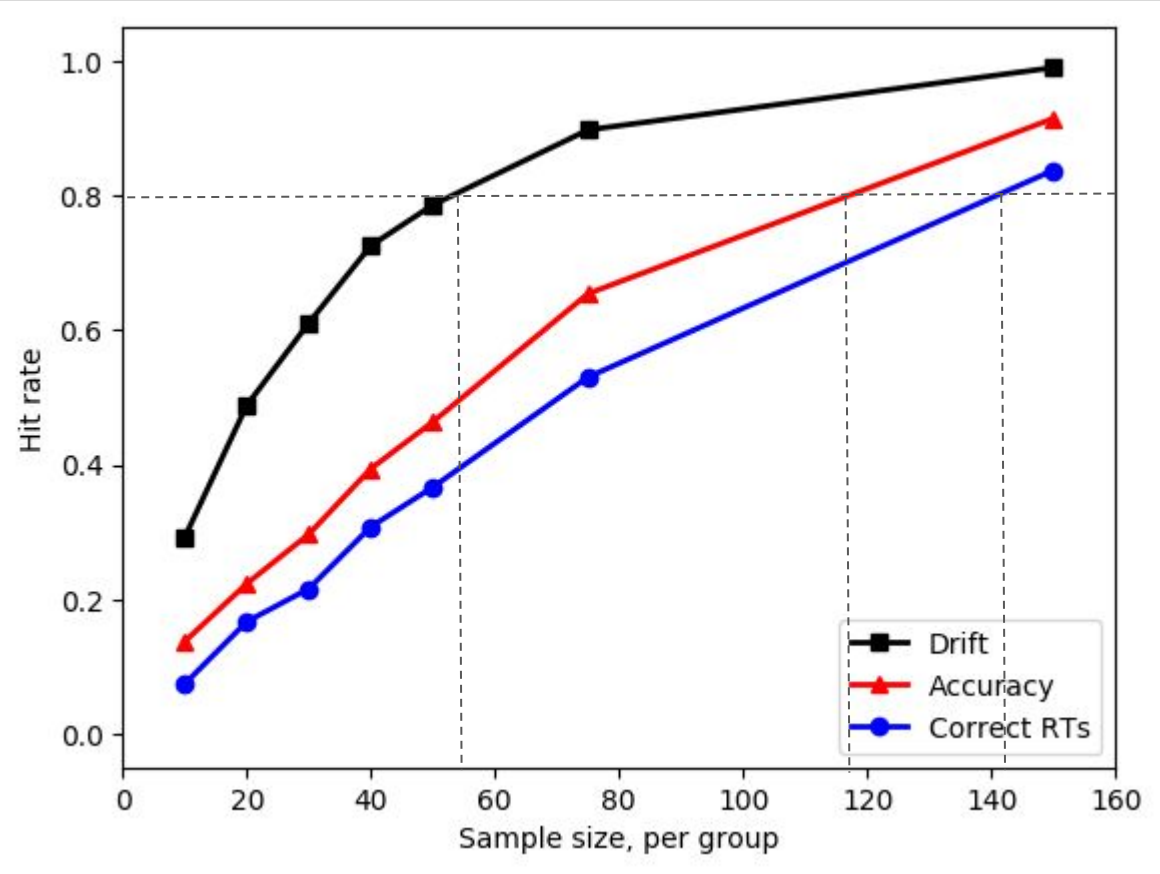


d’

With Sato

Parameters:
drift: 1 vs 1.1
boundary: 2 vs 1.9
intersubj var = 0.05
trials/ppt = 40

No SATO, but larger true effect



ppts/group for 80% power:

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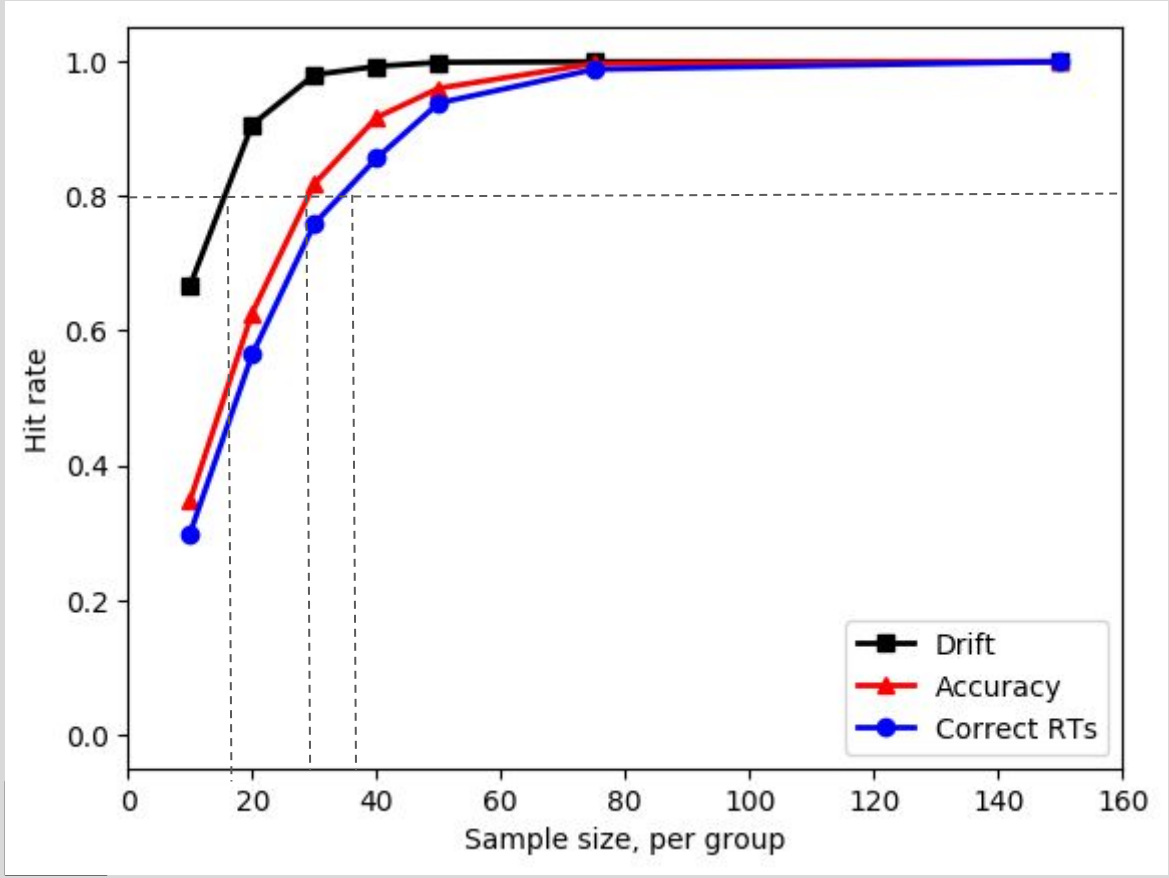
Acc: ~115
Drift: ~55

trials/ppt = 40



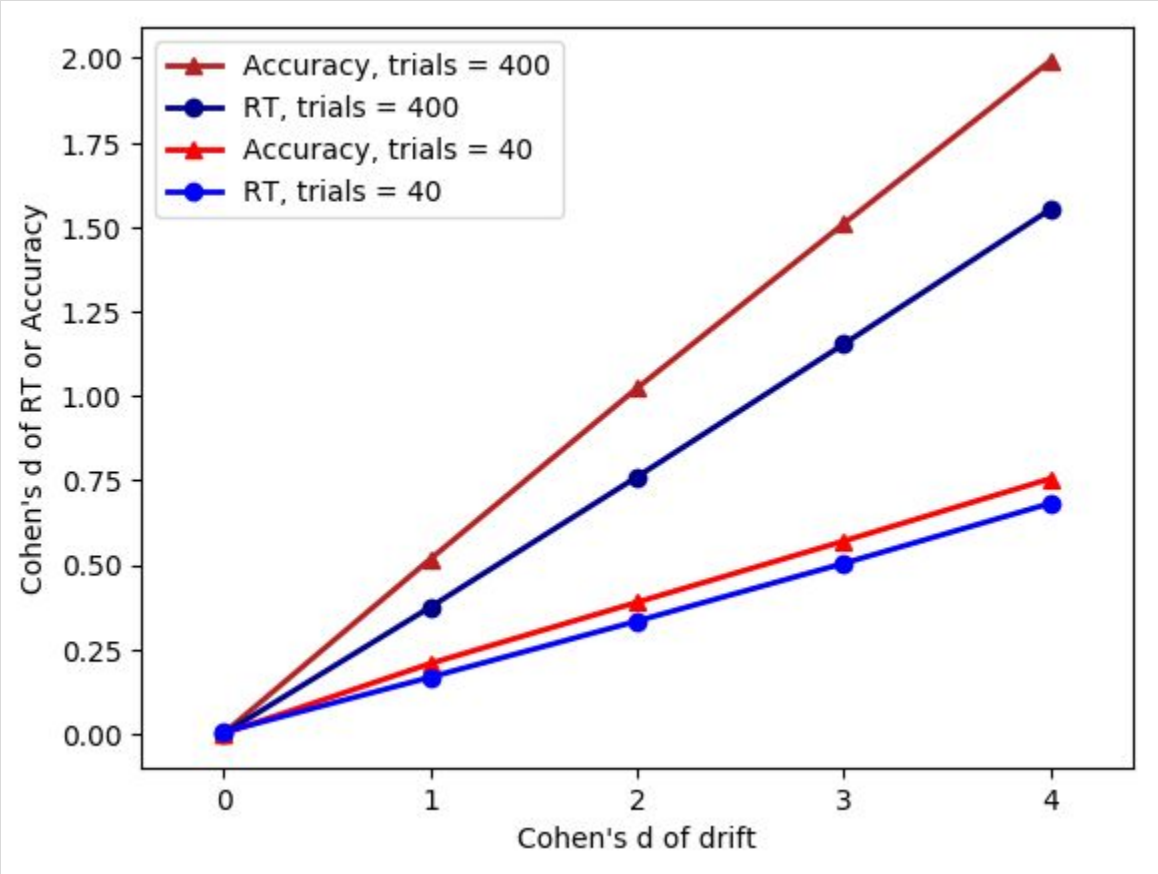
ppts/group for 80% power, larger effect:

RT: ~38
Acc: ~30
Drift: ~18

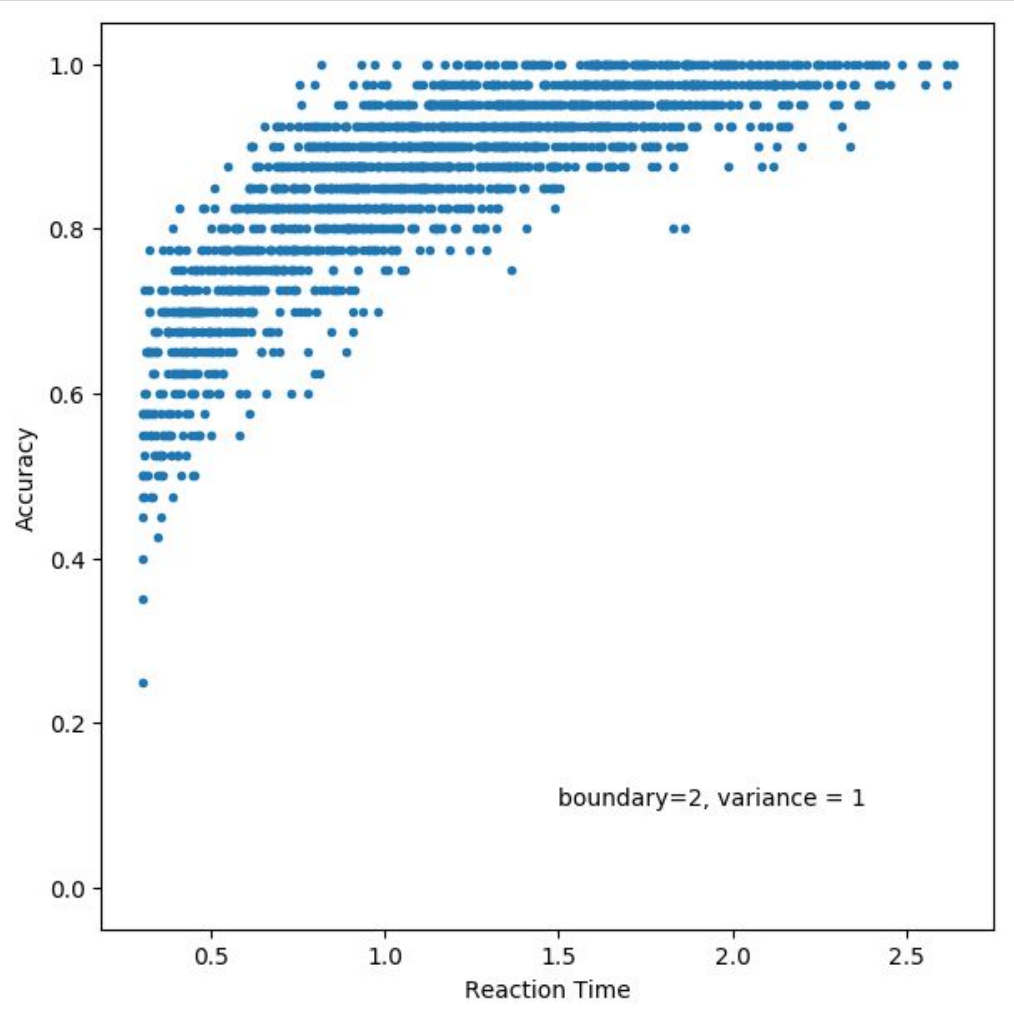
trials/ppt = 400

Why accuracy better than RT?


Accuracy
RT
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Cohen's d of RT or Accuracy
0
1
2
3
4
Cohen's d of drift


Accuracy, trials = 400
RT, trials = 400
Accuracy, trials = 40
RT, trials = 40
Cohen's d of RT or Accuracy
Cohen's d of drift
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
1
2
3
4

Visualising the Speed-Accuracy trade-off


1.0
0.8
0.6
0.4
0.2
0.0
Accuracy
0.5
1.0
1.5
2.0
2.5
Reaction Time
boundary=2, variance = 1

Massive benefits of decision modelling

Power gain over analysing reaction time or accuracy alone

commonly allows <50% subjects for same power

Avoid false positives due to speed-accuracy trade-offs

example: Pirrone, A., Dickinson, A., Gomez, R., Stafford, T. and Milne, E. (2017). Understanding perceptual judgement in autism spectrum disorder using the drift diffusion model. *Neuropsychology, 31* (2), 173-180

Future work

Generalise work to different decision models and parameter regimes

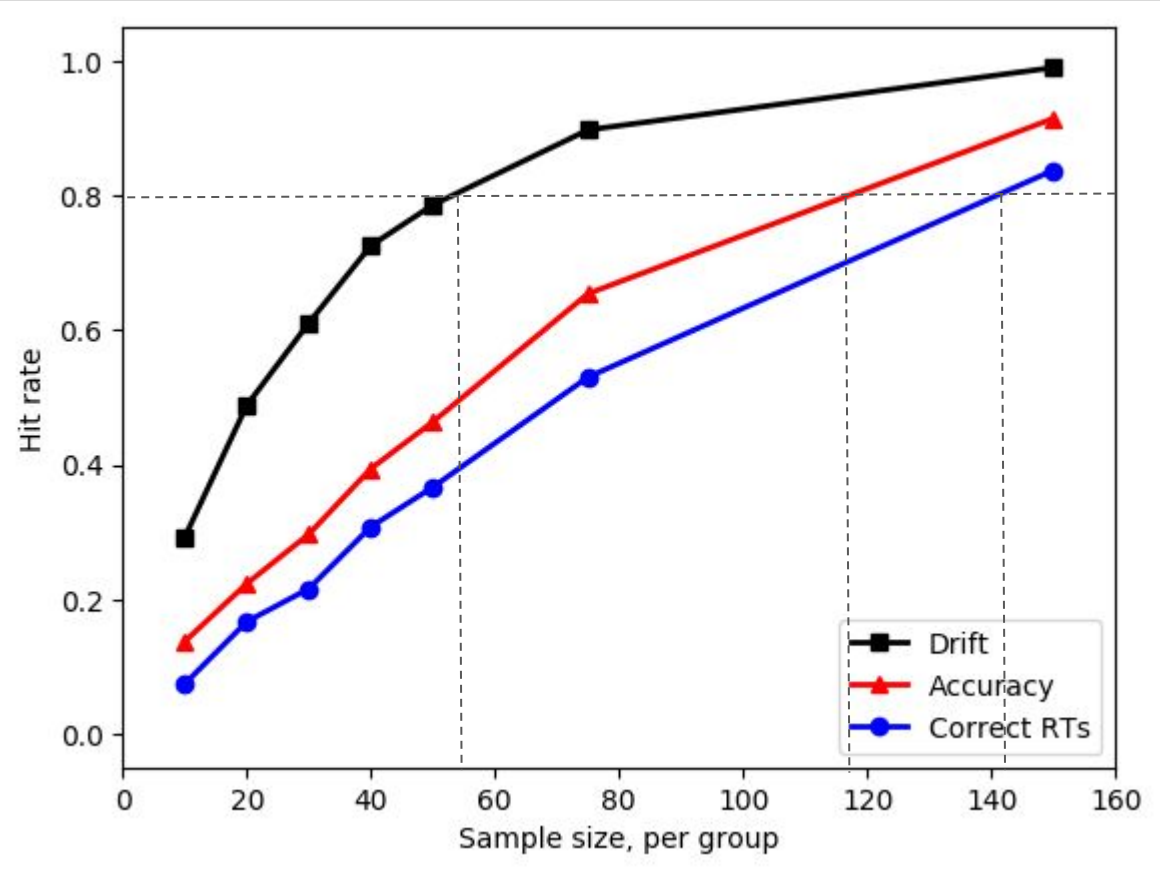
Interactive tool for exploring experiment design

https://github.com/tomstafford/ddm_sims

t.stafford@shef.ac.uk

END

Slides beyond this for reference only

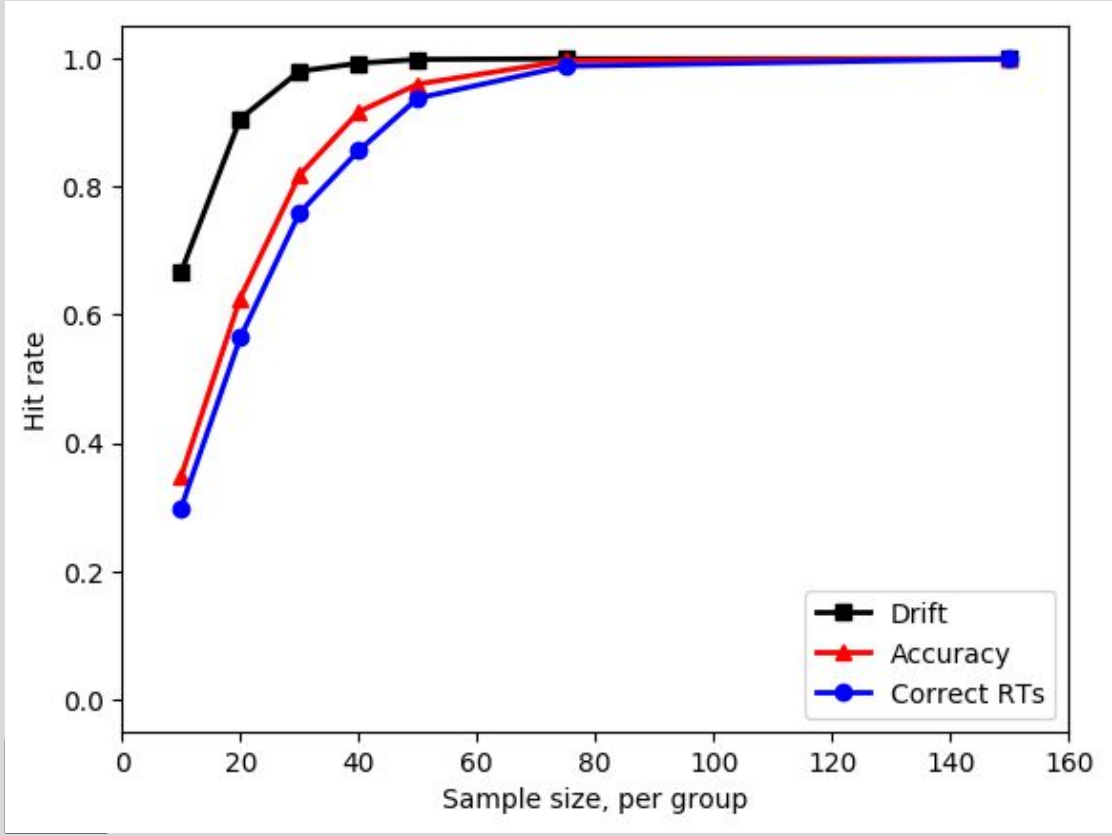


ppts/group for 80% power:

RT: ~140
Acc: ~115
Drift: ~55

trials/ppt = 40

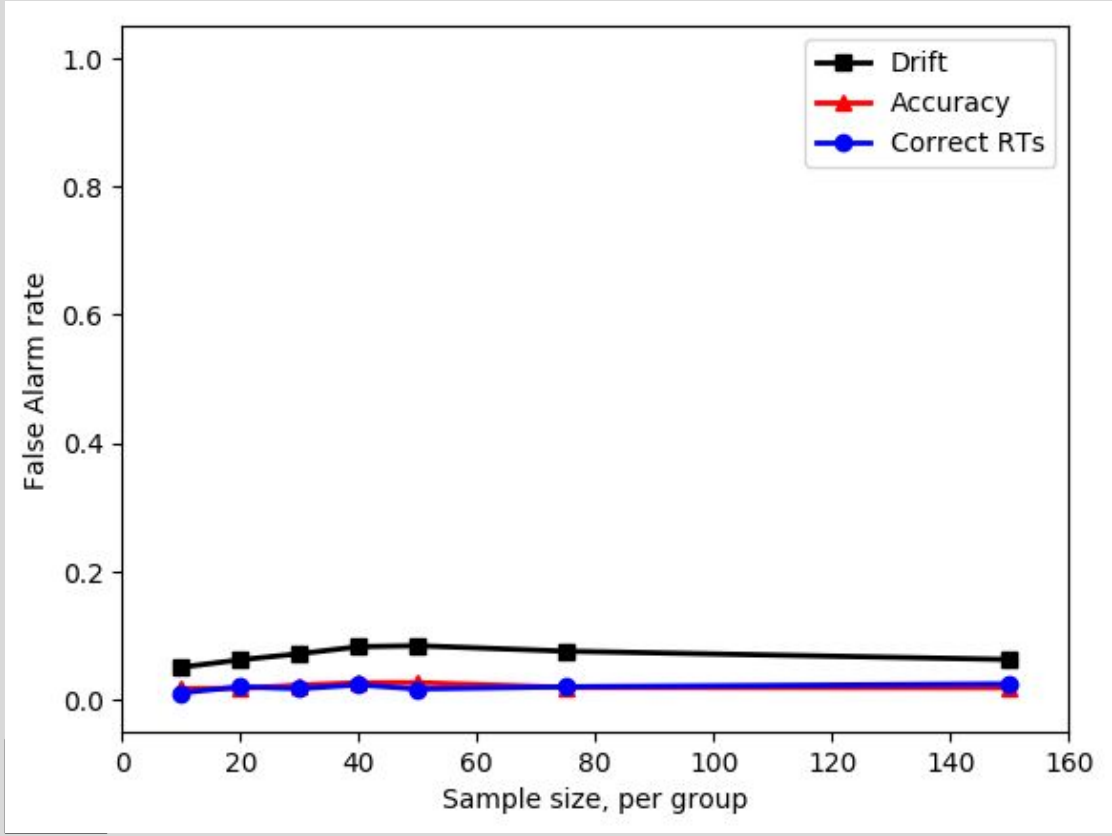
No SATO, Large drift effect (= 4)



Hit Rate

No Sato, larger effect

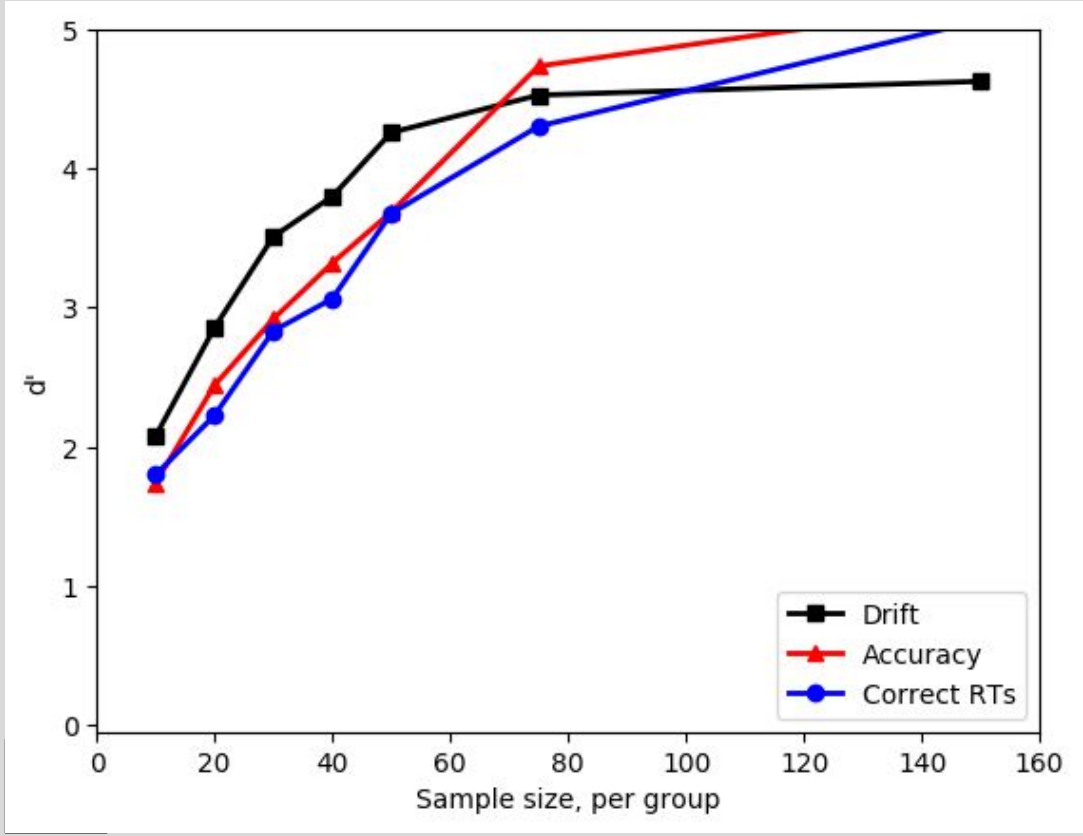
Parameters:
drift: 1 vs 1.2
boundary: 2 vs 2
intersubj var = 0.05
trials/ppt = 40



False Alarms

No Sato,
larger effect

Parameters:
drift: 1 vs 1.2
boundary: 2 vs 2
intersubj var = 0.05
trials/ppt = 40

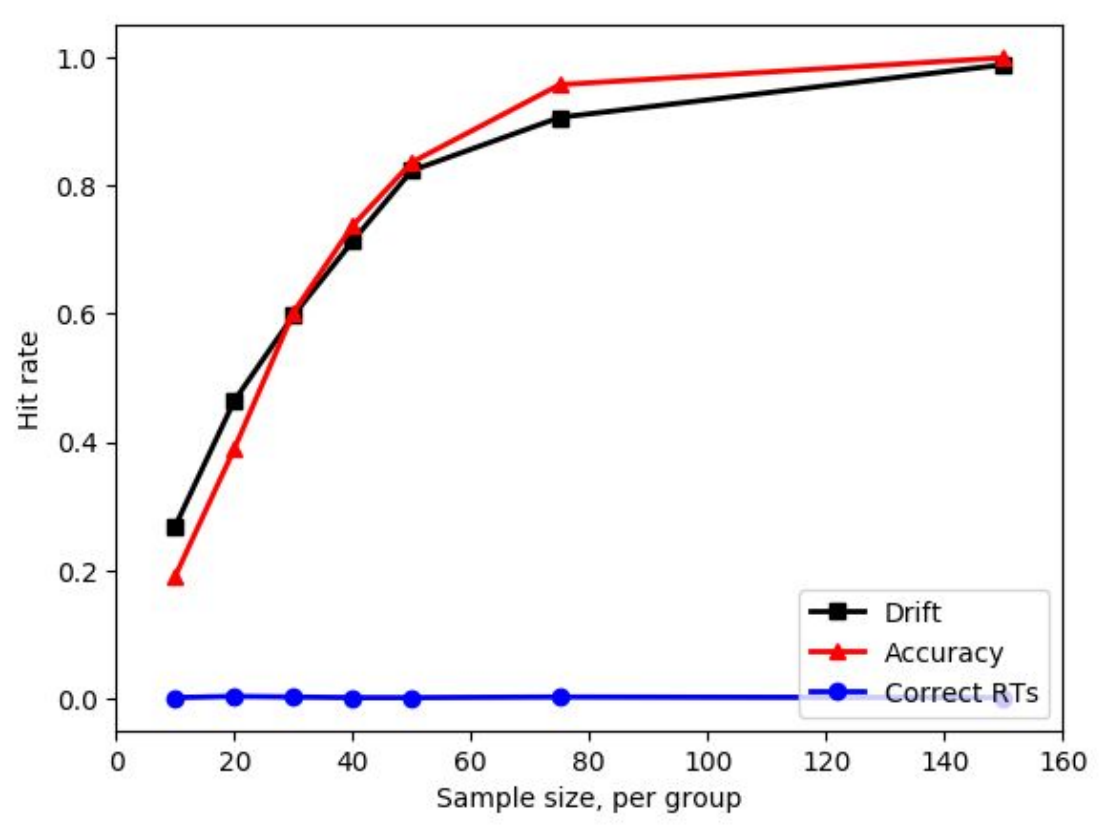


d’

No Sato, larger effect

Parameters:
drift: 1 vs 1.2
boundary: 2 vs 2
intersubj var = 0.05
trials/ppt = 40

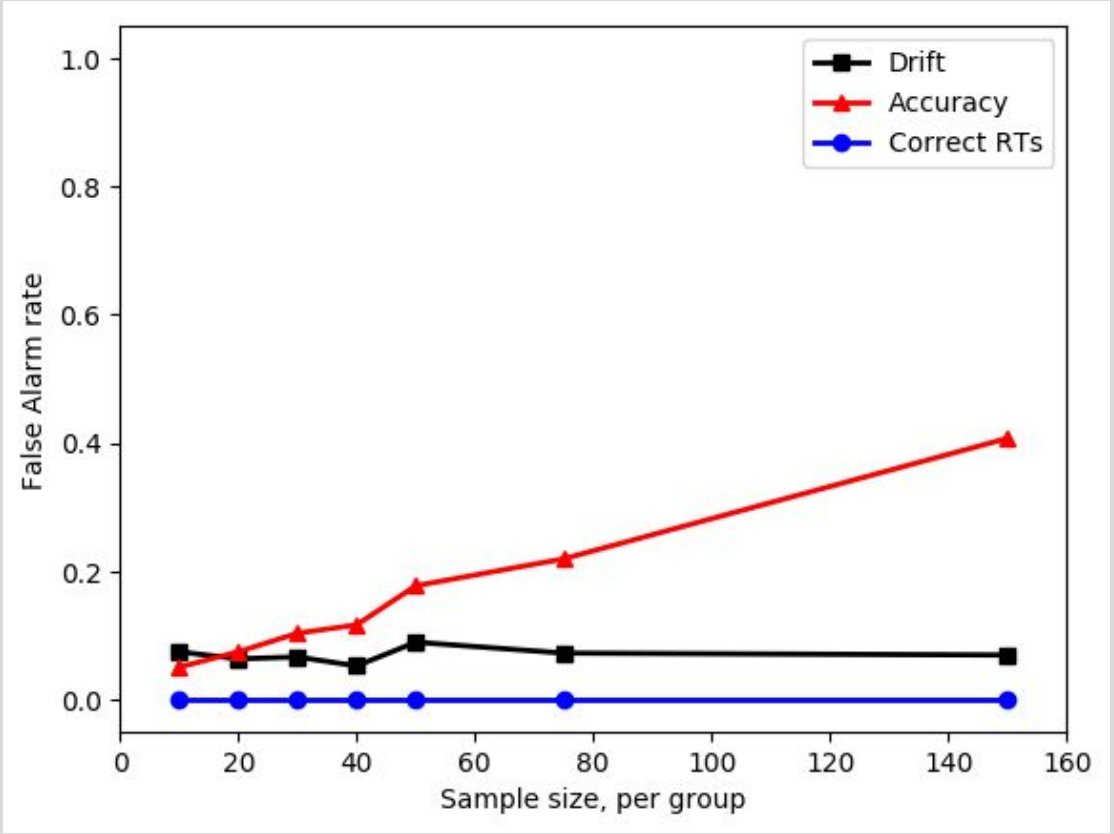
SATO, Boundary shift up



Hit Rate

With Sato

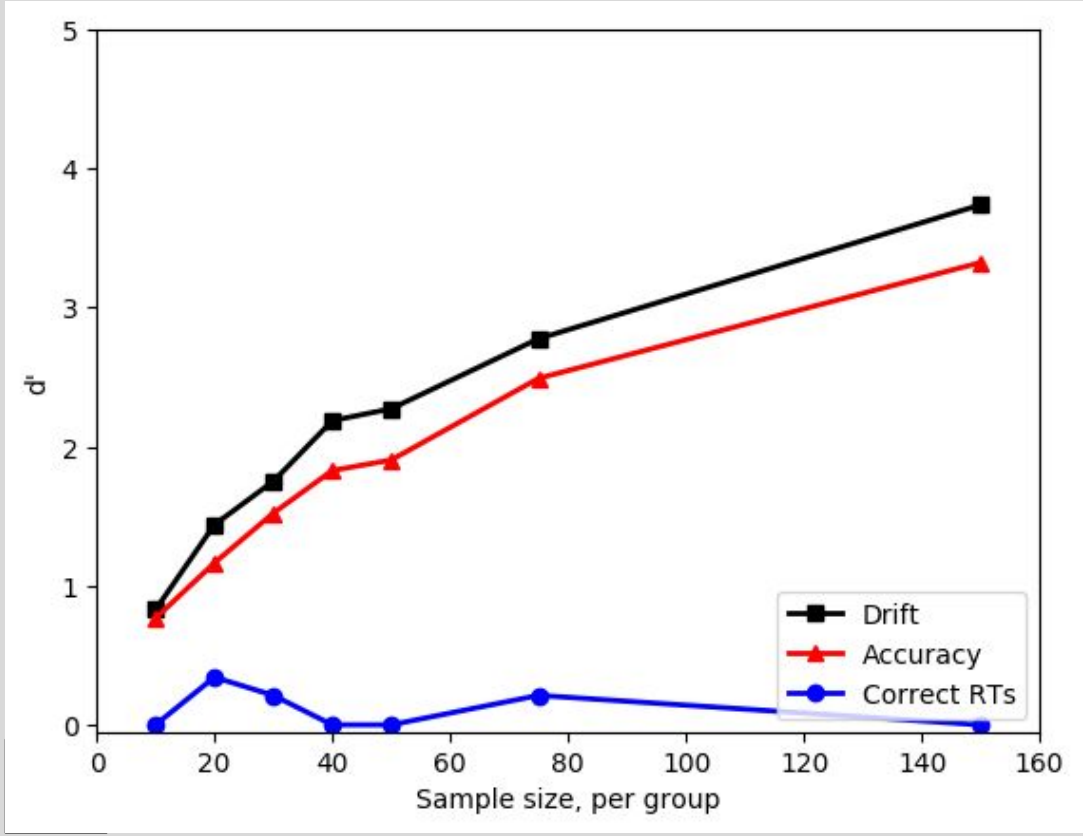
Parameters:
drift: 1 vs 1.1
boundary: 2 vs 2.1
intersubj var = 0.05
trials/ppt = 40



False Alarms

With Sato

Parameters:
drift: 1 vs 1.1
boundary: 2 vs 2.1
intersubj var = 0.05
trials/ppt = 40



False Alarms

With Sato

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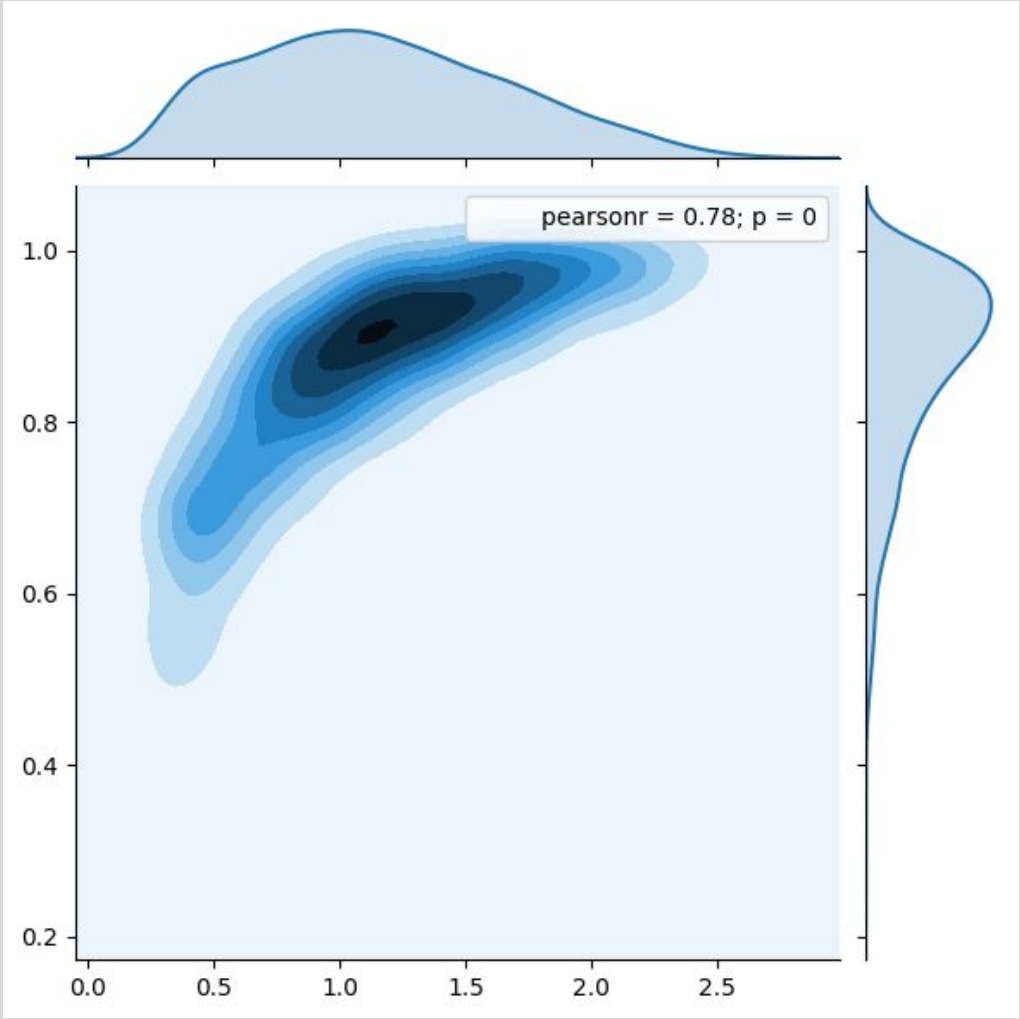
intersubj var = 0.05
trials/ppt = 40

Visualising the Speed-Accuracy trade-off


pearsonr = 0.78; p = 0
1.0
0.8
0.6
0.4
0.2
0.0
0.5
1.0
1.5
2.0
2.5

Explanatory material

Simulation strategy, part 1

1. Simulate n_e experiments where:

    Two groups, A & B, by drift and boundary parameters which are either the same or different:

        if different drift parameters: one group has superior sensitivity

        if different boundary parameters: groups make different SATOs

    n_p participants from each perform t decision making trials:

        participant drift and boundary sampled from group parameters with variation

Simulation strategy, part 2

2. Fit DDM to simulated data from each experiment.

Test difference in recovered parameters

If true difference in drift -> inferred difference = Hit

-> inferred lack of difference = Miss

If no true difference in drift -> inferred difference = False positive

-> inferred lack of difference = CR