Drift in neural population activity causes working memory to deteriorate over time

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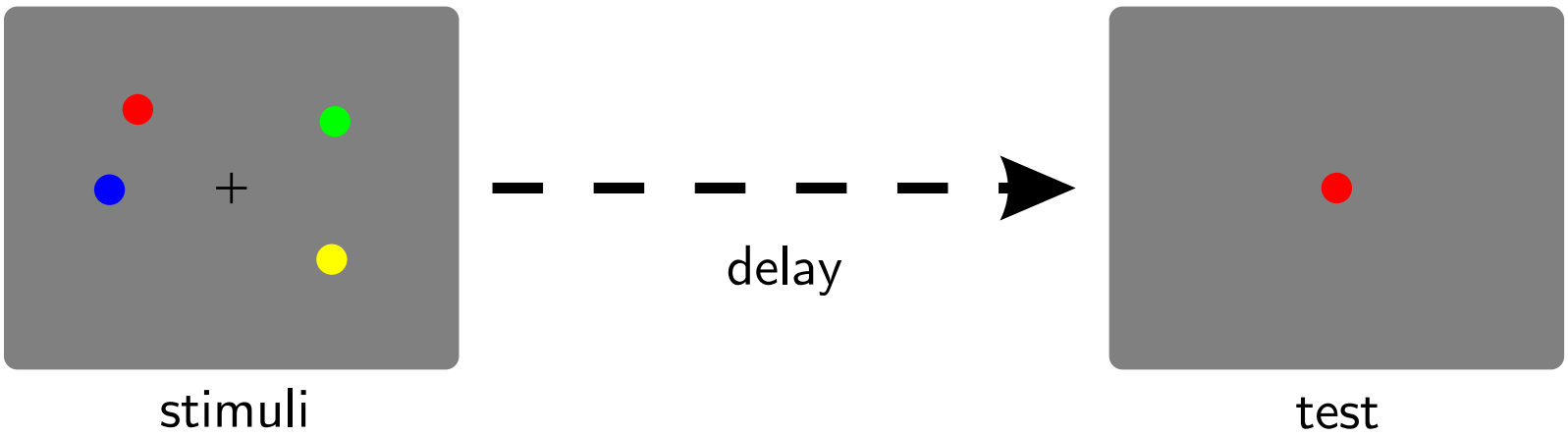
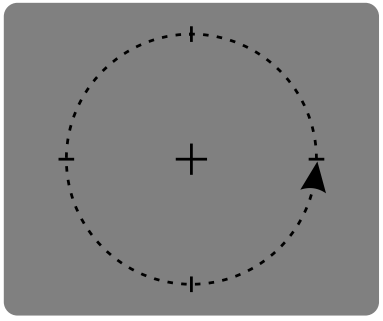
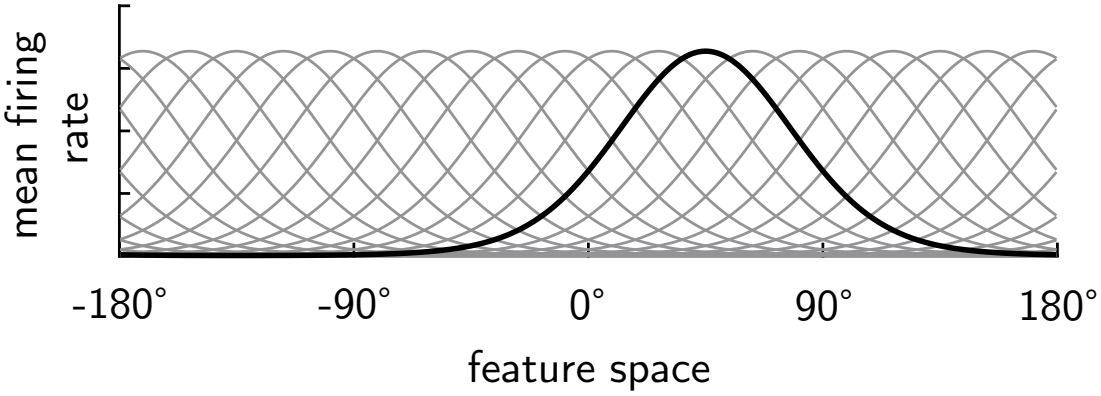
Visual working memory

- detailed, but capacity-limited storage over short durations
- effects of set size: well studied, competing accounts either based on fixed slots or continuous memory resource (Zhang & Luck 2008; Ma, Husain & Bays 2014)
- effects of delay duration: less well understood, few quantitative models (Zhang & Luck 2009, Ricker, Spiegel & Cowan 2014)



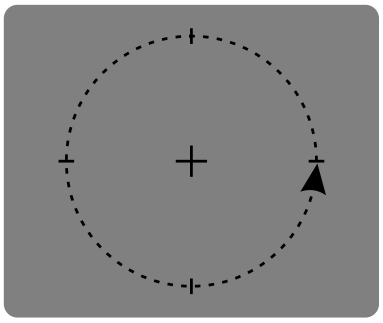
Population coding

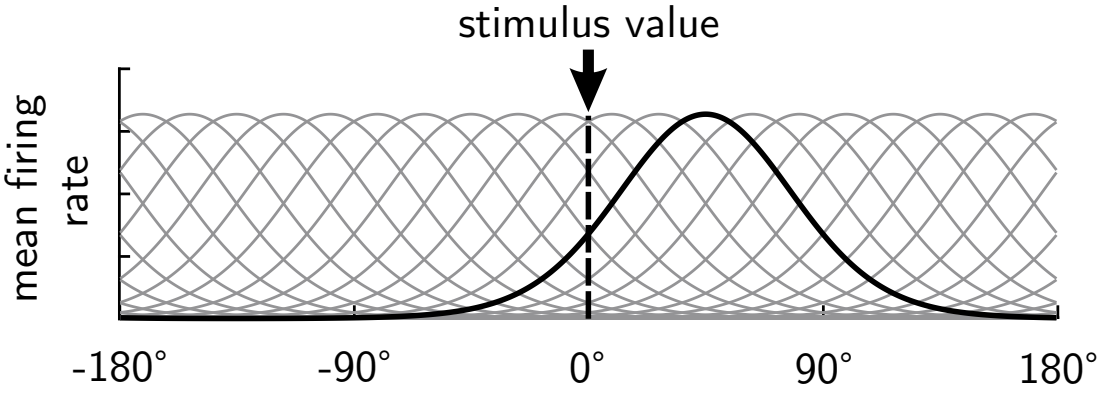




neural tuning curves

Population coding





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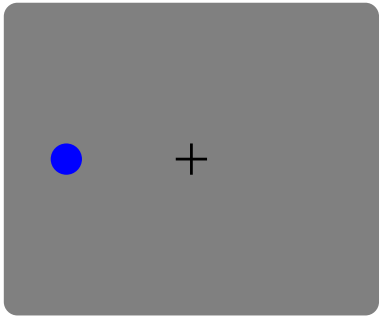
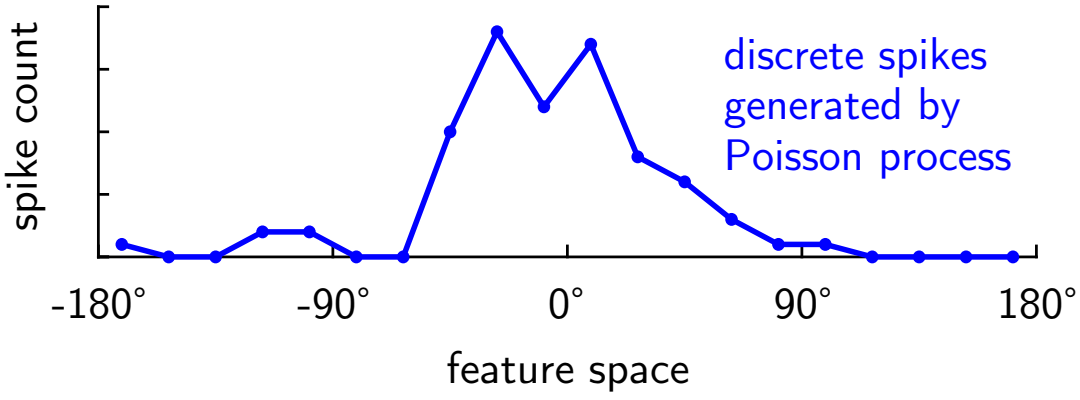
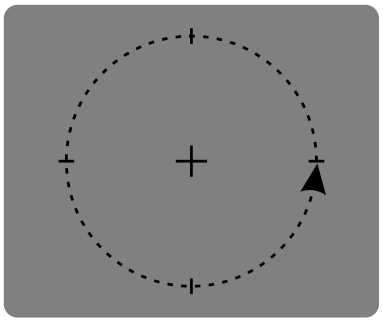
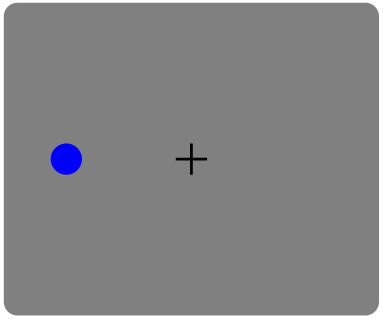


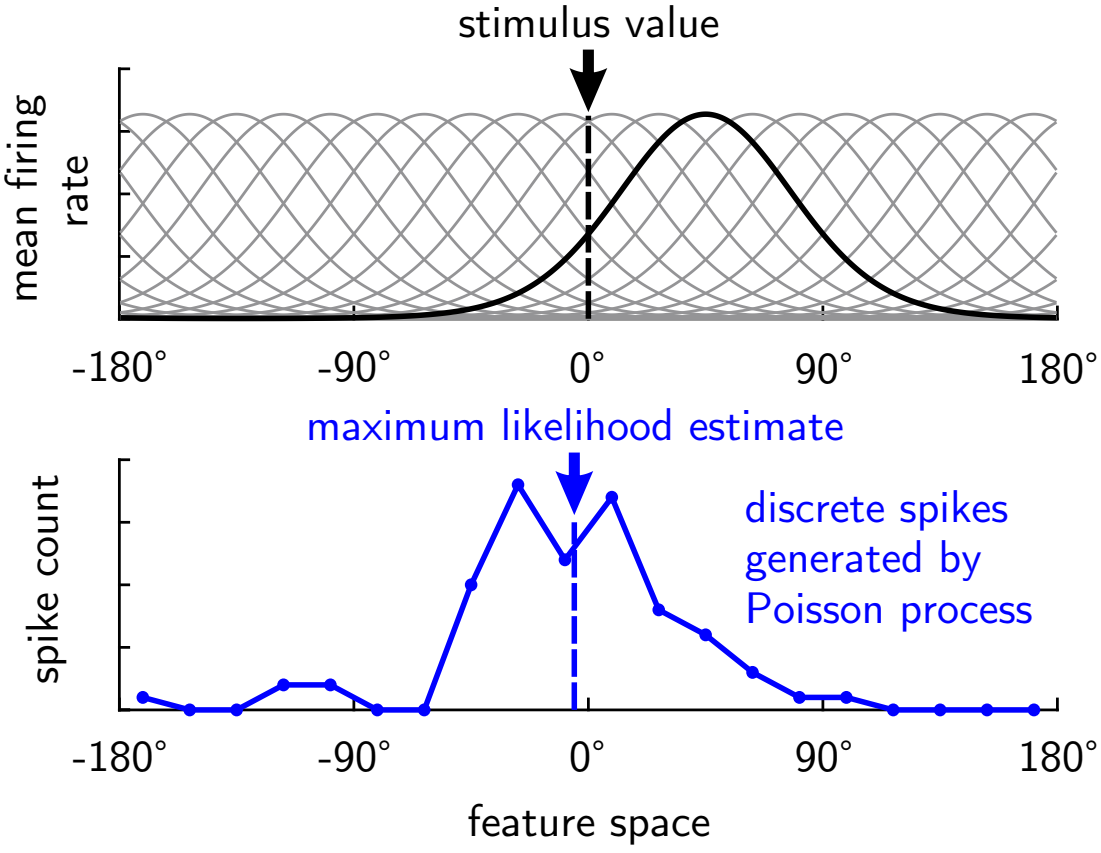


population activity

Population coding







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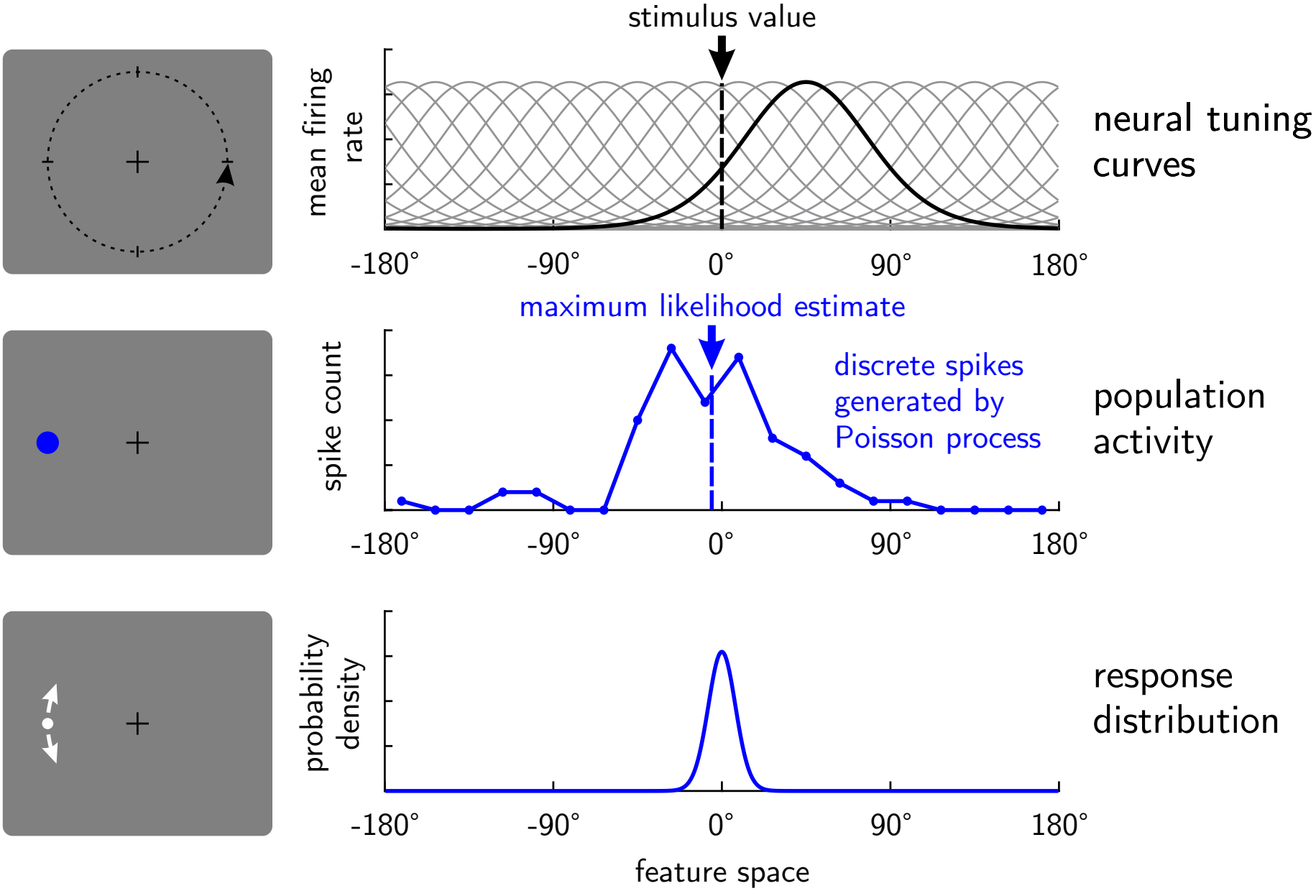
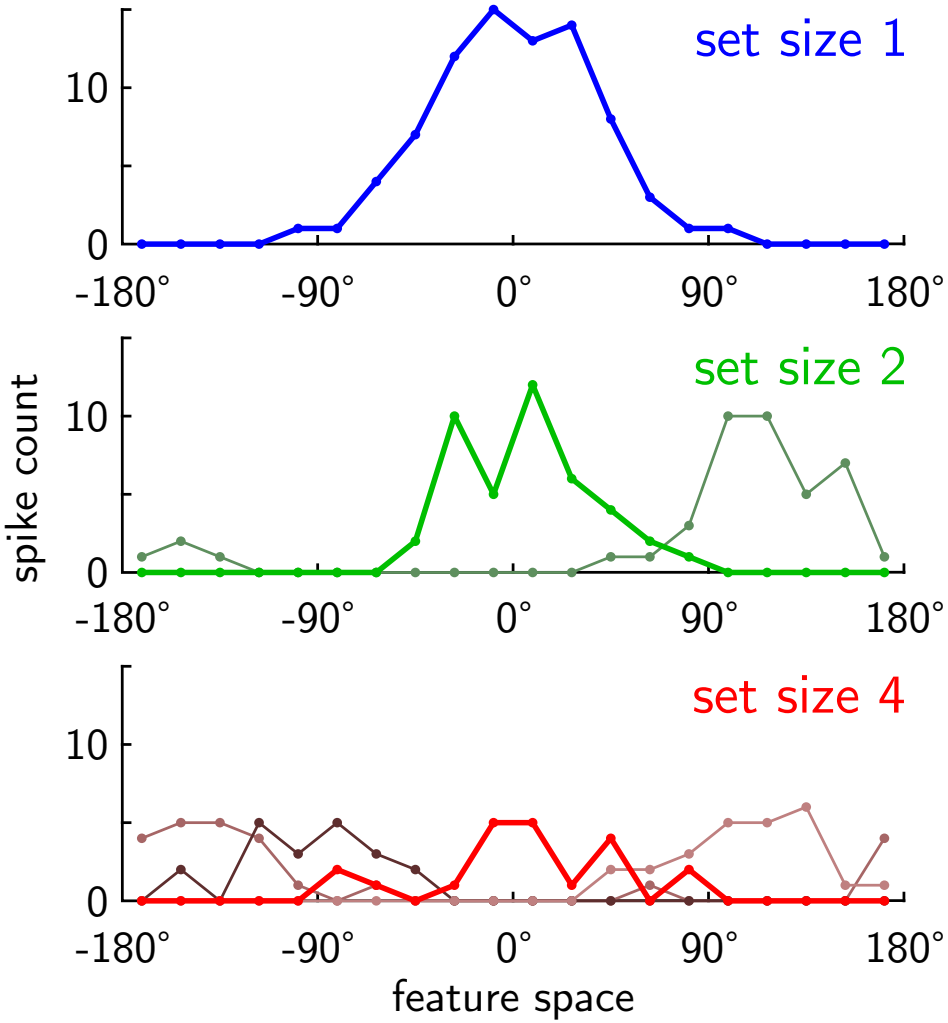
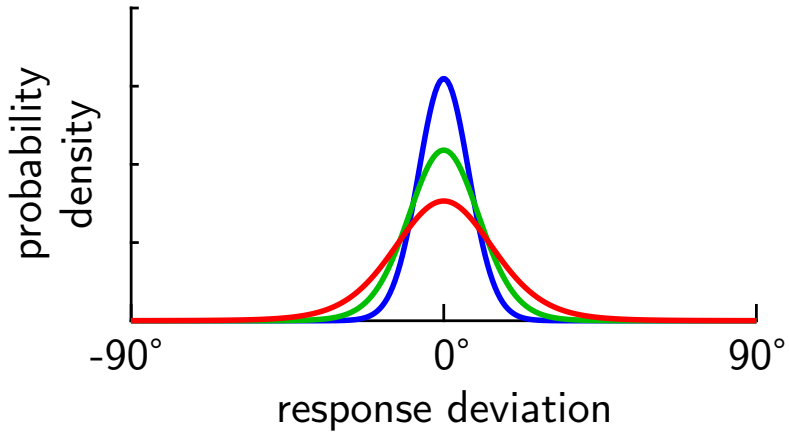


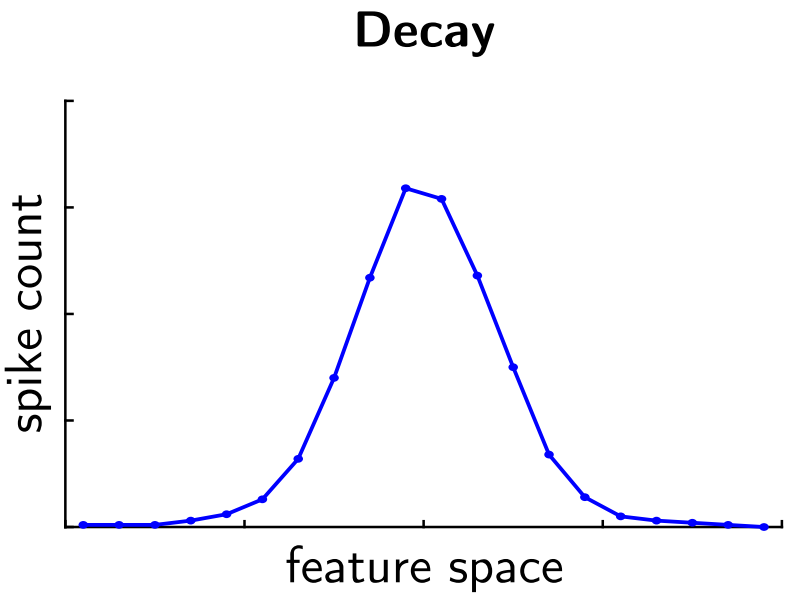
Set size effects





set size effects explained by normalization of total activity in the population (Bays 2014)

Delay effects



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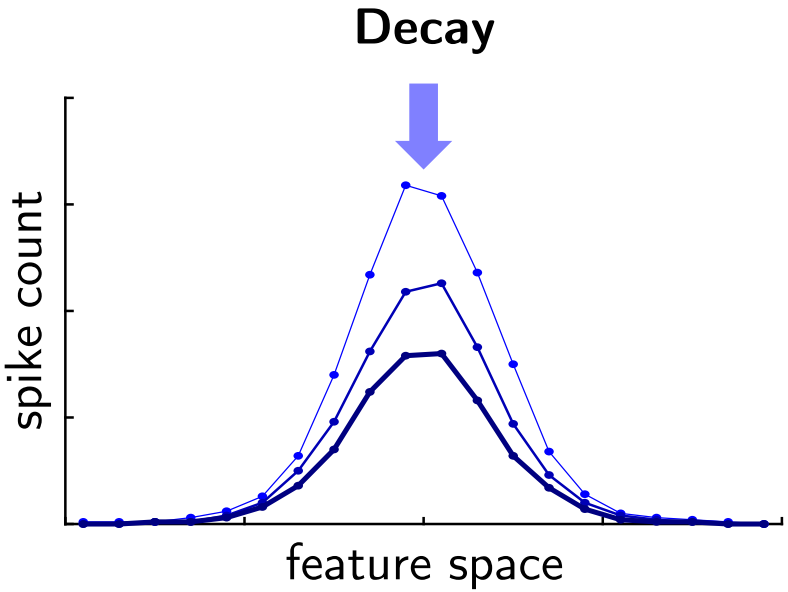
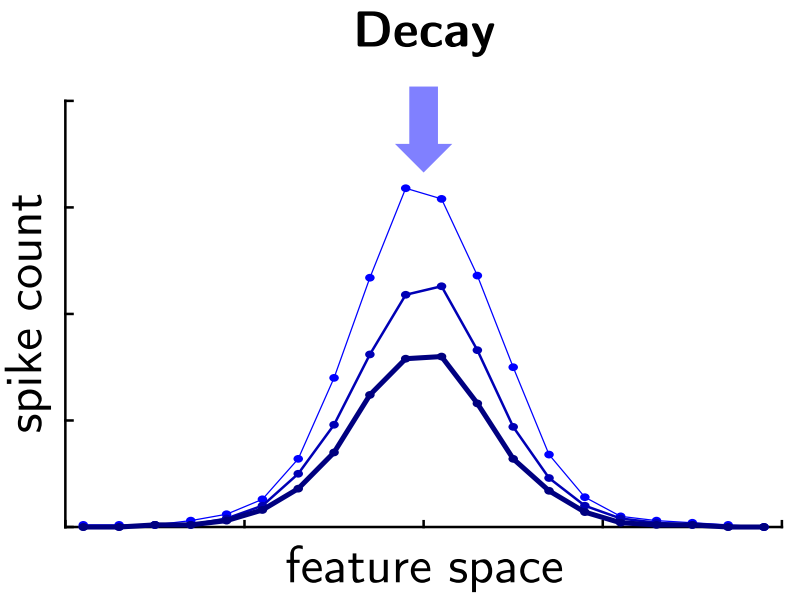
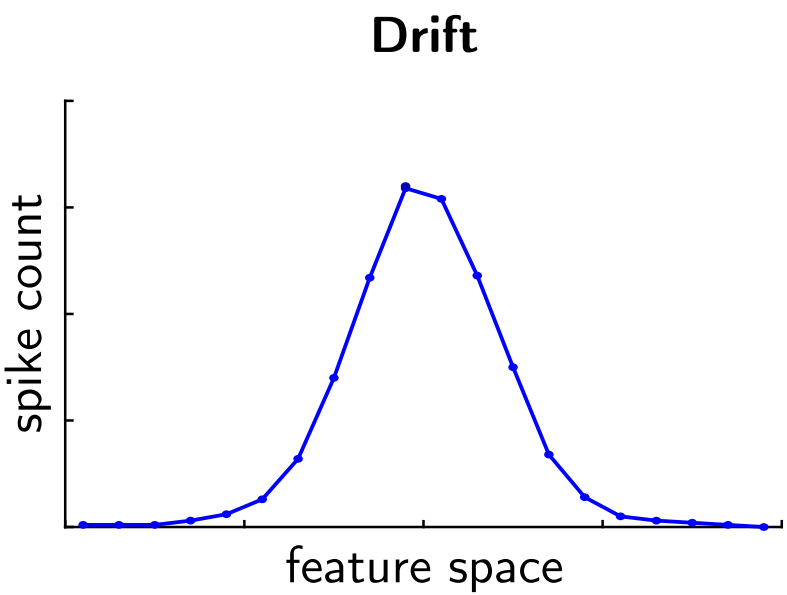


decreasing spike count over time (equivalent to set size effect)

Delay effects





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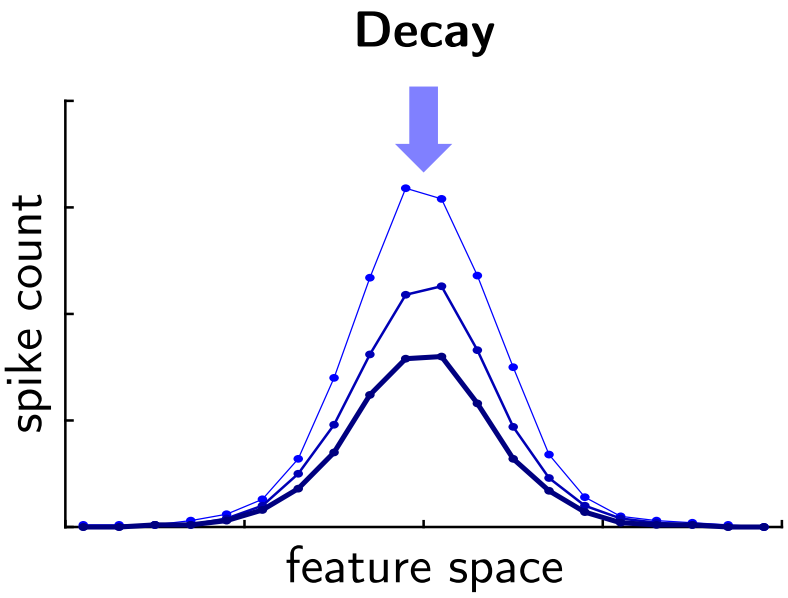
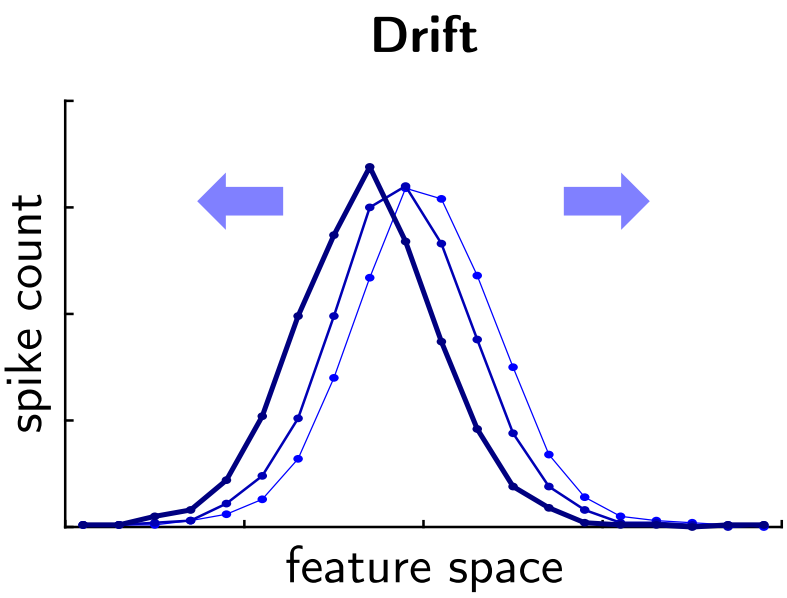


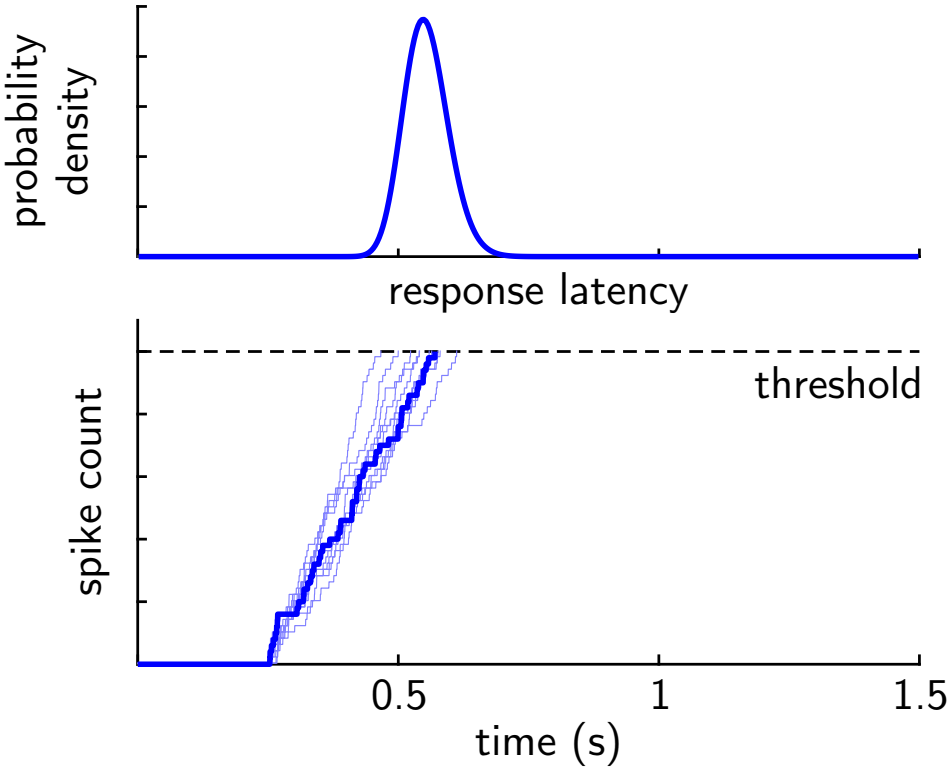
decreasing spike count over time (equivalent to set size effect)



decreasing precision without change in spike count (as in line attractor / dynamic field models)

Response latencies

- using response latencies in saccade task to estimate activity levels
- assuming integration to threshold for response initiation (Ratcliff 1978, Carpenter & Williams 1995, Pearson et al. 2014)



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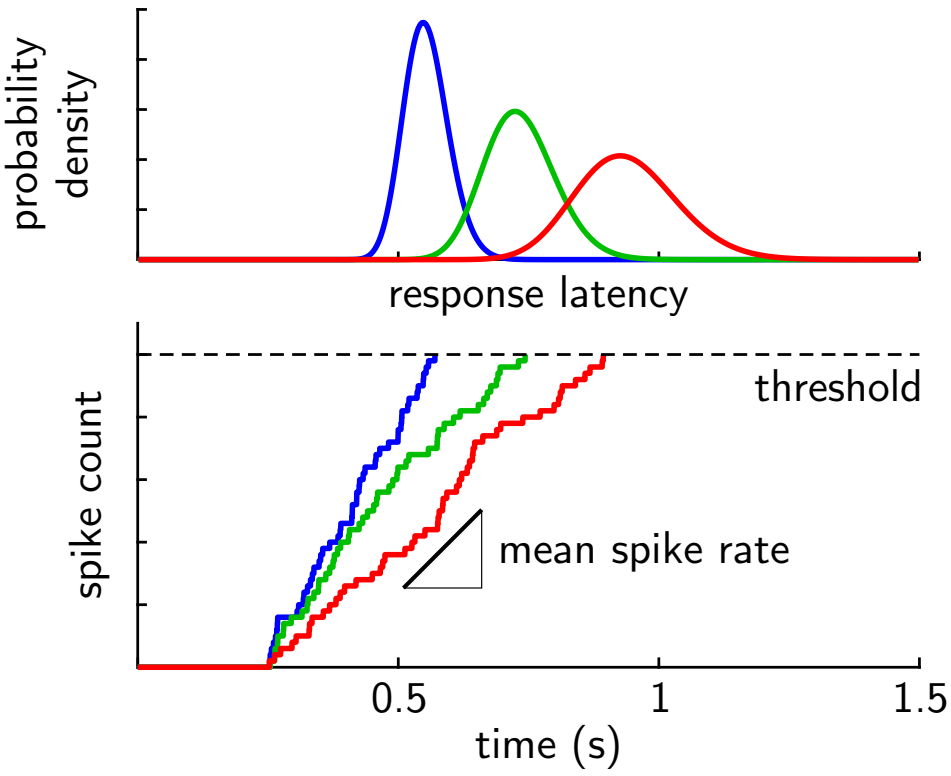
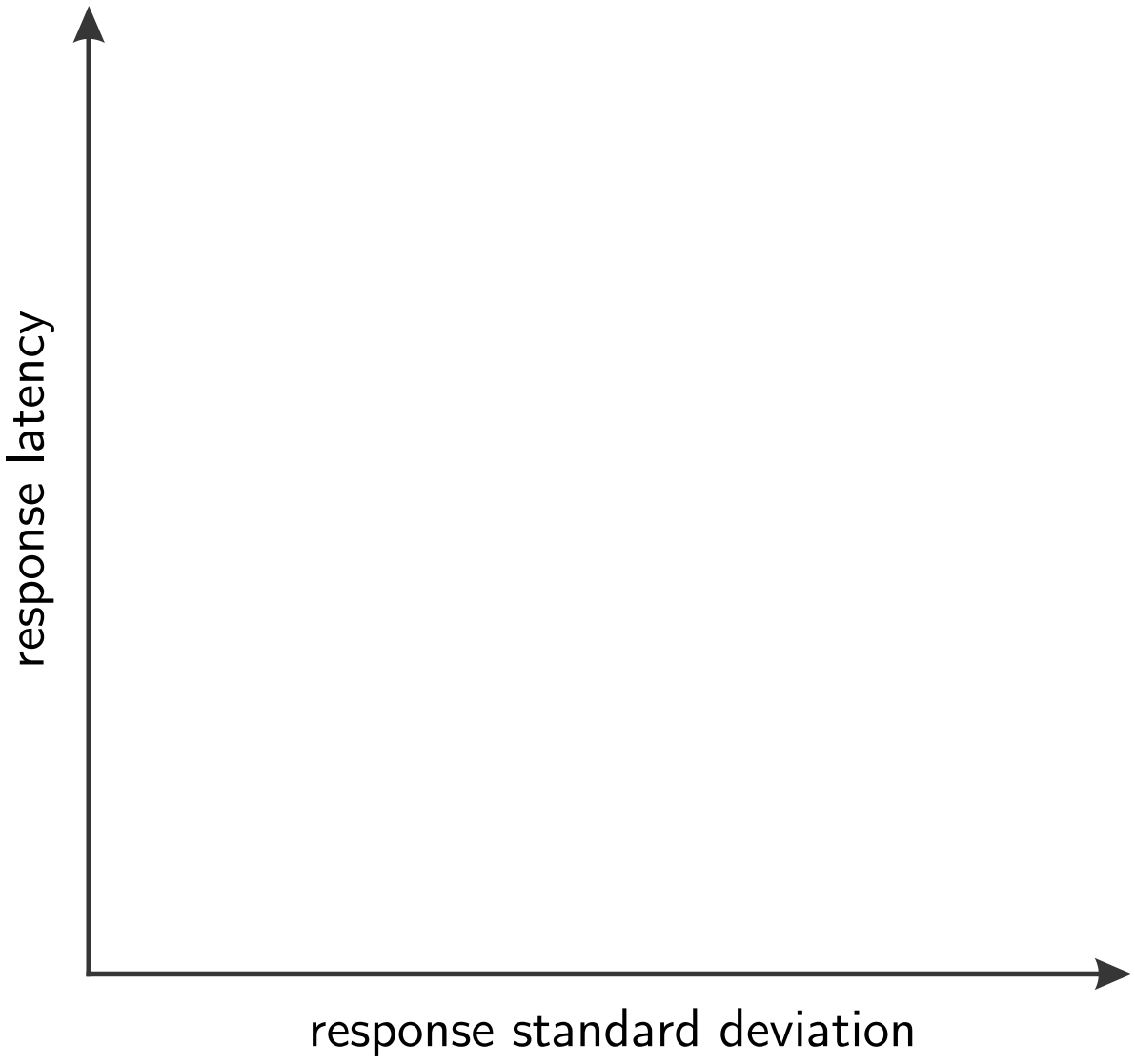
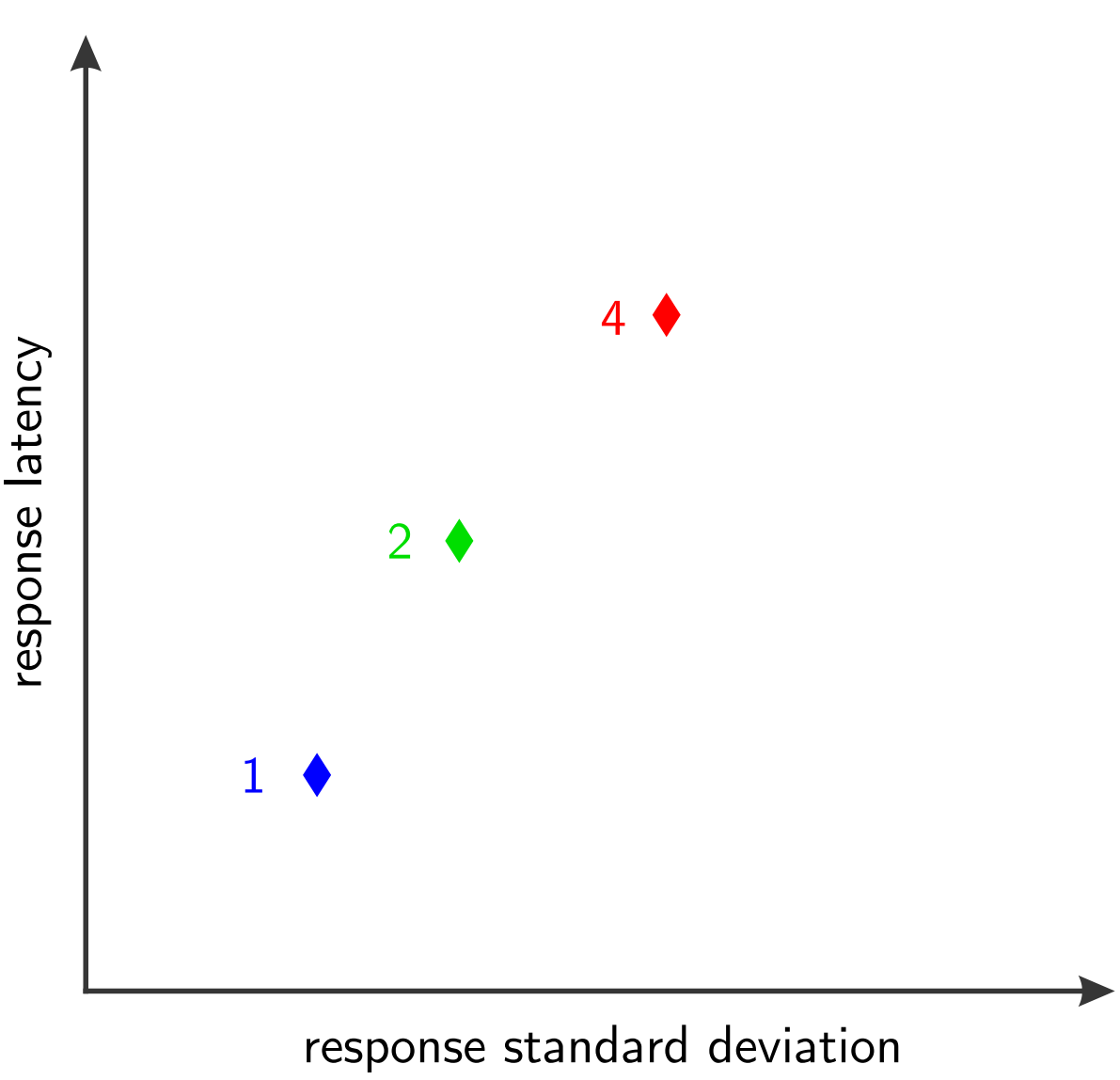
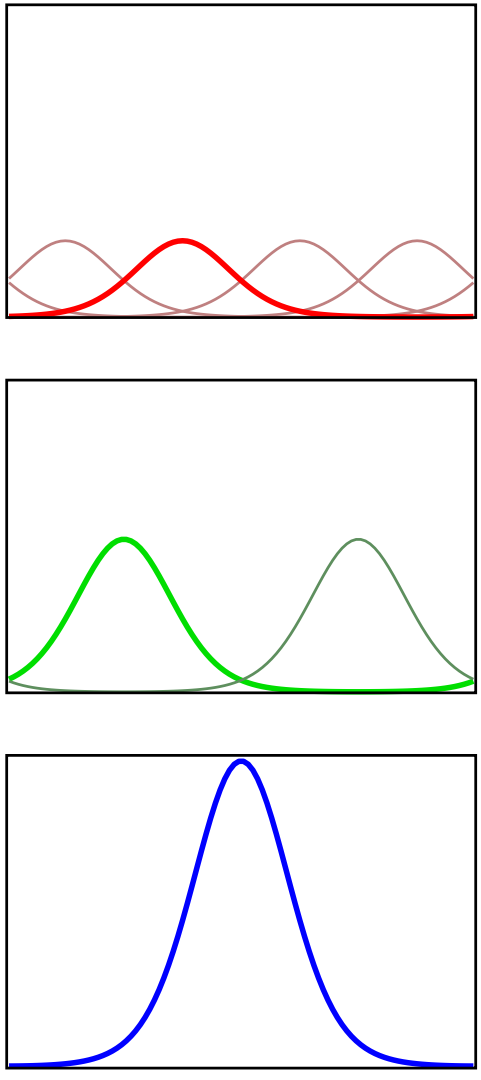


Predictions: Latency vs. precision

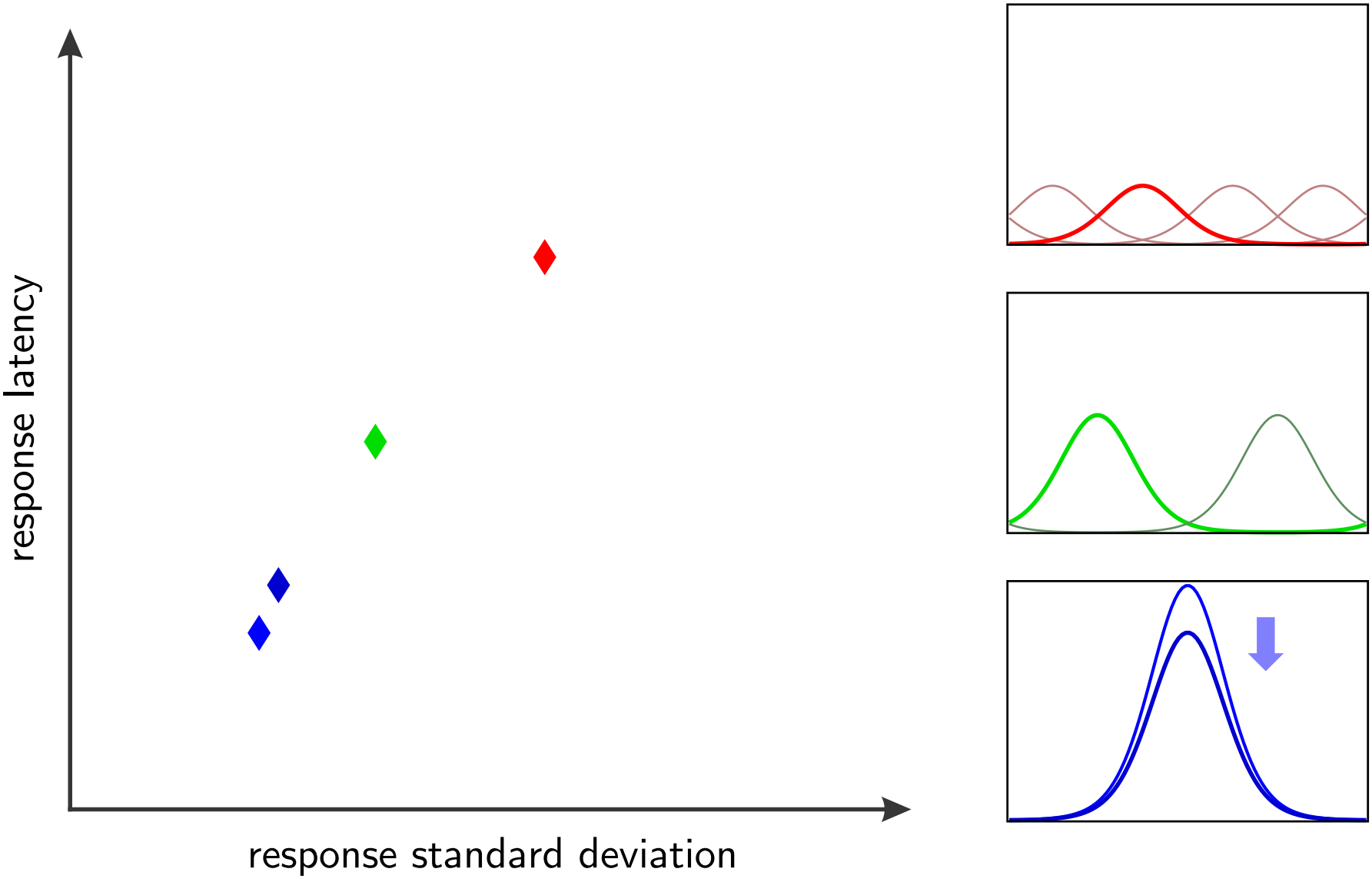


Predictions: Set size effects

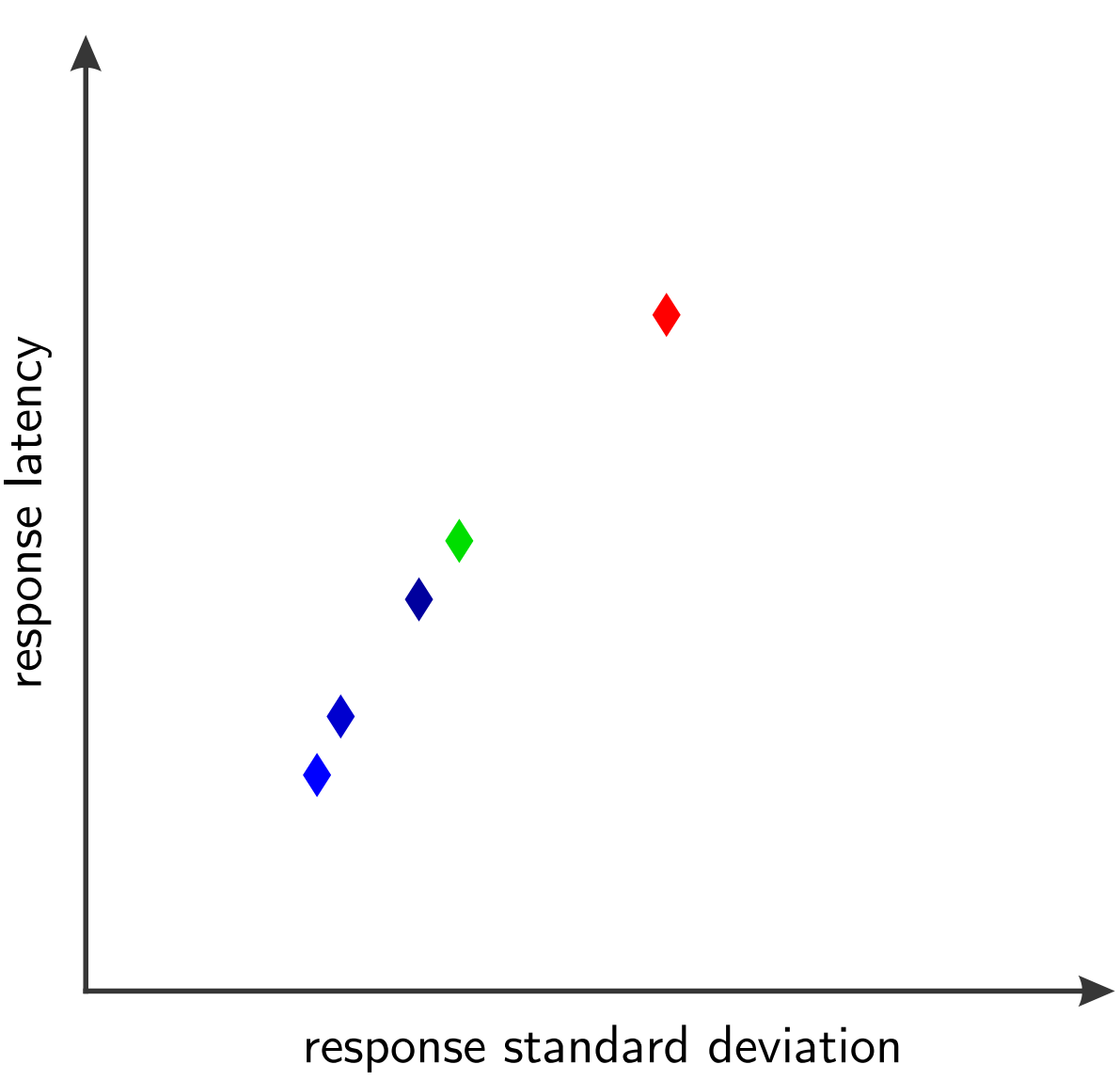


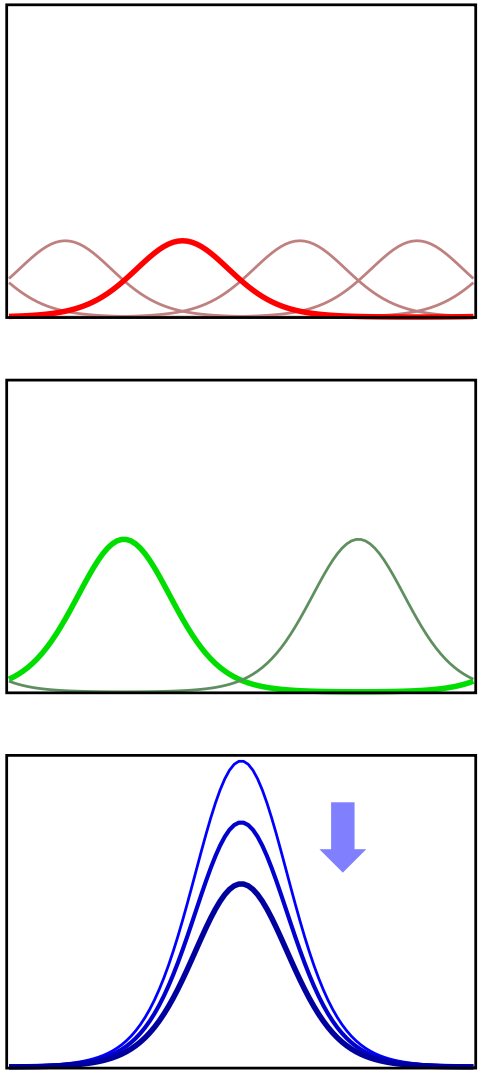


Predictions: Decay model

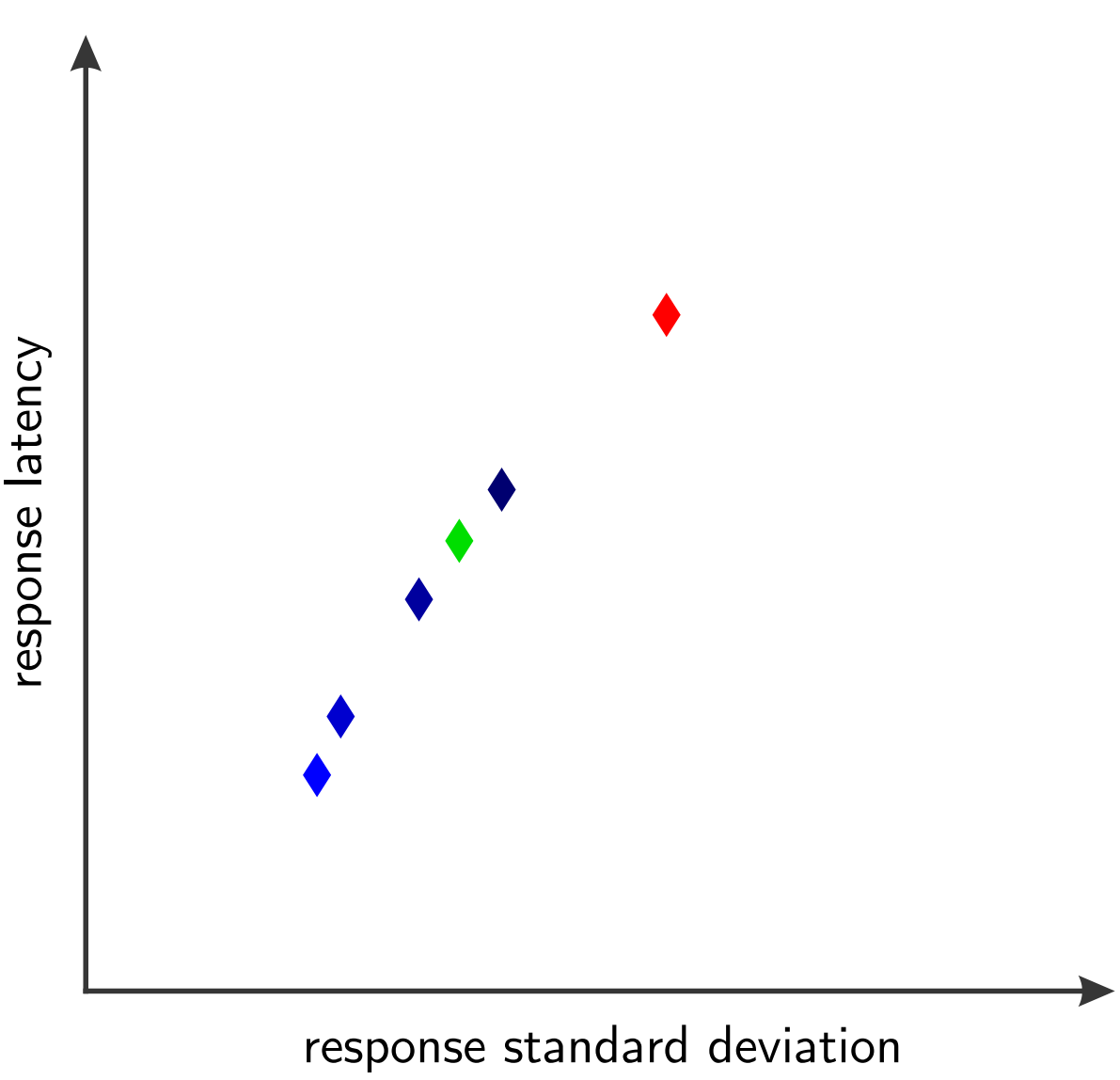


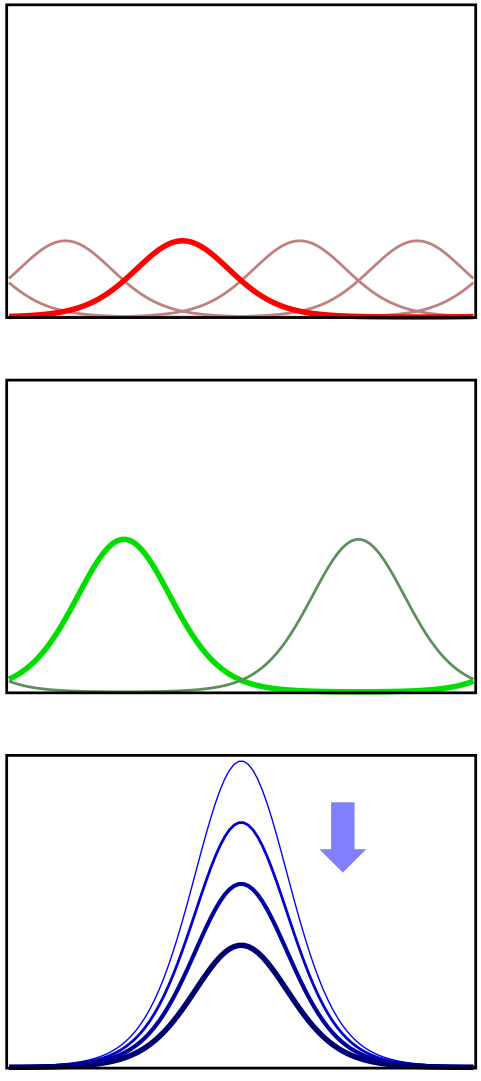
Predictions: Decay model





Predictions: Decay model





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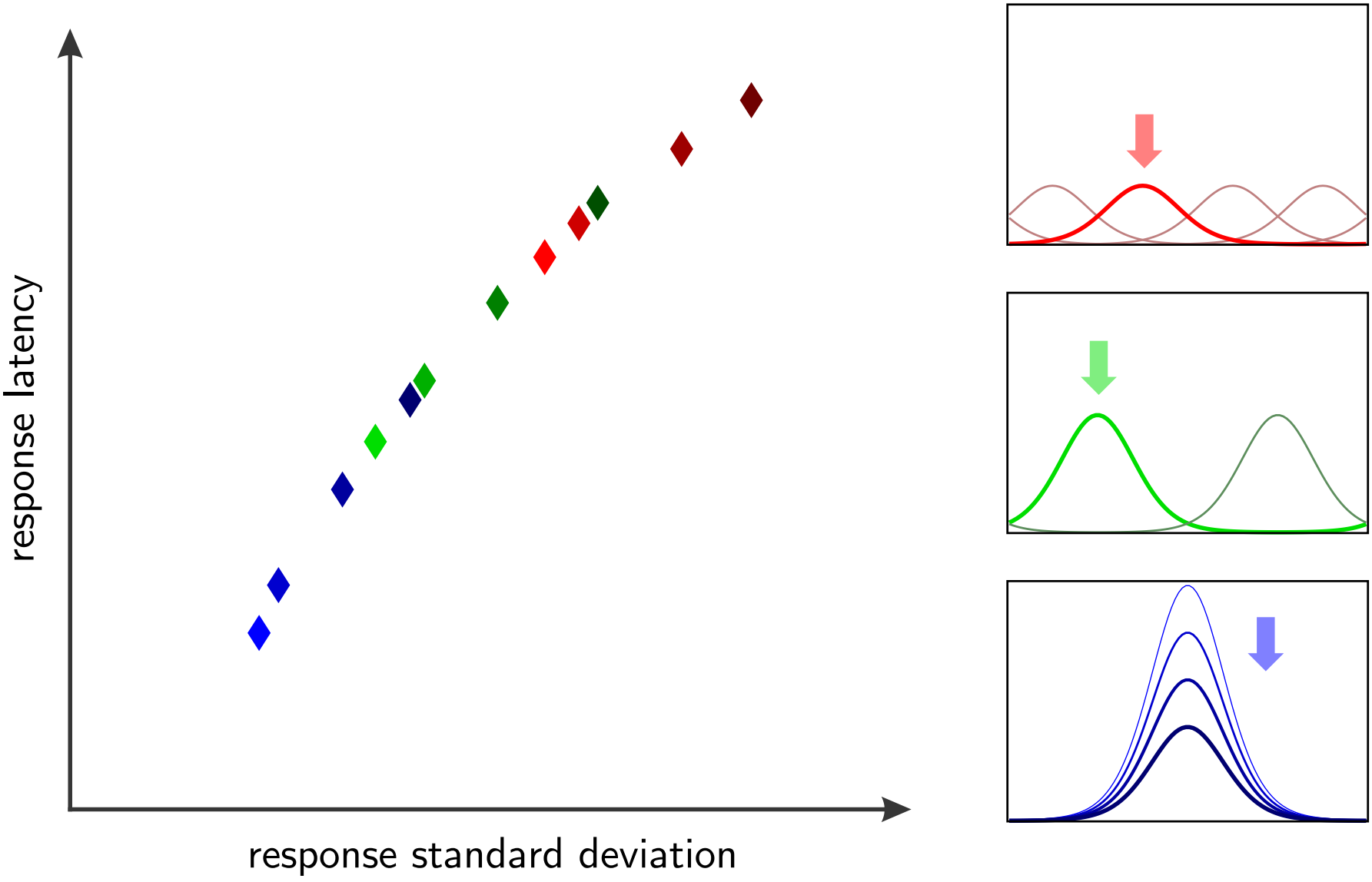
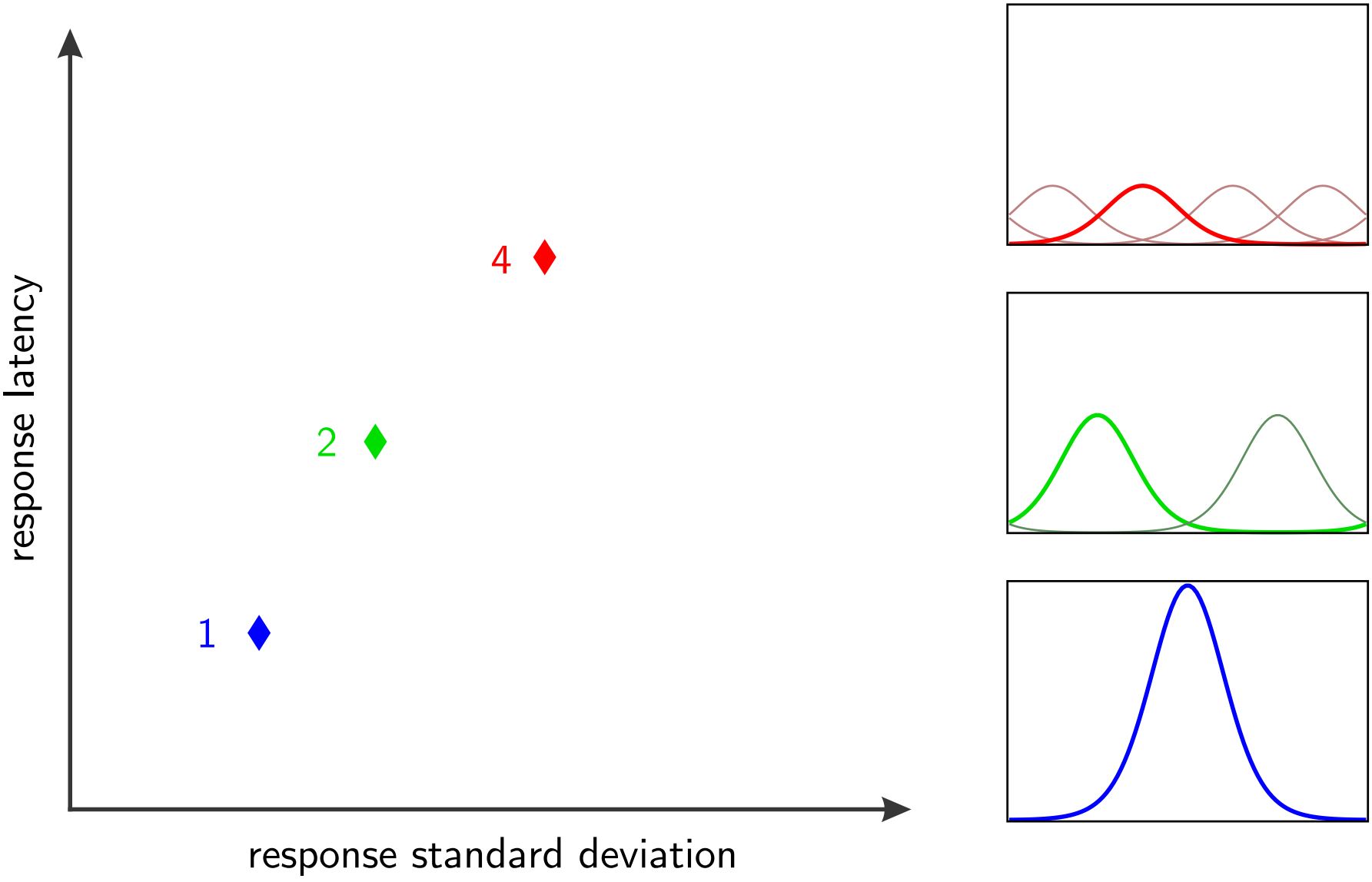
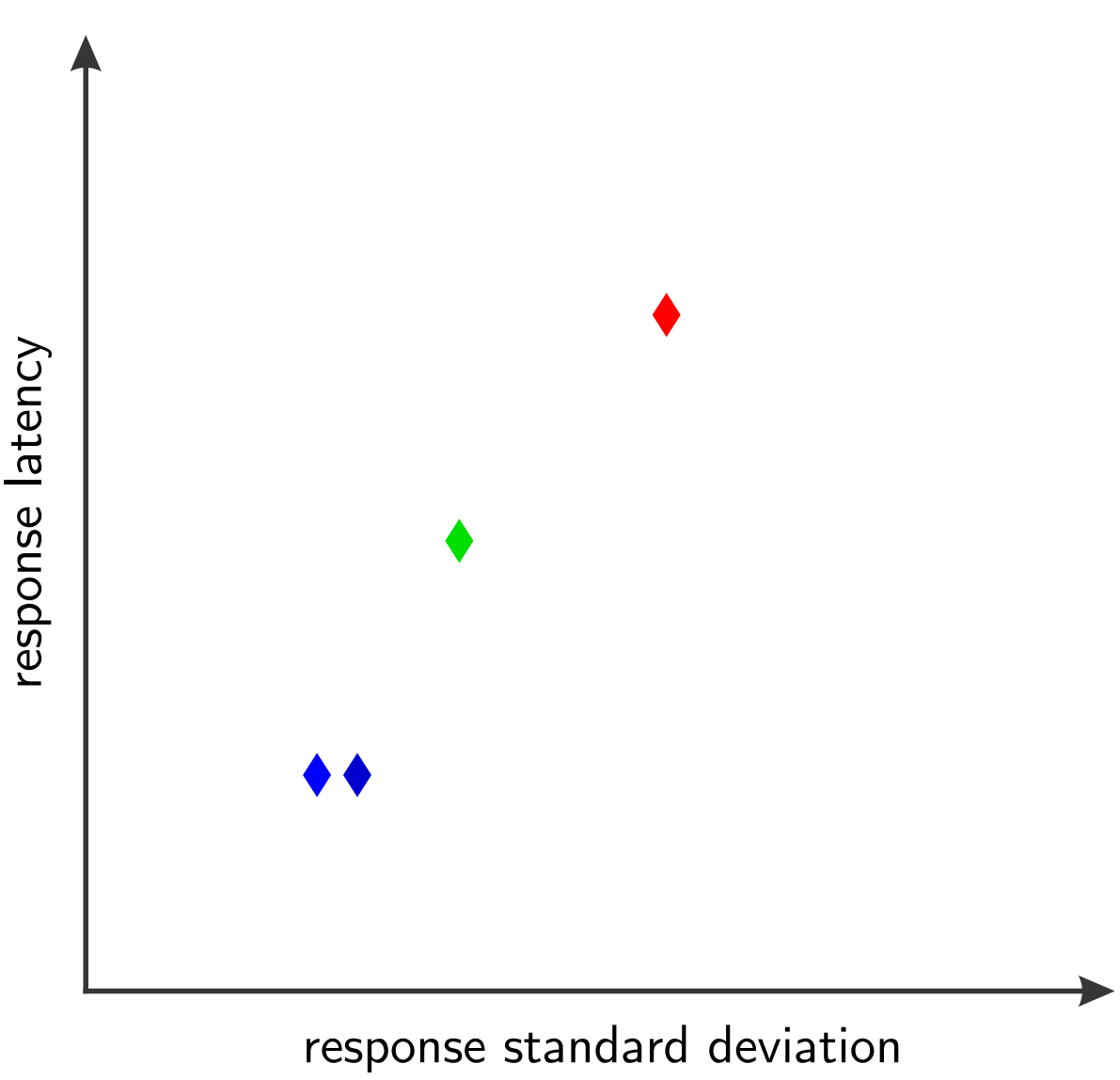
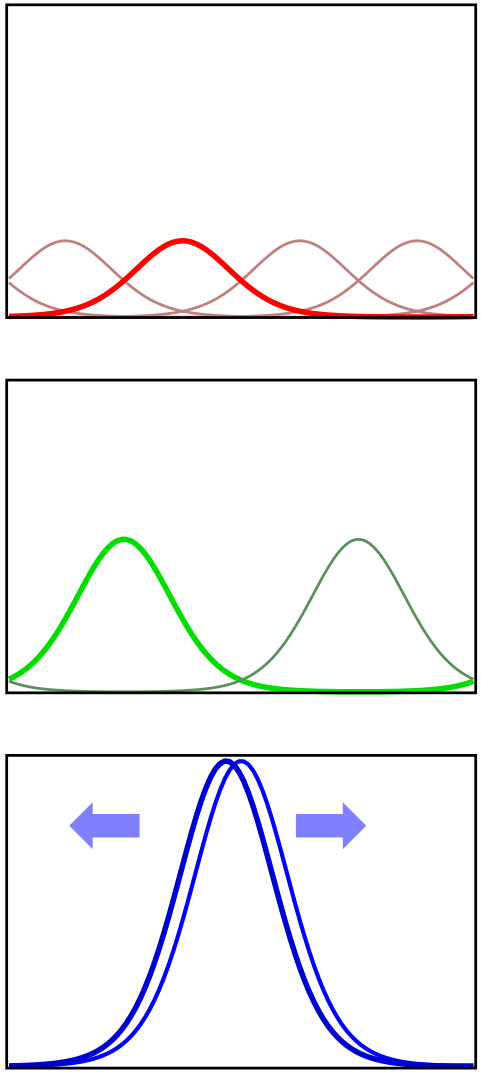


Predictions: Drift model

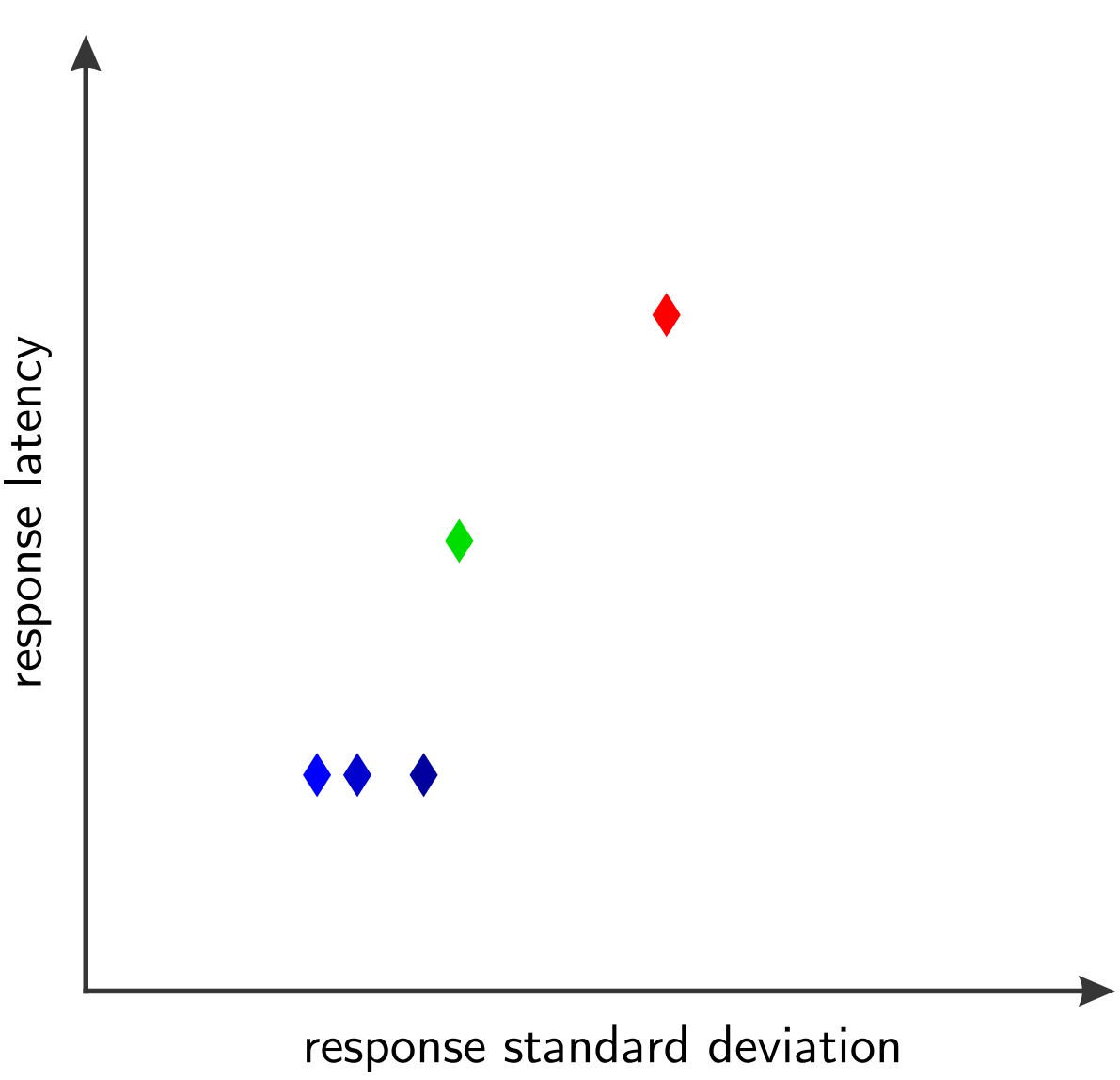


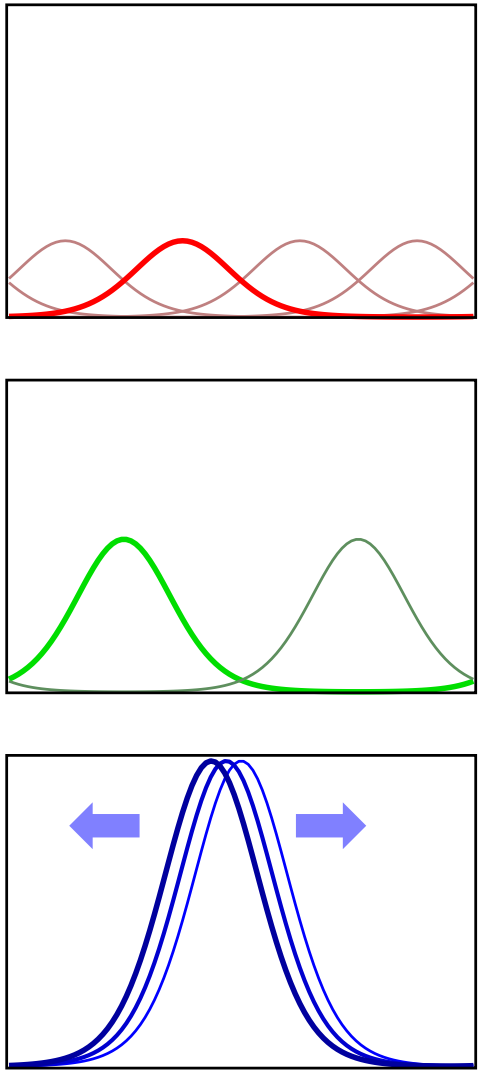
Predictions: Drift model





Predictions: Drift model





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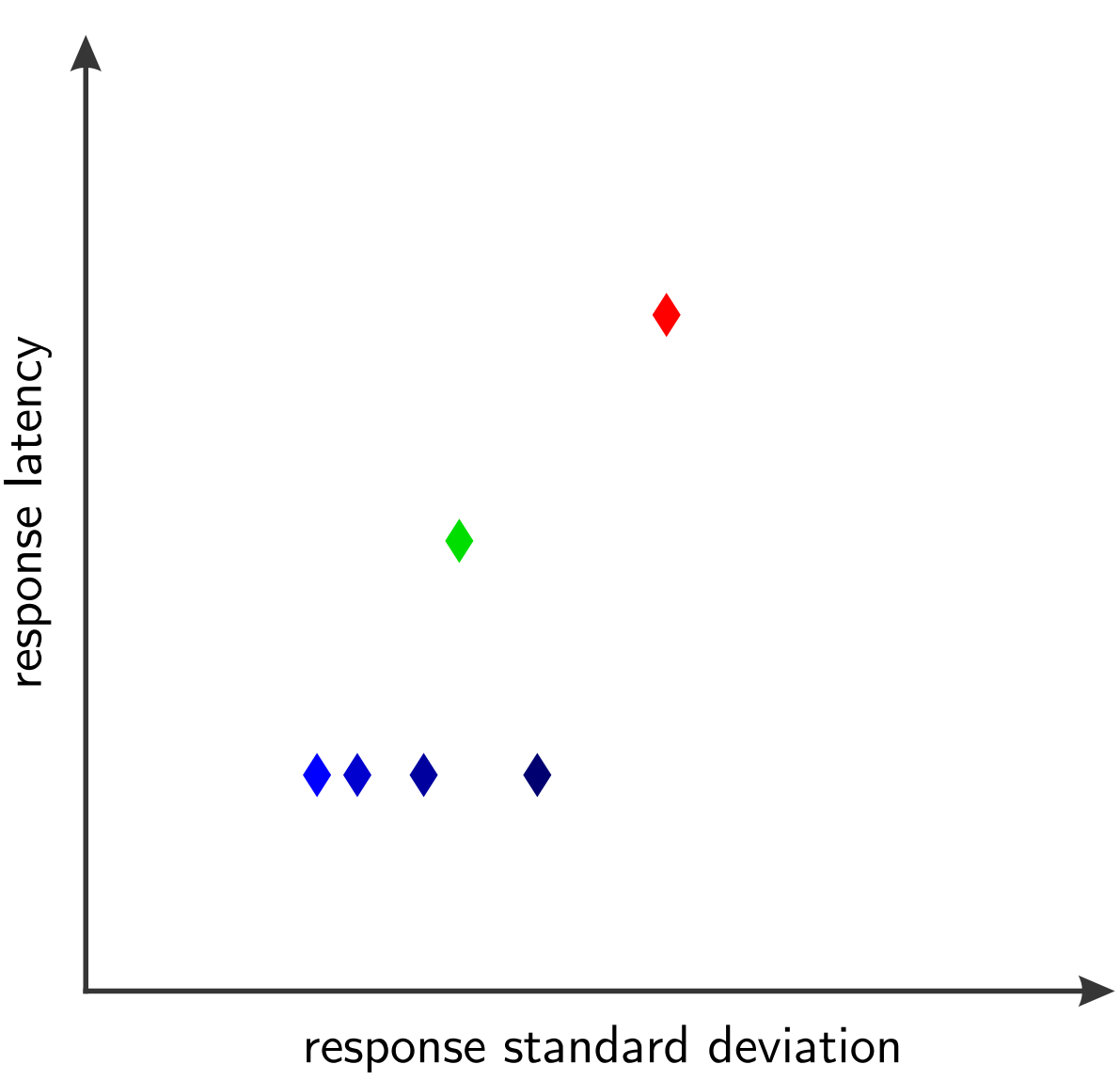
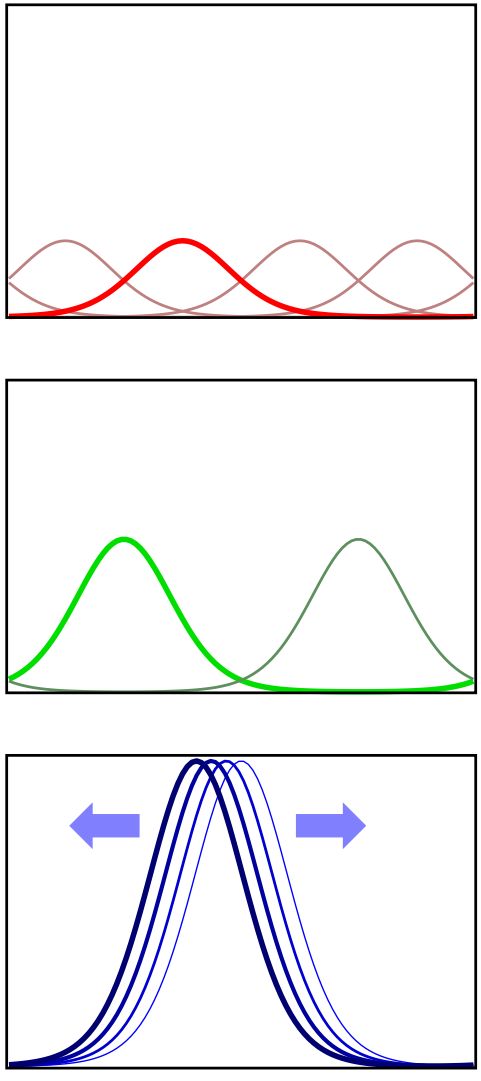
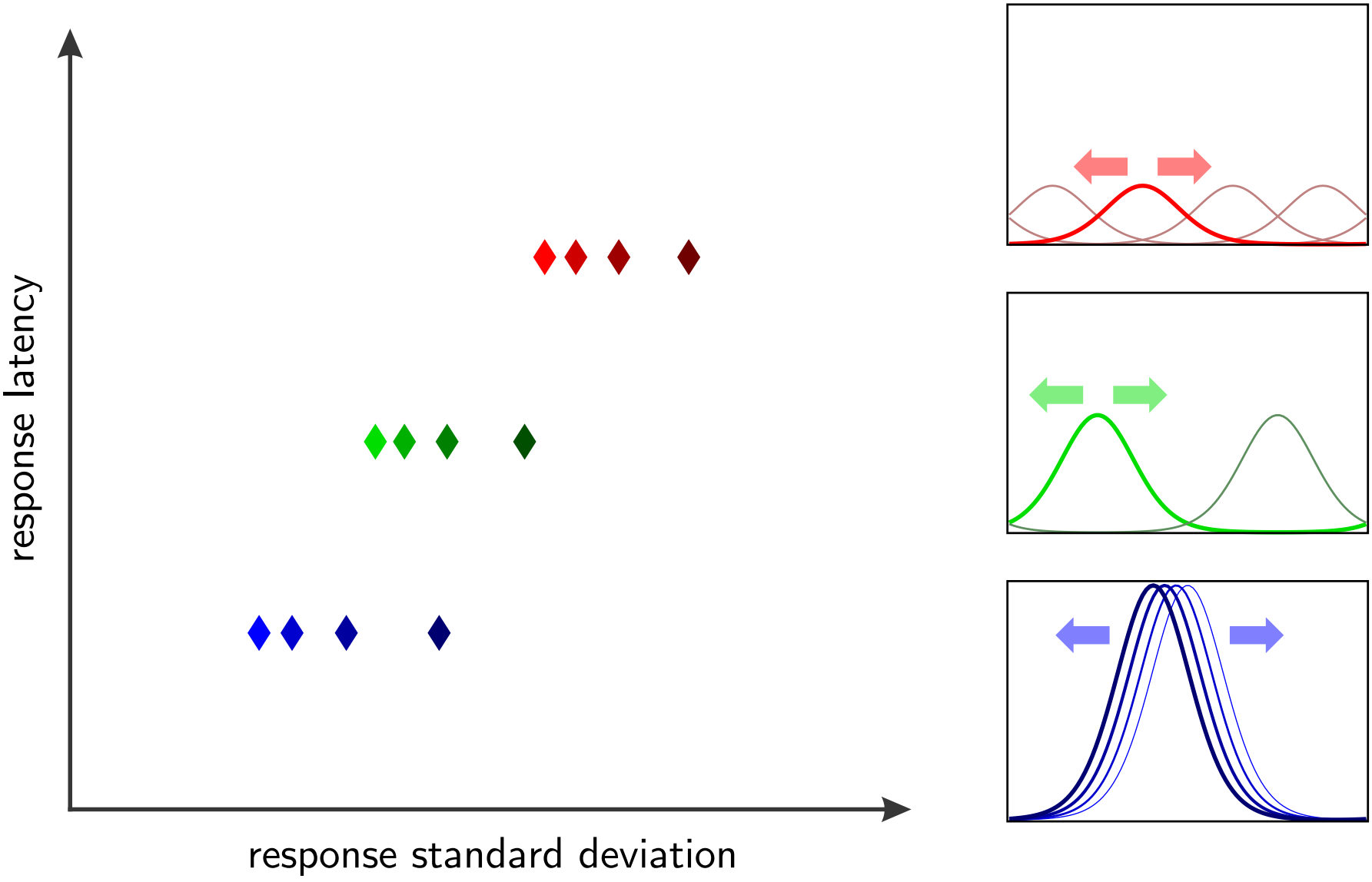
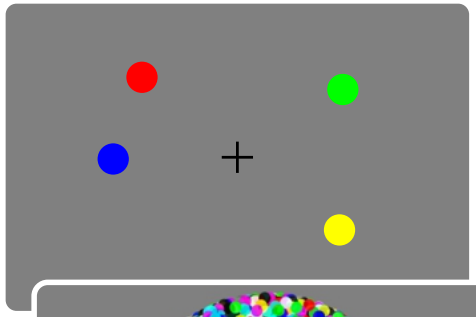




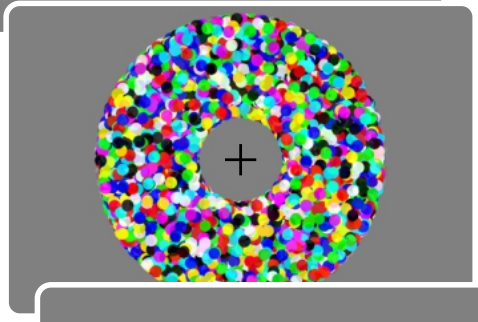
Predictions: Drift model



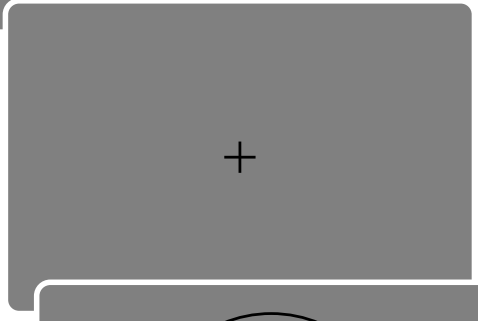
Behavioral task



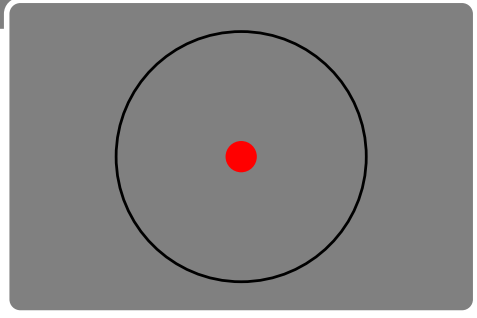
stimuli (2s)



mask (0.1s)

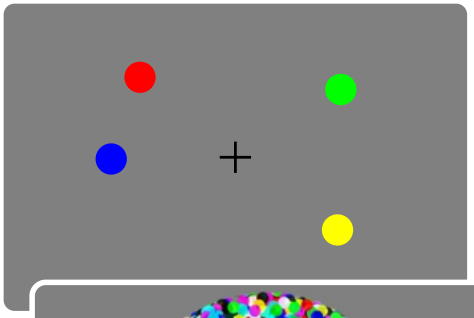


variable delay

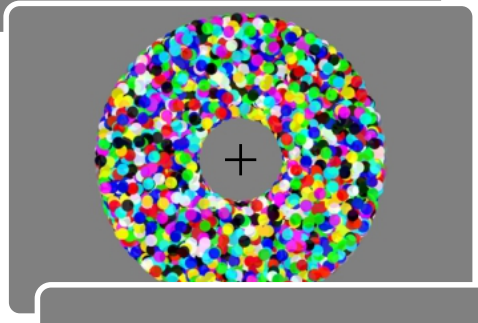


cue

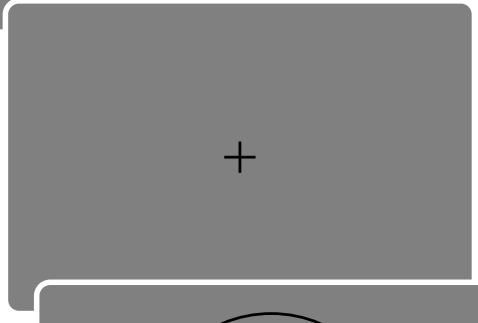
Behavioral task



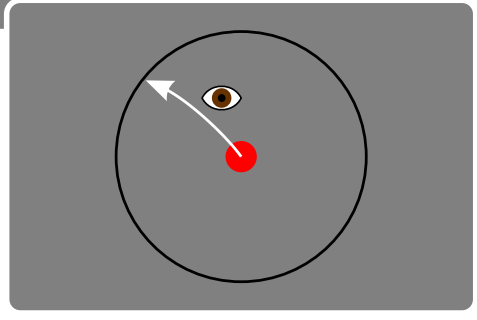
stimuli (2s)



mask (0.1s)

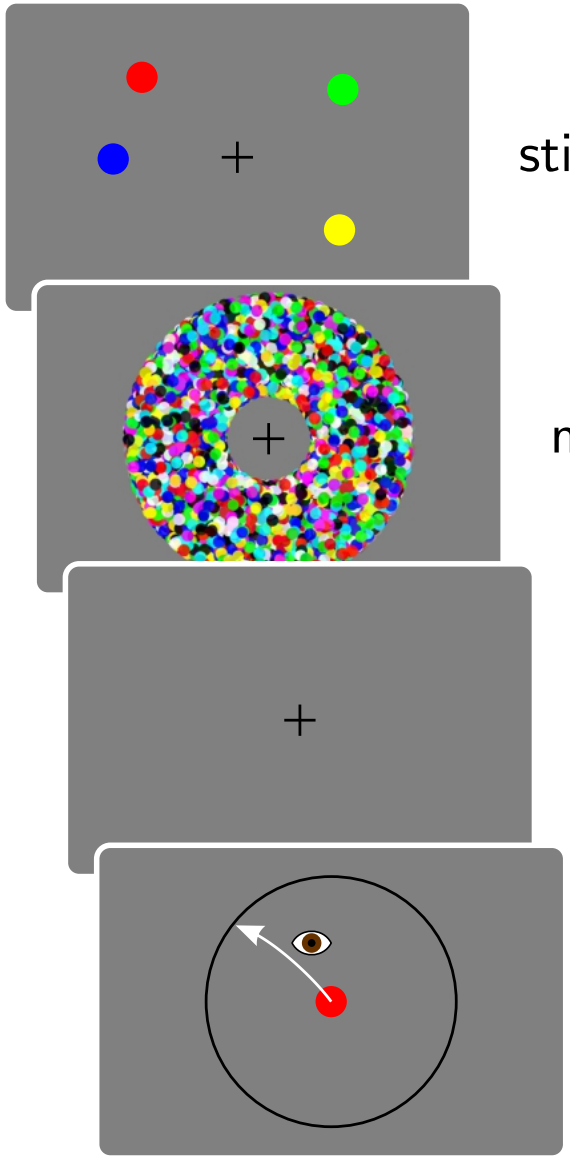


variable delay



cue & response

Behavioral task



stimuli (2s)

mask (0.1s)

variable delay

cue & response

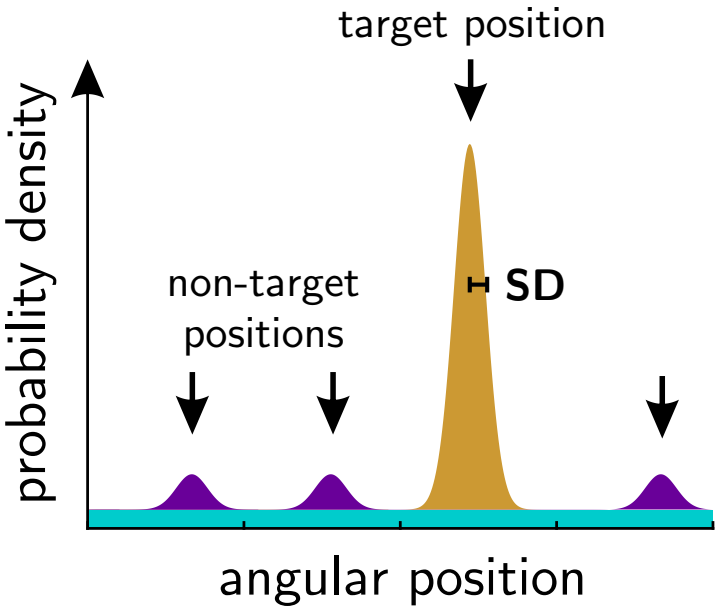
set sizes:
1, 2, 4

total delay duration:
0.5s, 1s, 2s, 4s

response latency:
saccade onset

response location:
first stable fixation after saccade

Mixture model



mixture model with three components:

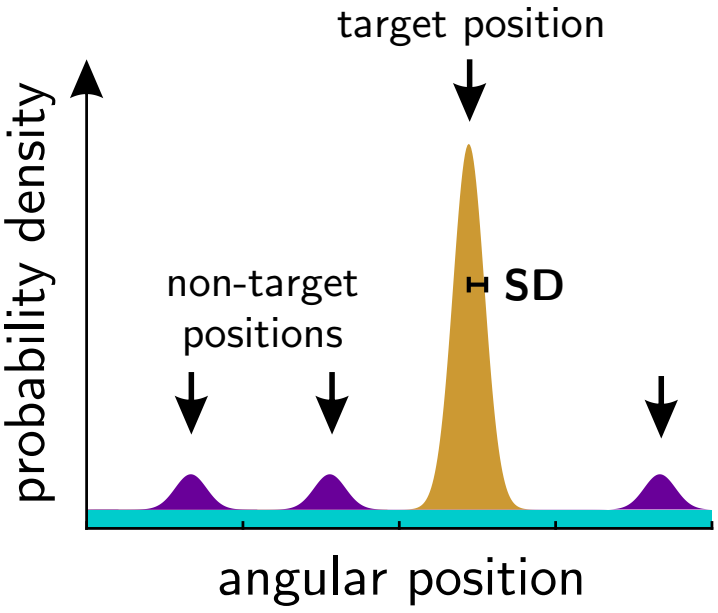
target response

non-target response

random guess

(Zhang & Luck 2008, Bays, Catalao, Husain 2008)

Mixture model



mixture model with three components:

target response

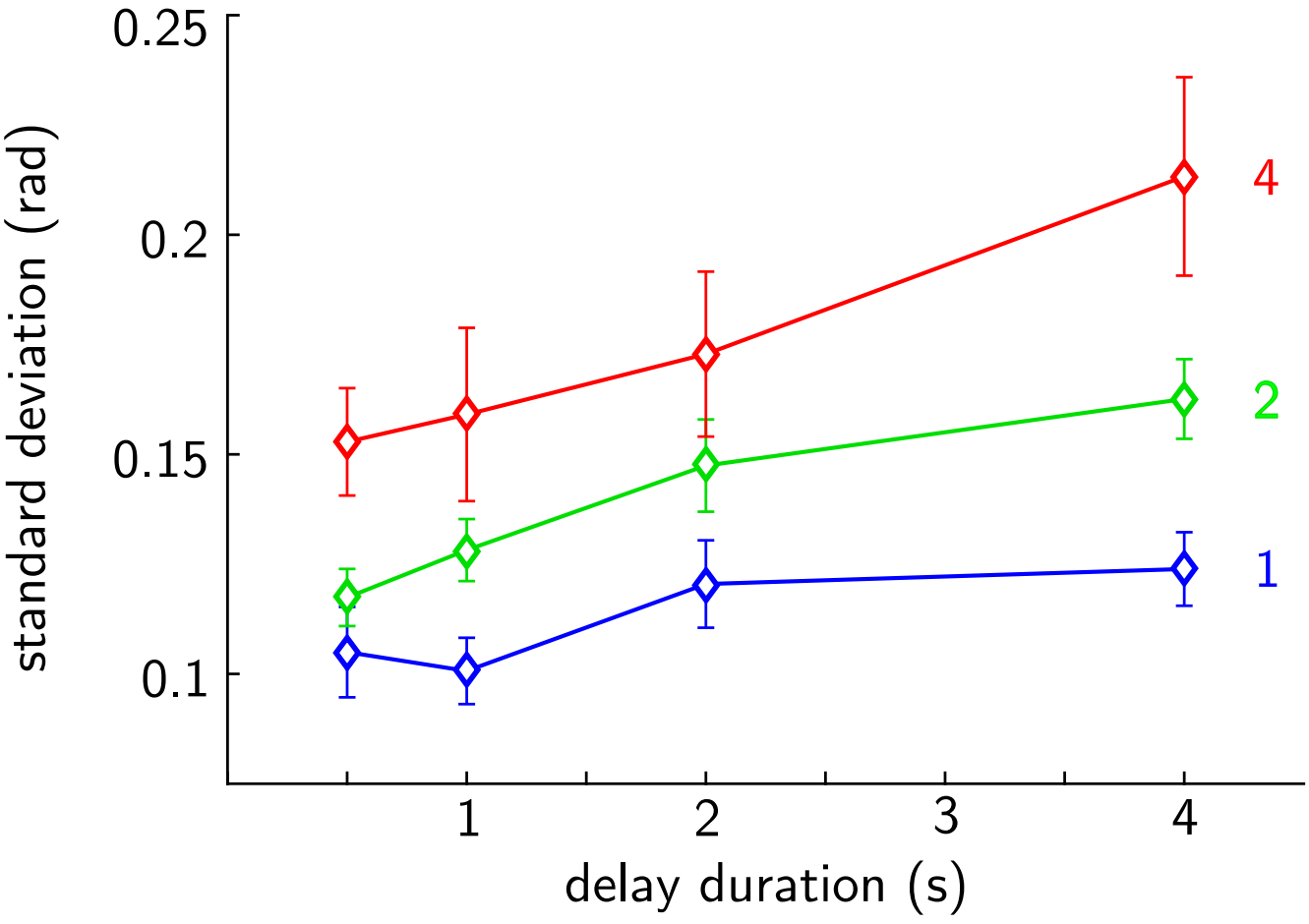
non-target response

random guess

(Zhang & Luck 2008, Bays, Catalao, Husain 2008)

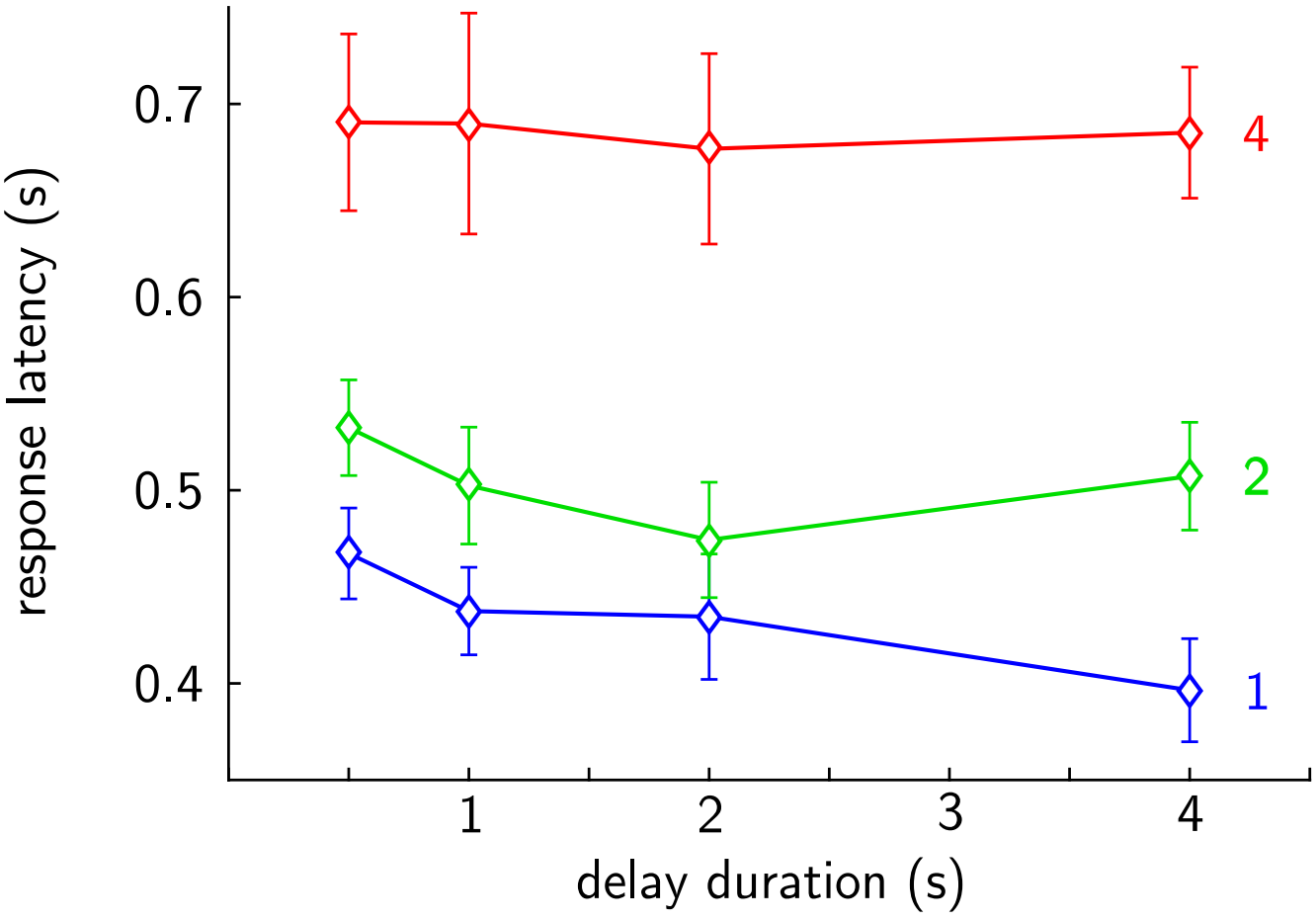
- 97% of responses to target (93% at set size 4)
- no significant effect of delay on mixture proportions

Recall precision



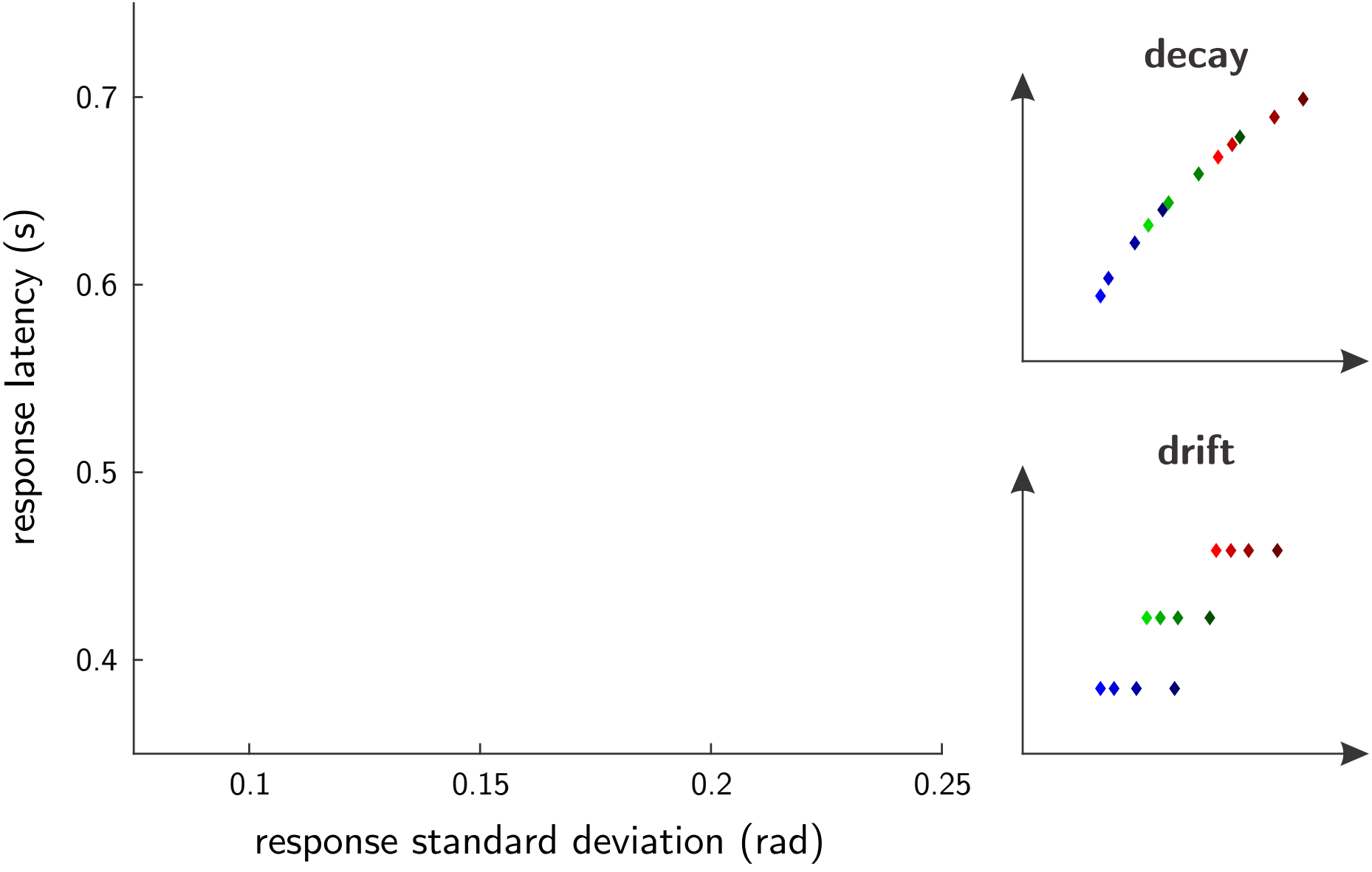
- significant effect of both set size and delay ($p < 0.01$)

Response latencies



- significant effect of set size ($p < 0.01$), but not delay ($p = 0.60$)

Combined results



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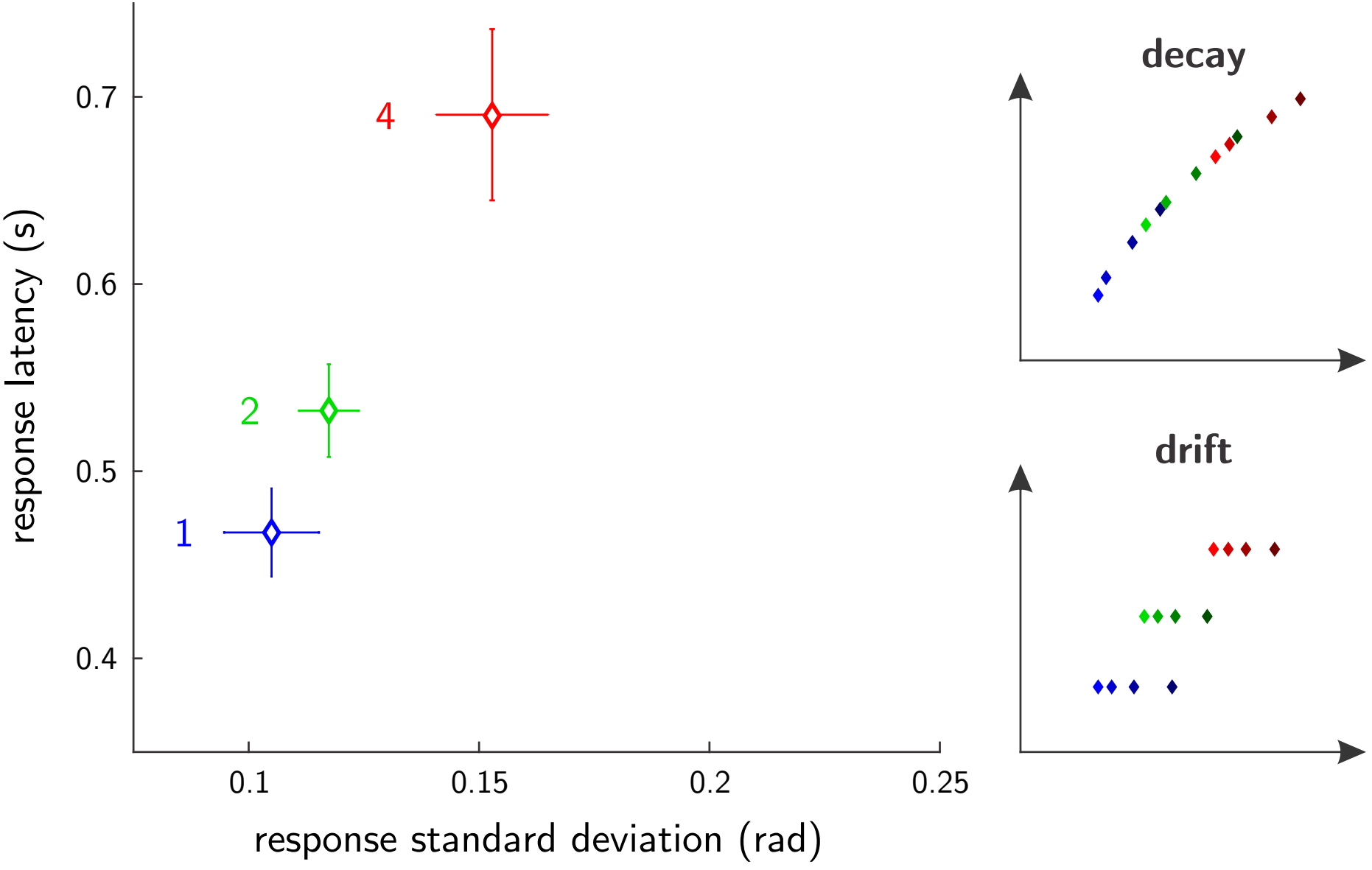

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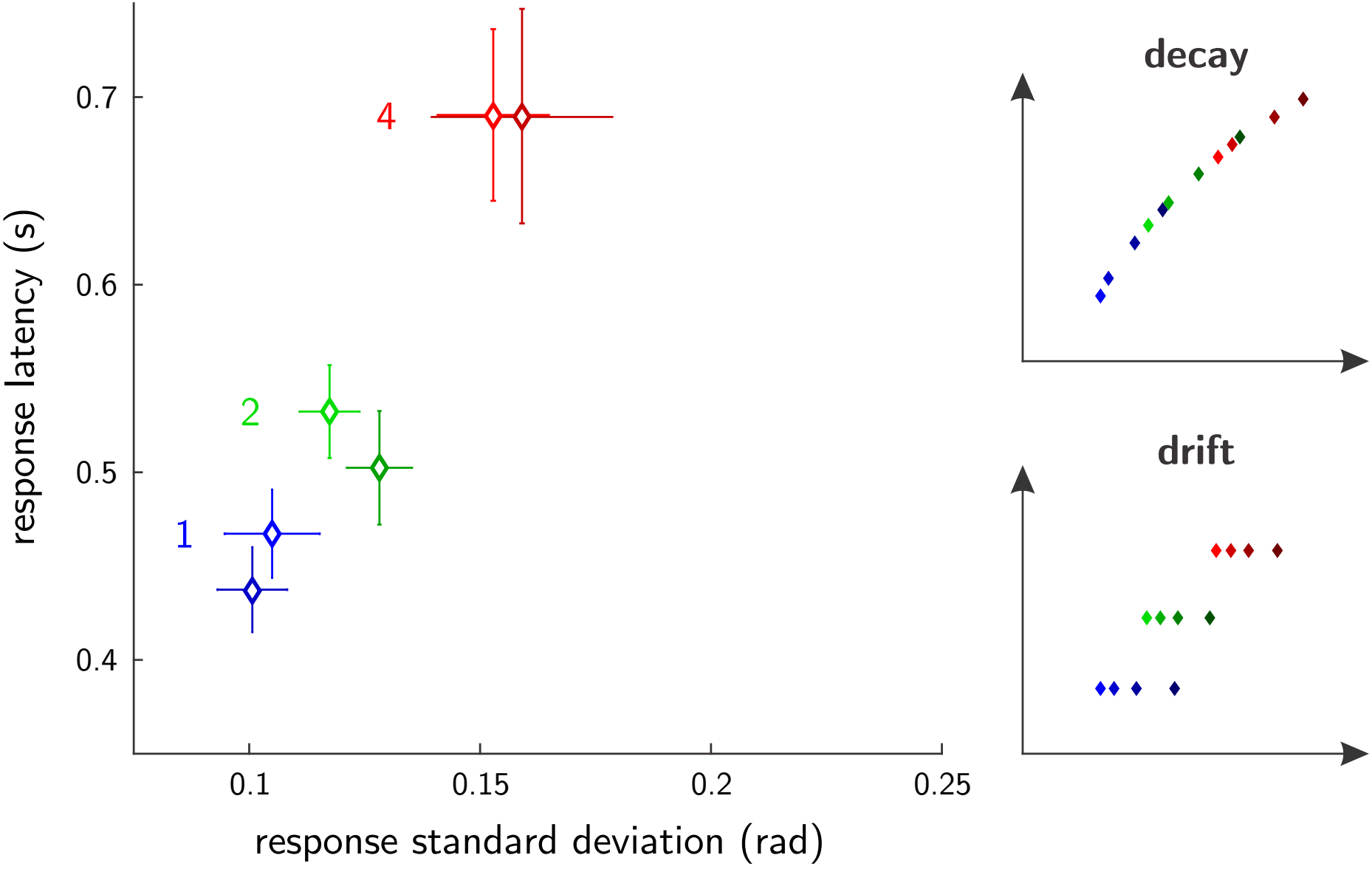

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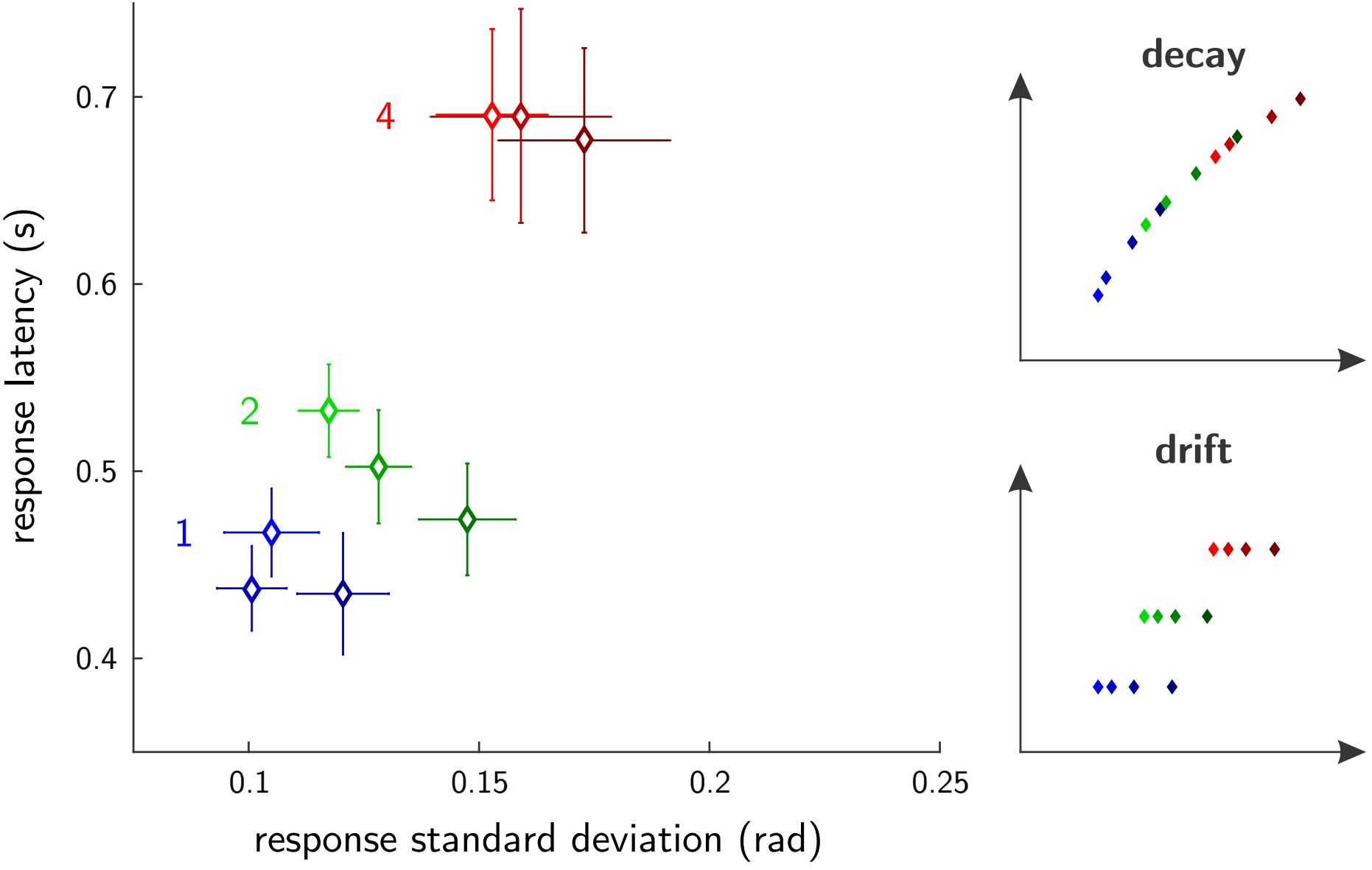

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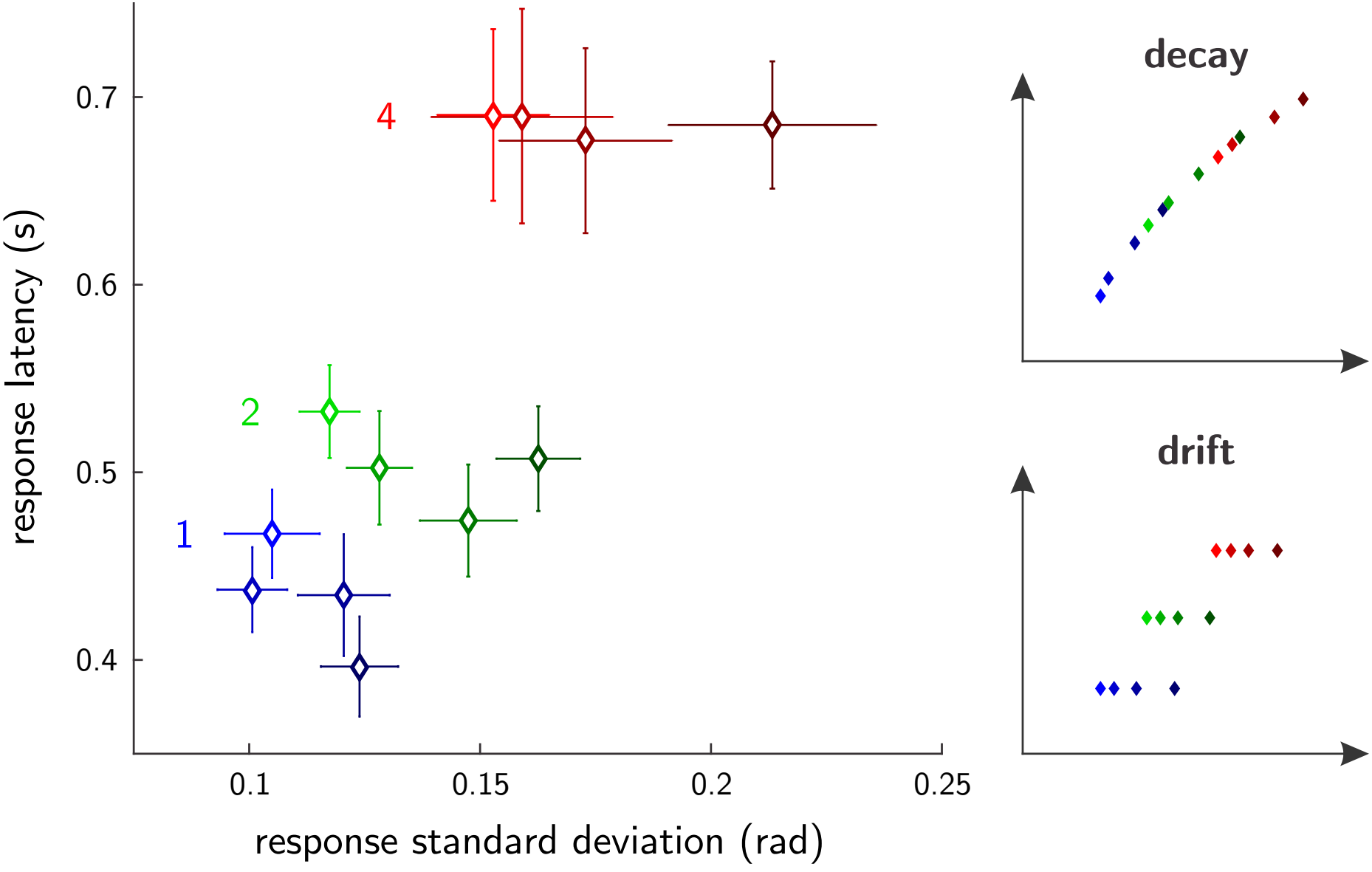

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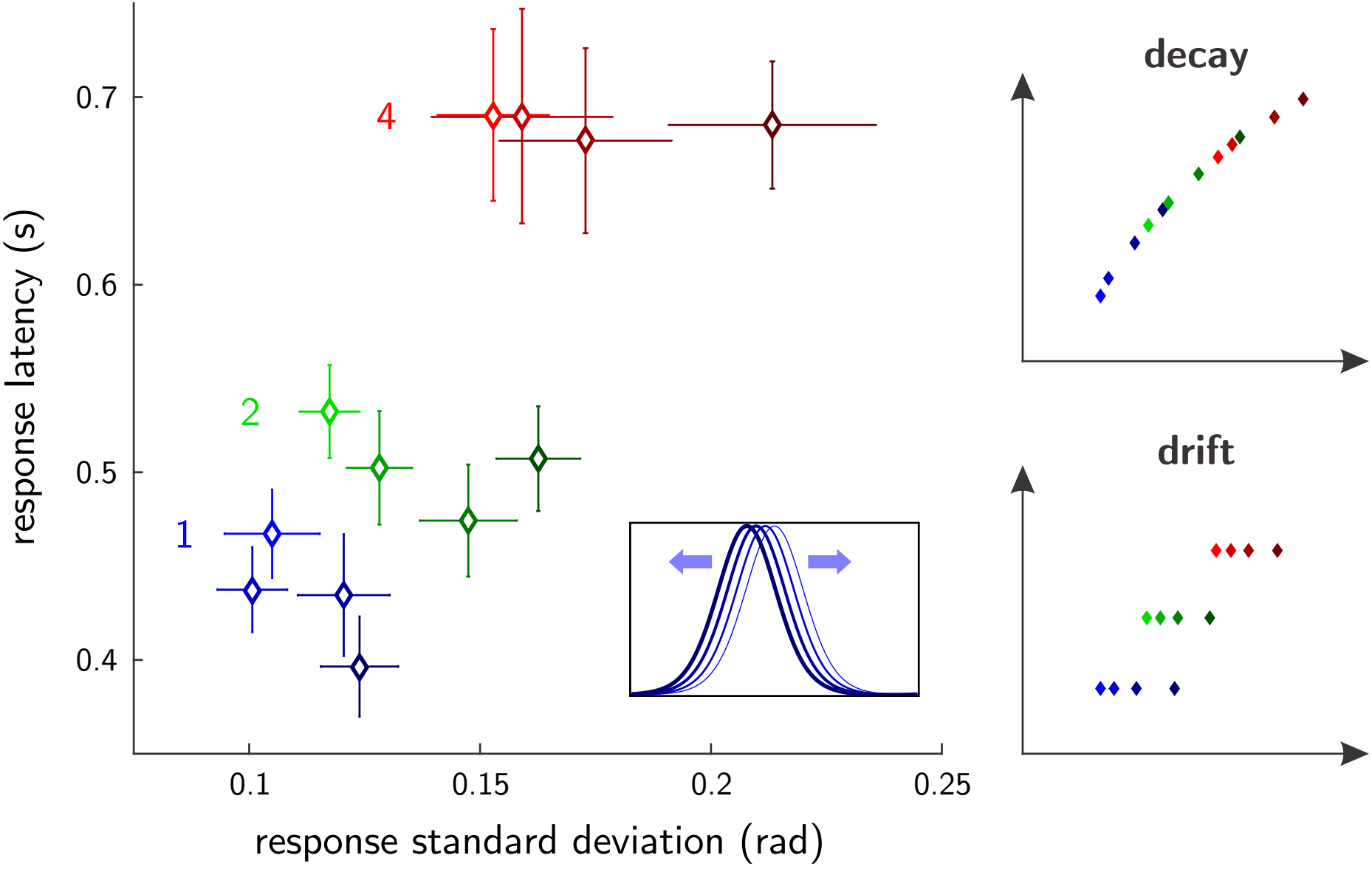
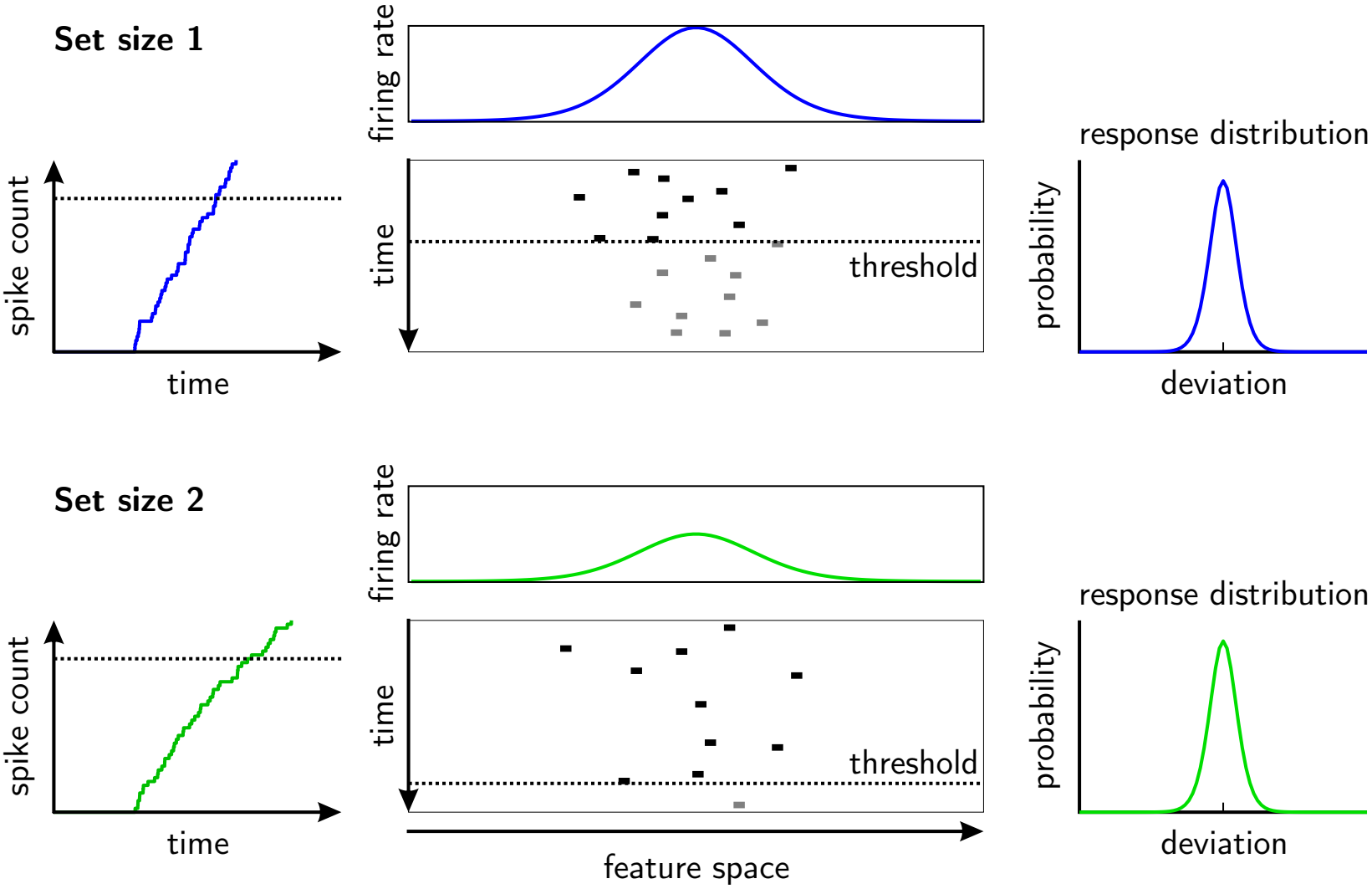
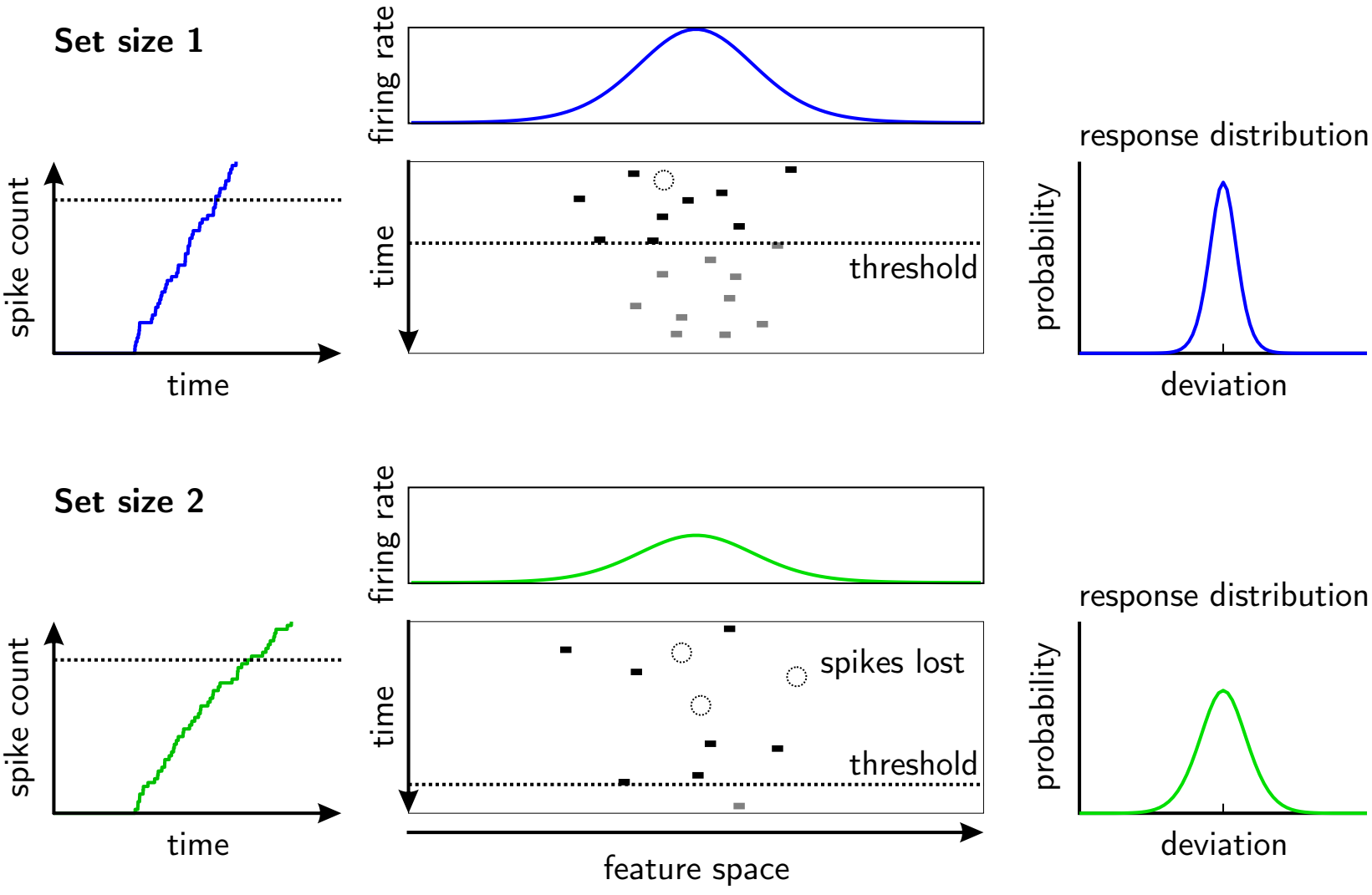


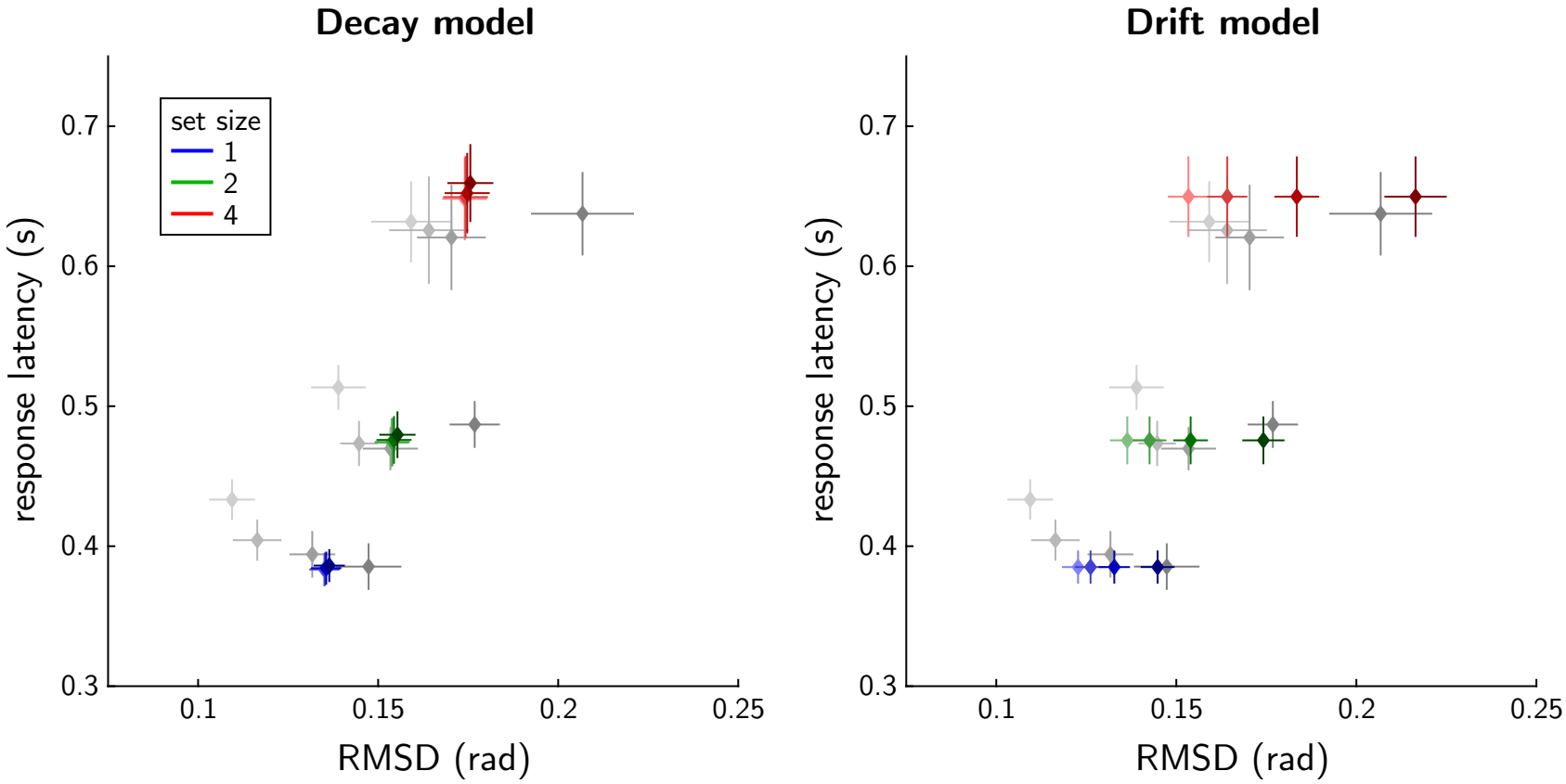
Modeling reaction time and errors



Modeling reaction time and errors

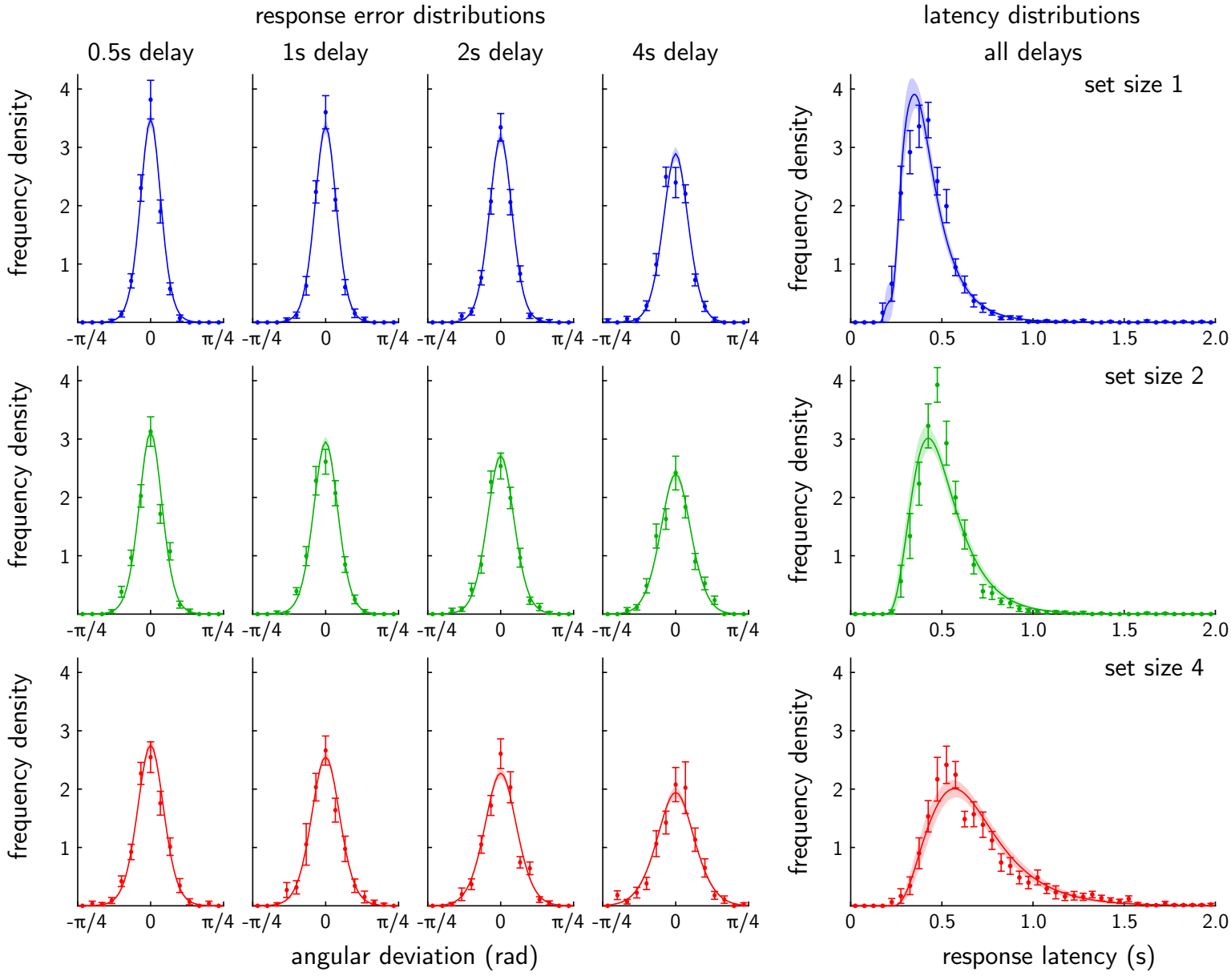


Model fits



Schneegans & Bays (2018), *Journal of Neuroscience*, 38(21)

Response distributions



Conclusions

- two possible mechanisms for delay effects in population model
- predictions tested in spatial recall task with saccadic response
  - recall precision decreases systematically with delay duration
  - response latencies show no systematic effect of delay duration
- findings are consistent with drift, but not decay in neural activity

Conclusions

- two possible mechanisms for delay effects in population model
- predictions tested in spatial recall task with saccadic response
  - recall precision decreases systematically with delay duration
  - response latencies show no systematic effect of delay duration
- findings are consistent with drift, but not decay in neural activity
- but drift alone does not explain response errors for earliest delay durations

Thank you!

Paul Bays

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