Some new approaches to volition

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European Research Council
Established by the European Commission

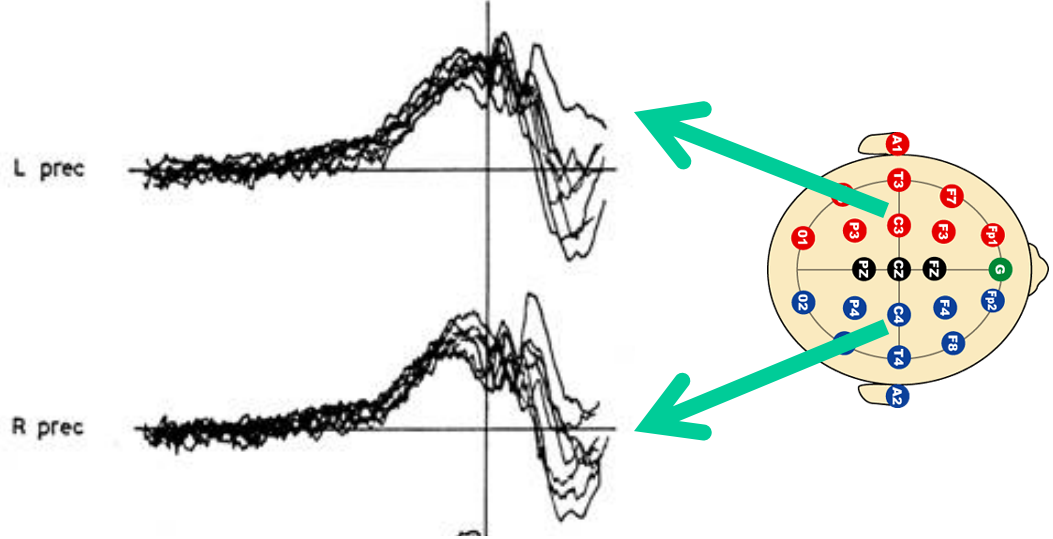
Internally-generated ⟷ Externally-triggered

‘free will’ ⟷ reflex

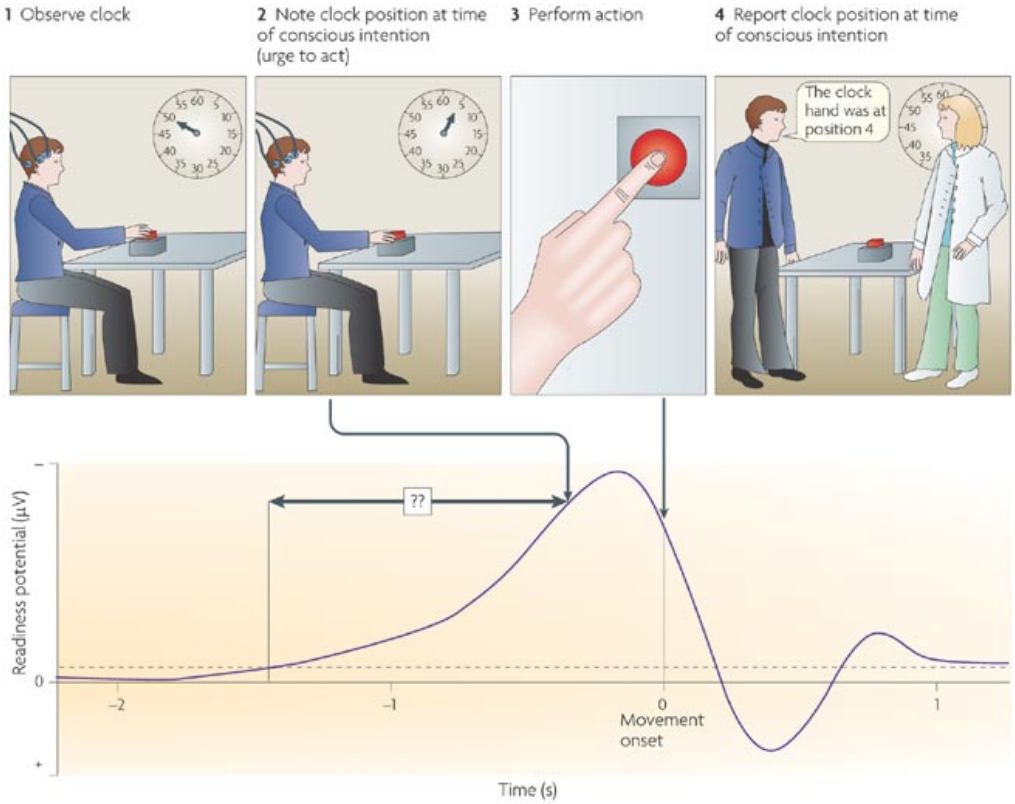
“freedom from immediacy” (Shadlen)

⟷

Smart action ⟷ Stereotypy



Readiness Potential
(Kornhuber and Deecke 1966)



Methodological difficulties

(e.g., Libet, 1985, BBS target article)

- No experimental control of input
- Measurement approach is poor

- Instruction is strange:
  'make a voluntary action when you feel like it'

- "But that's not what we mean by volition"

Volition: Key features	Neuroanatomical constraint
Leads to movement	Strong connections **to** motor areas
Reasons-responsive	Strong connections **from** reward areas
Outcome-directed	Strong connections **to** networks for planning, and monitoring
No obvious trigger stimulus (non-reflexive)	**Weak** connections **from** sensory areas Connections **from** memory areas??
Innovative/ spontaneous	Relative independence from subcortical "habitual" circuits
Characteristic subjective experience?	Neural basis remains controversial

No single feature is necessary, but a subset may be jointly sufficient for an action to be 'voluntary'

Roadmap

1. What brain events precede volitional action?

2. Are these events *uniquely* associated with the conscious intention to move?

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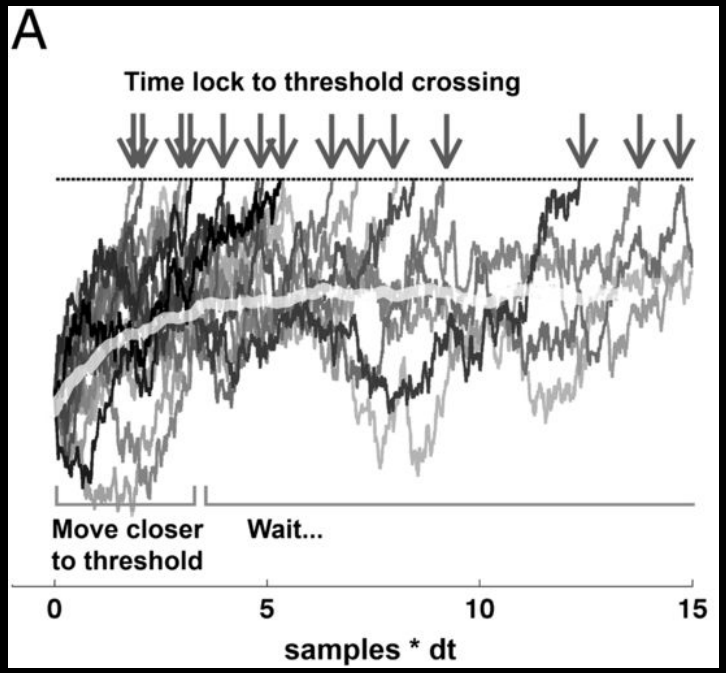
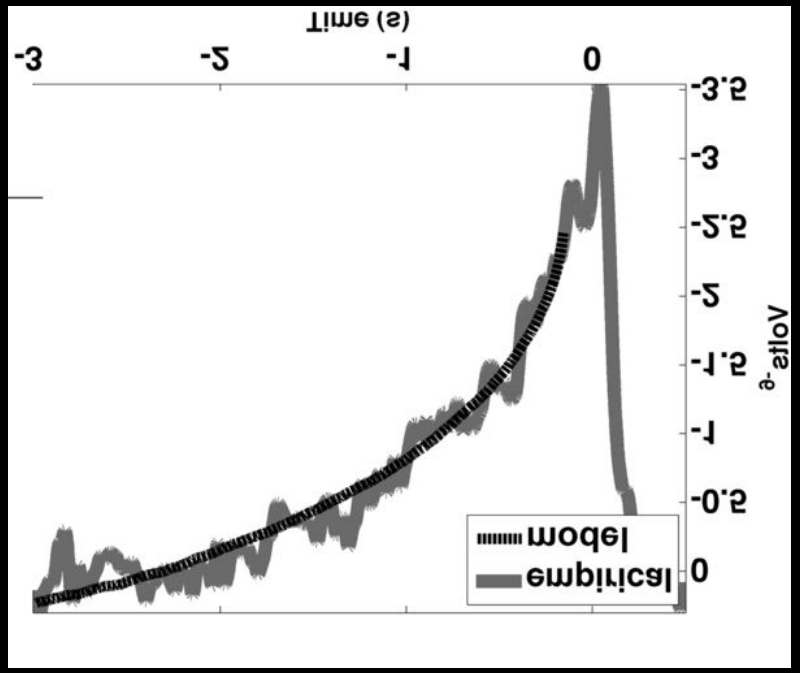
Is RP just averaged noise?

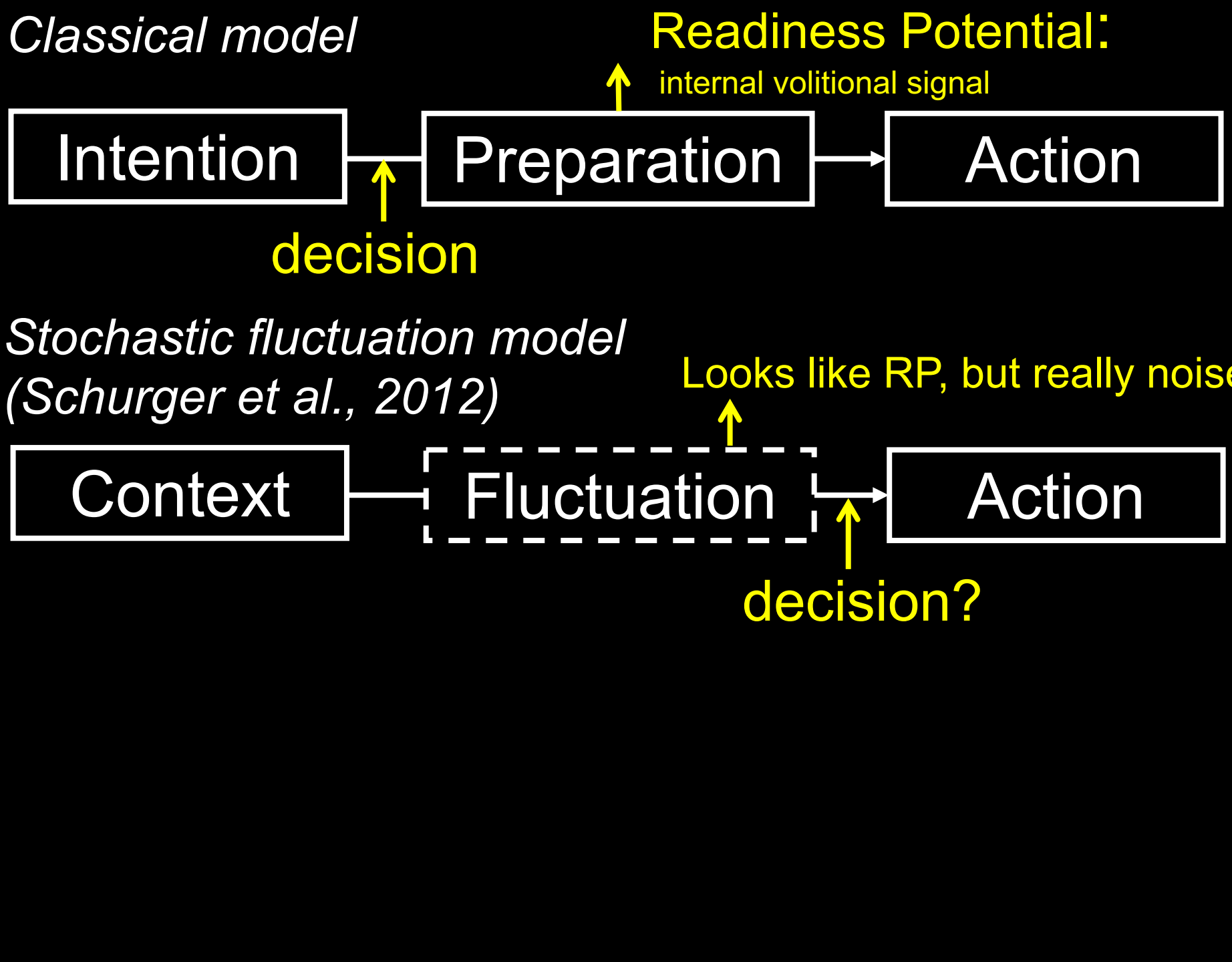


Schurger et al., PNAS 2014



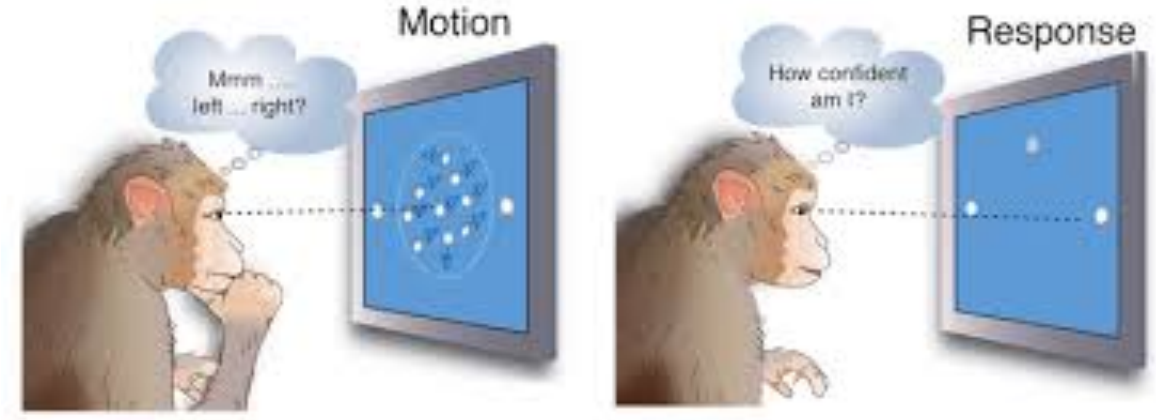
Leaky stochastic accumulator model

$$\delta x_i = (I - kx_i)\Delta t + \xi i\sqrt{\Delta t_i}$$

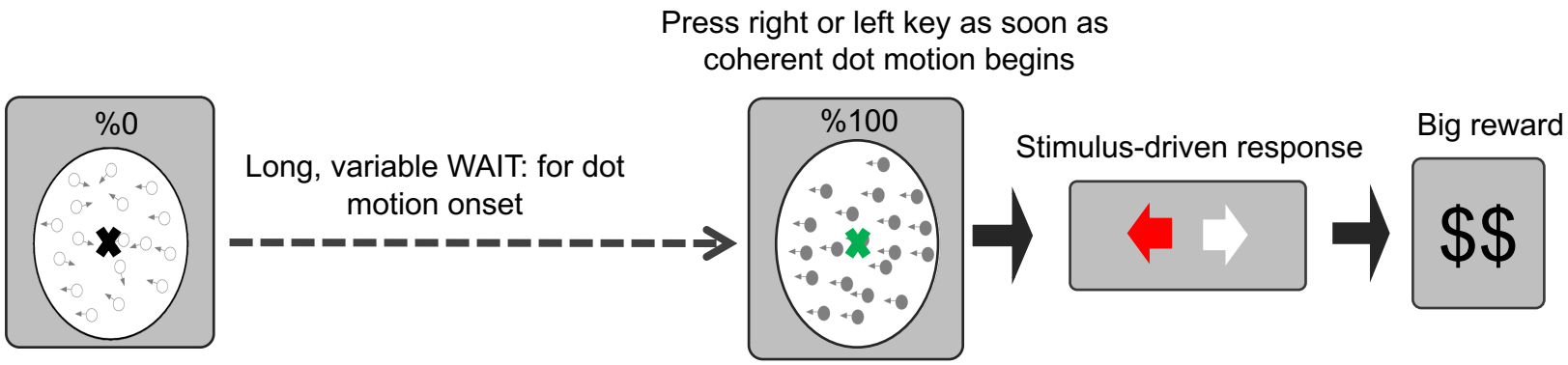

Classical model
Readiness Potential:
internal volitional signal
Intention
Preparation
Action
decision
Stochastic fluctuation model
(Schurger et al., 2012)
Looks like RP, but really noise
Context
Fluctuation
Action
decision?

Perceptual decision-making task

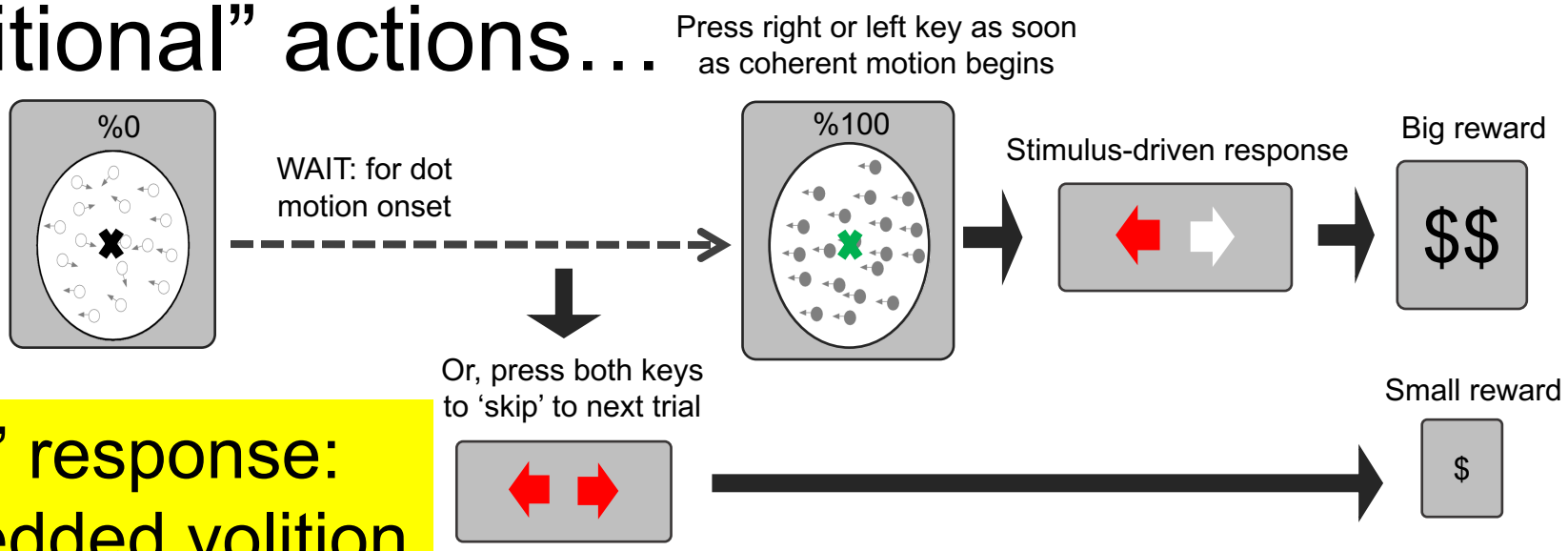
www.shadlenlab.columbia.edu



A



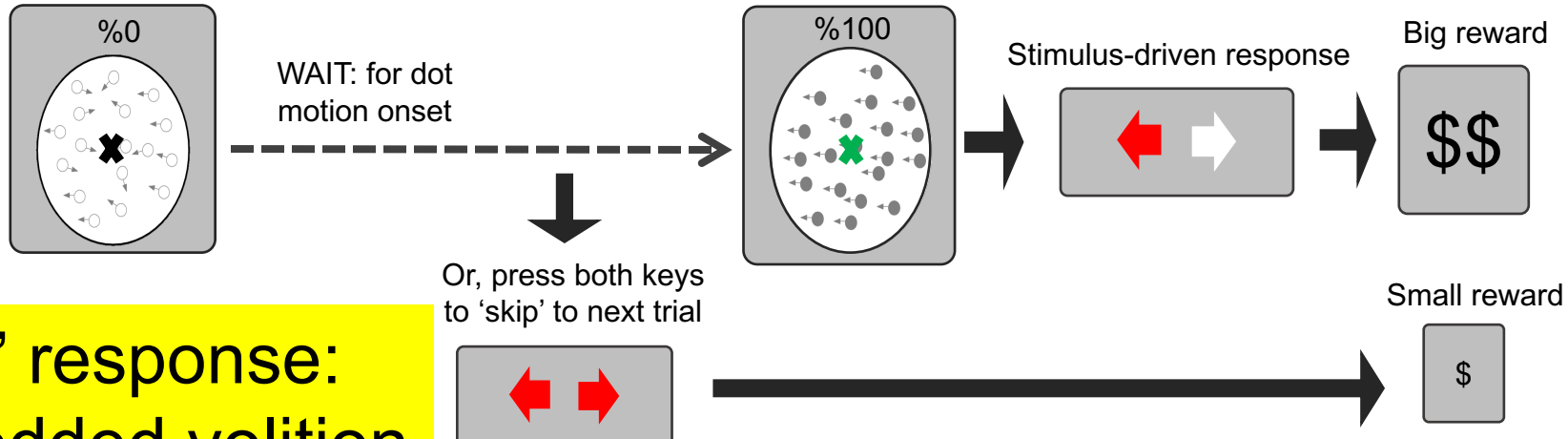
“Volitional” actions…



“Skip” response: Embedded volition

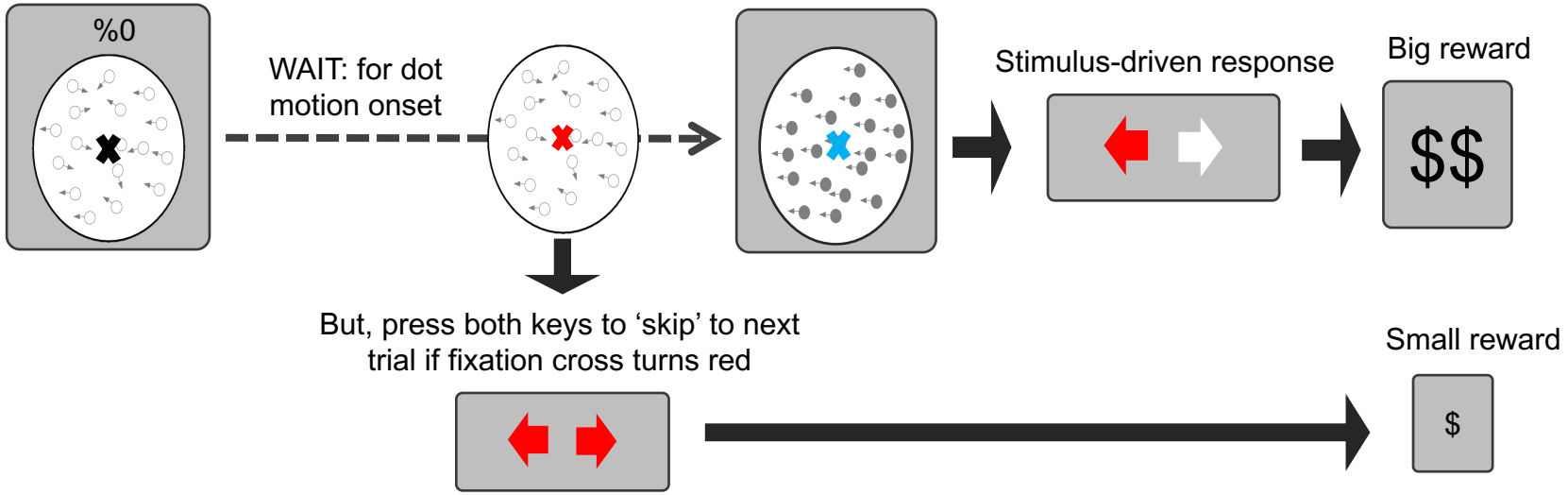
“Volitional” actions…

Press right or left key as soon as coherent motion begins

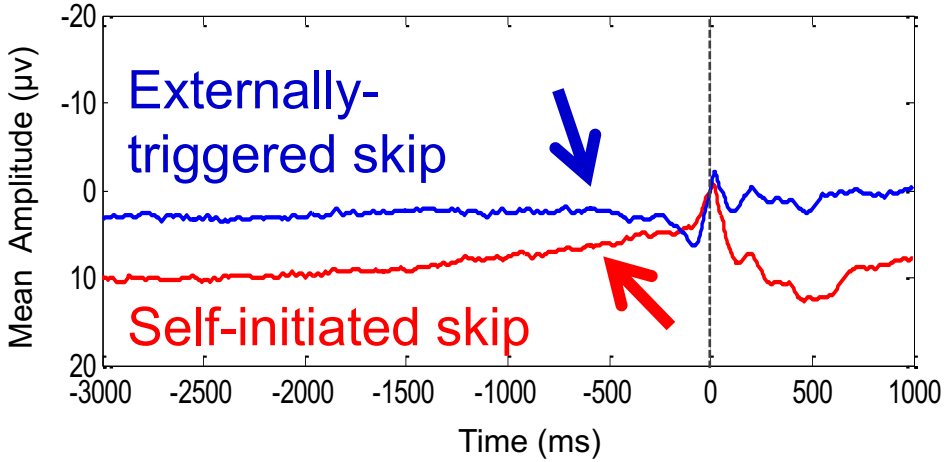


“Skip” response: Embedded volition

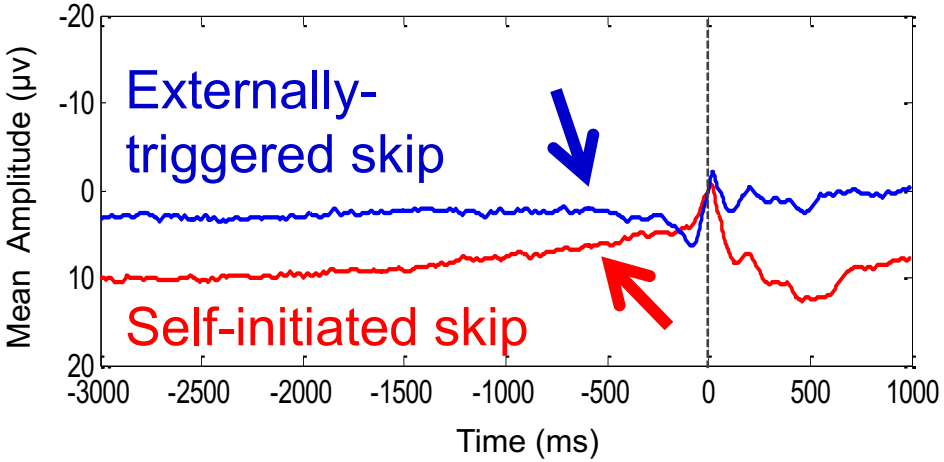
Control block: Instructed skip response



Fixation cross changes colour during the trial



No assumptions about RP onset time: baseline-corrected at time of action



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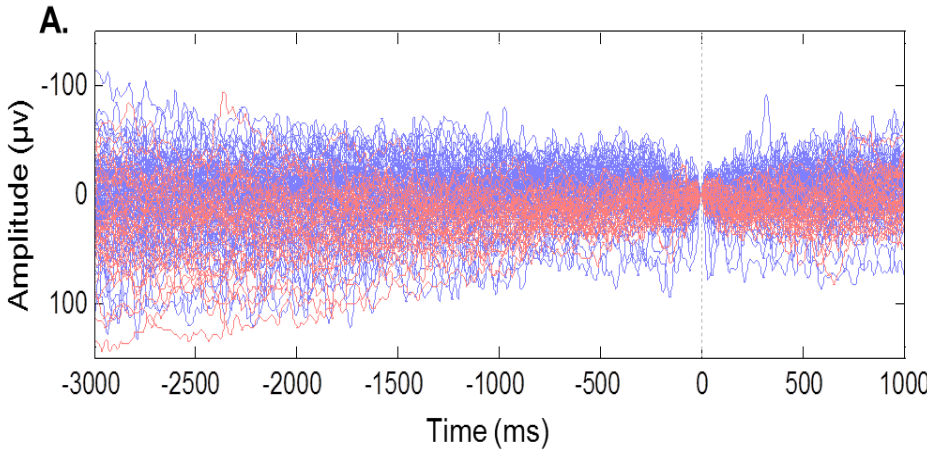
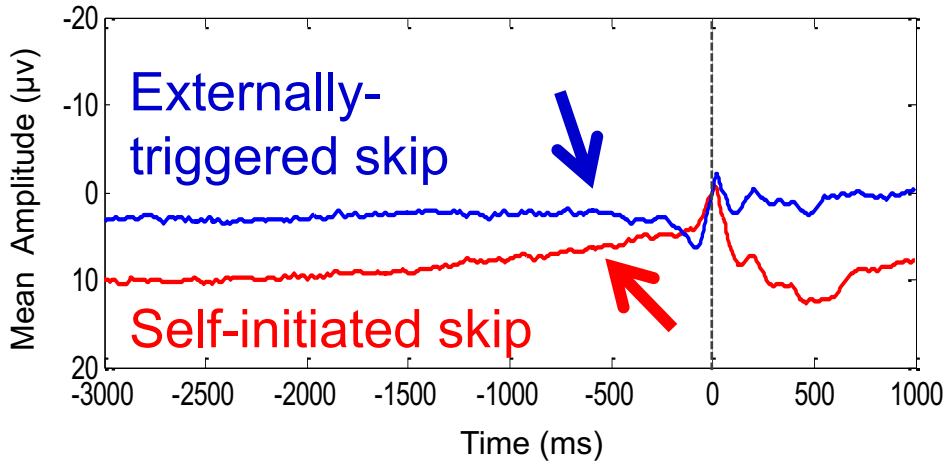


Individual-trial RPs



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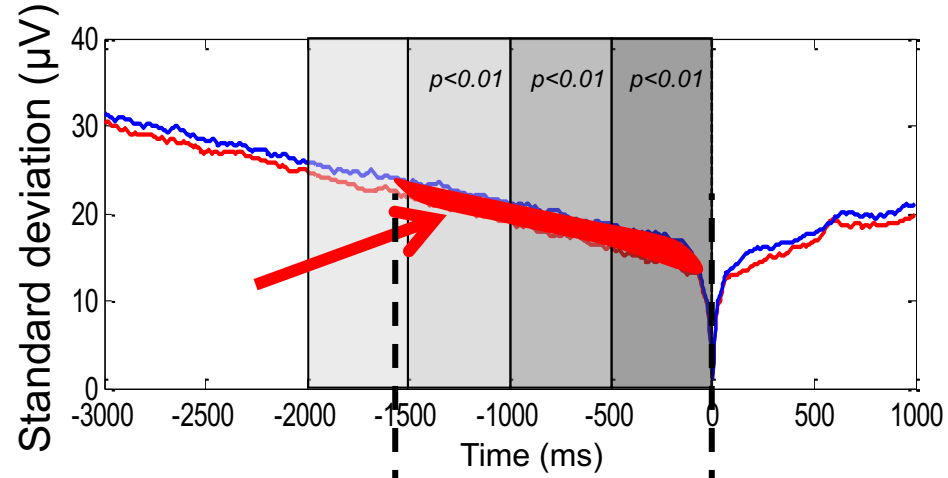
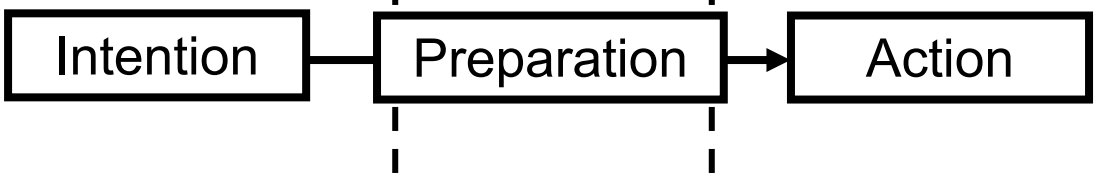
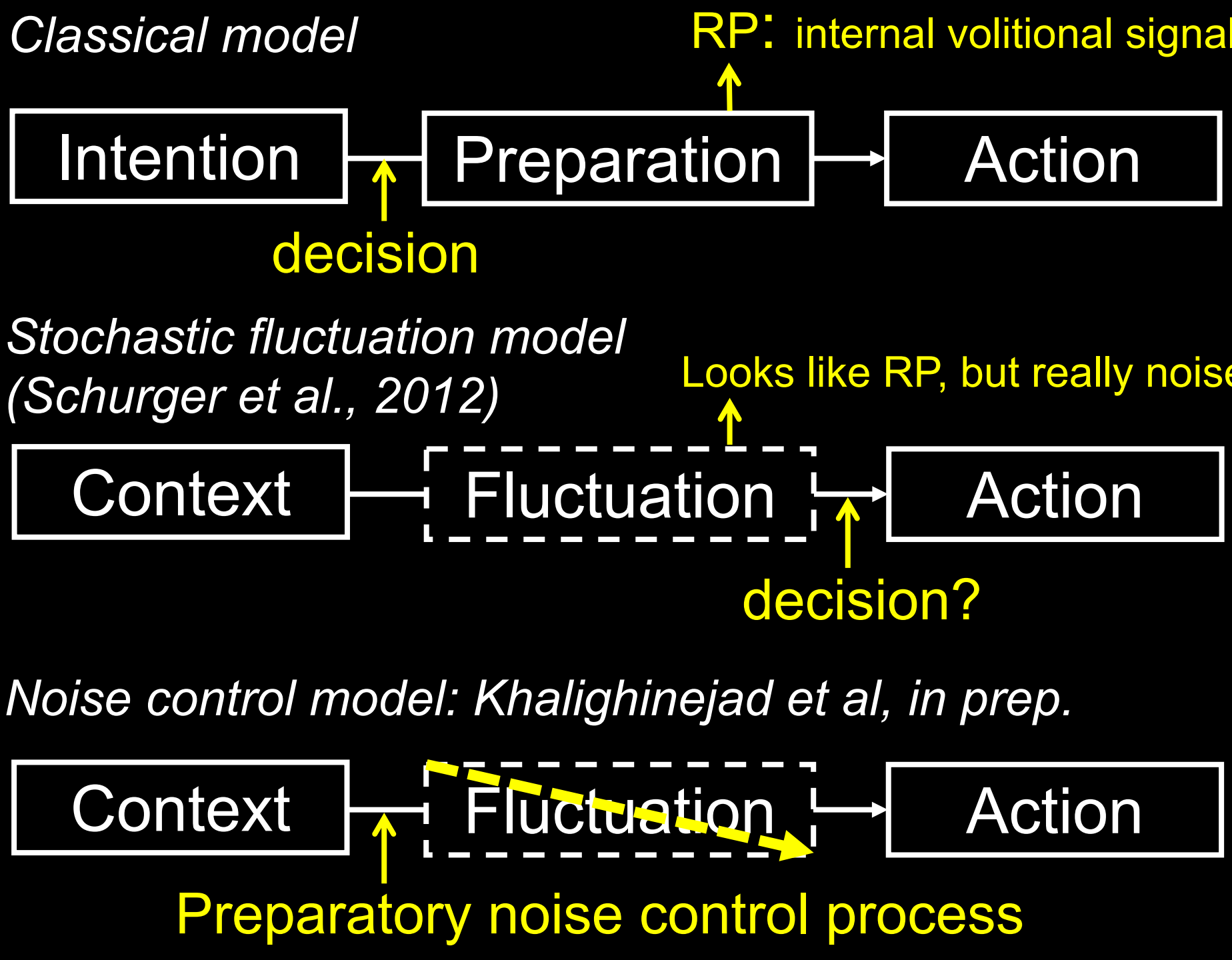


Standard deviation of individual trials:

- Self-initiated < externally-triggered
- Extra convergence for self-initiated

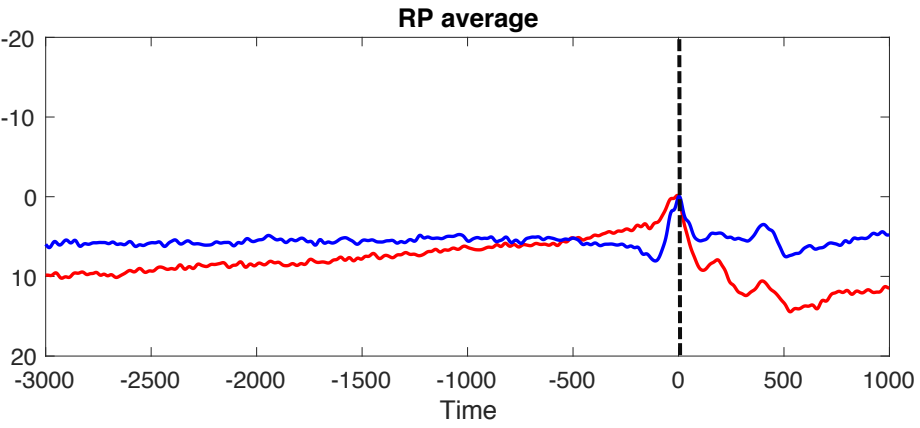


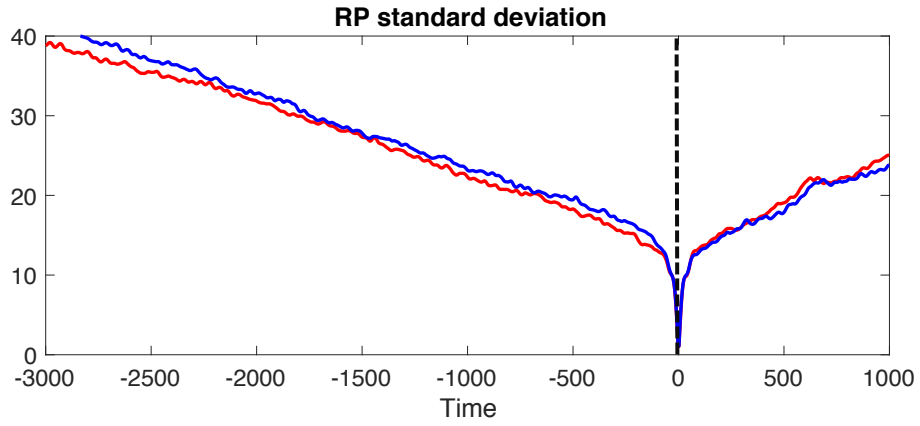
- Convergence on fixed precursor of voluntary action
- Putative internal volitional signal?


Classical model
RP: internal volitional signal
Intention
Preparation
Action
decision
Stochastic fluctuation model
(Schurger et al., 2012)
Looks like RP, but really noise
Context
Fluctuation
Action
decision?
Noise control model: Khalighinejad et al, in prep.
Context
Fluctuation
Action
Preparatory noise control process

Expt 2. Deliberation for volitional action

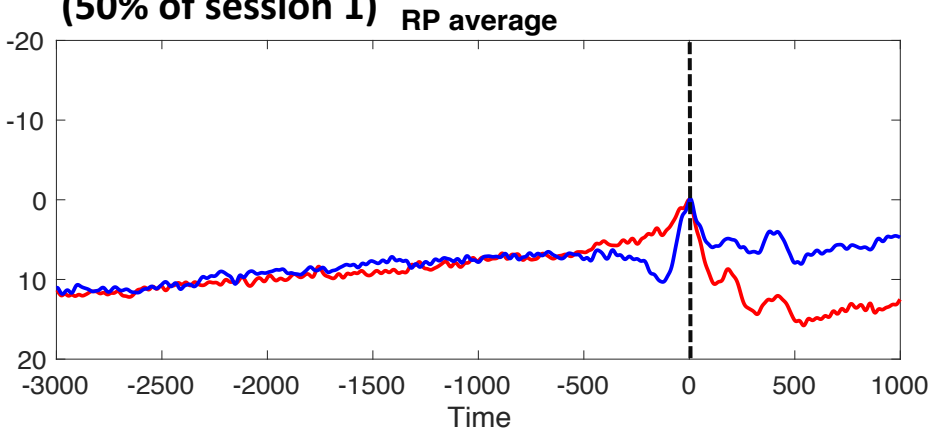
Session 1: Unlimited Skips

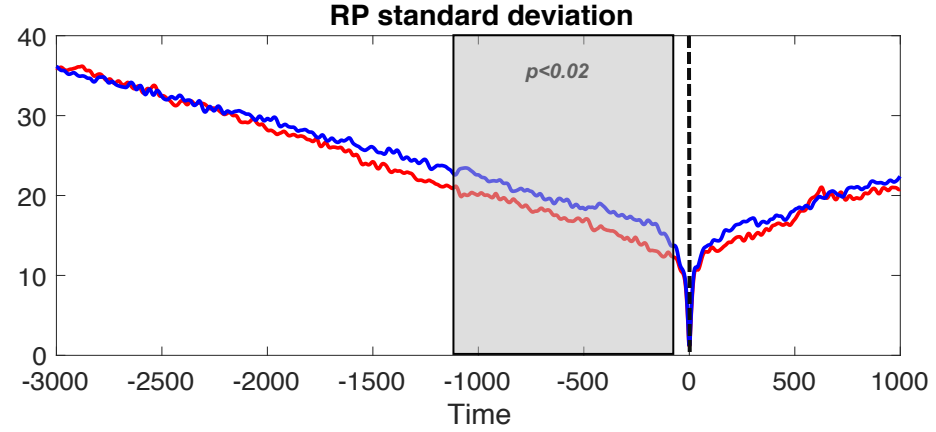




Session 2: Limited skips

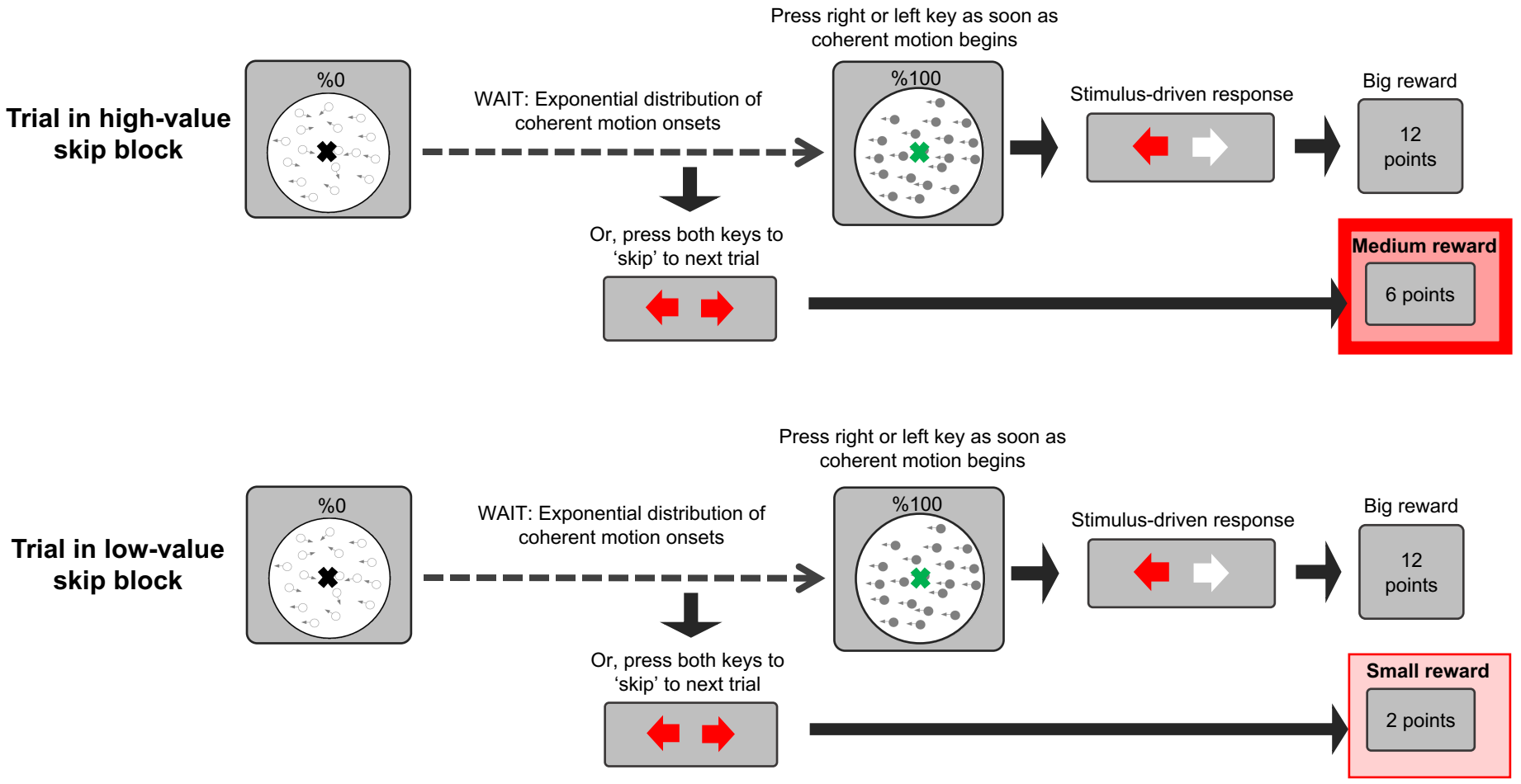
(50% of session 1)





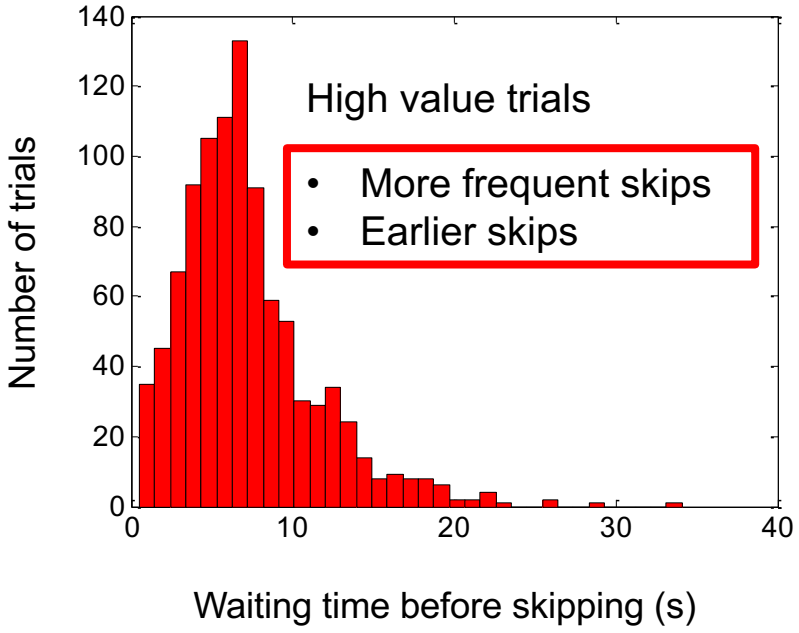
Less habitual,
more deliberately chosen

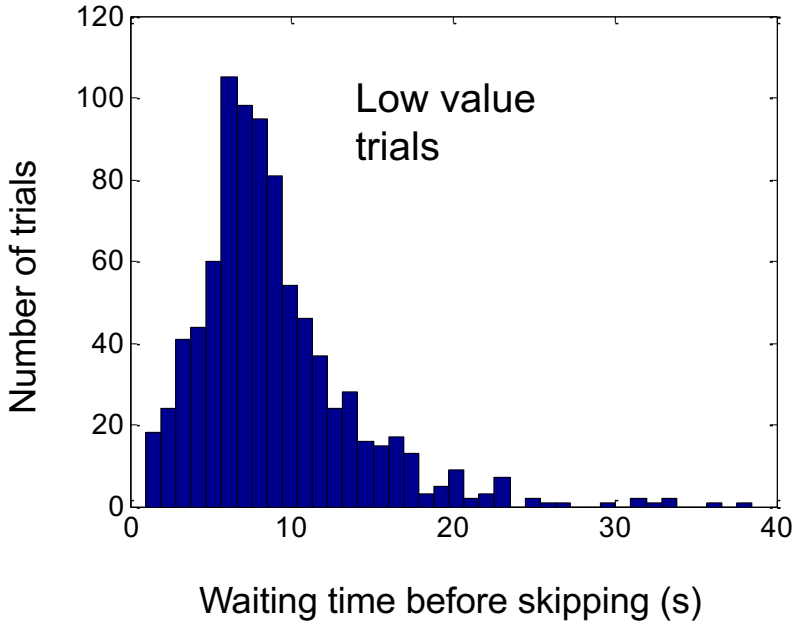
Expt 3. Varying the value of volitional action



Expt 3. Varying the value of volitional actions

Behavioural results





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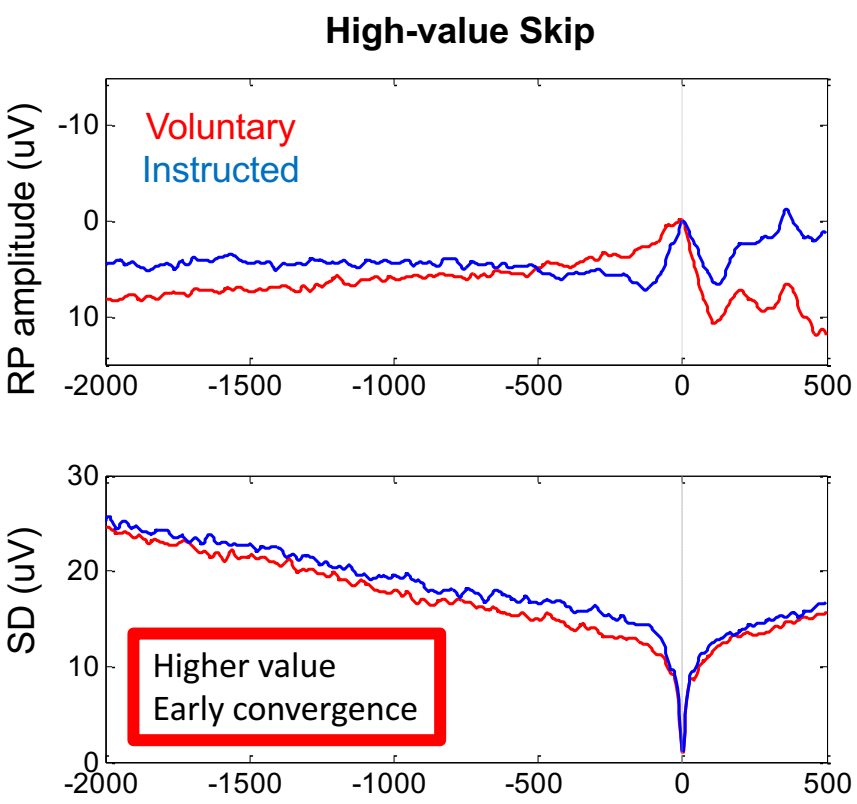
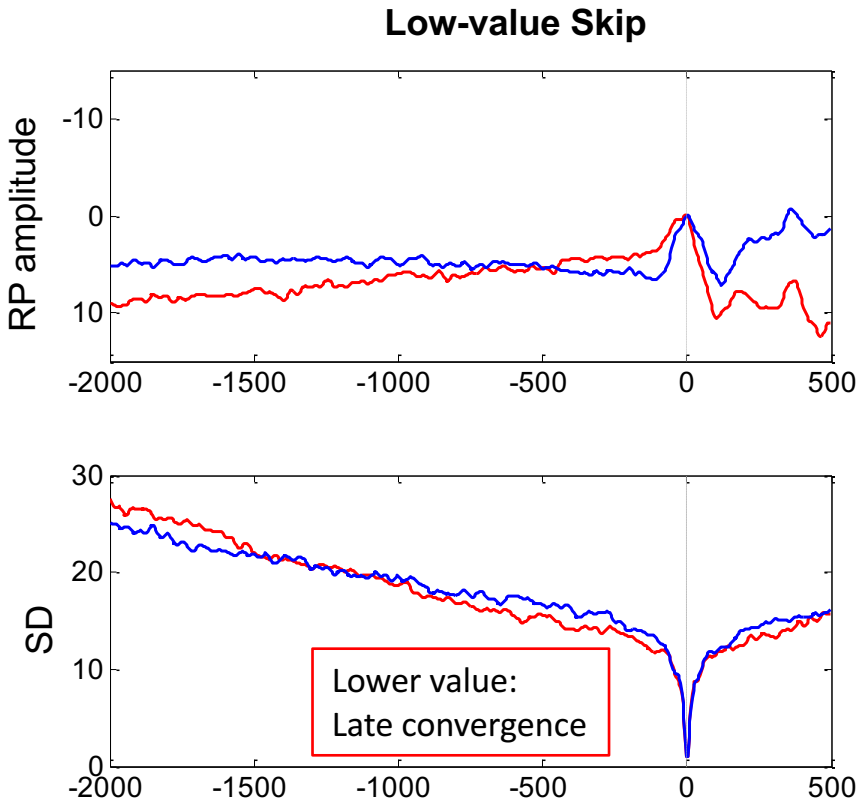
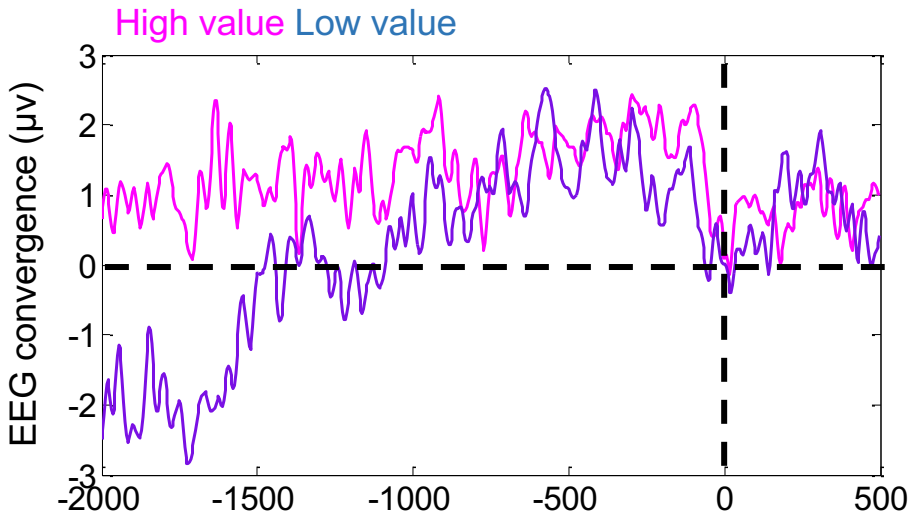


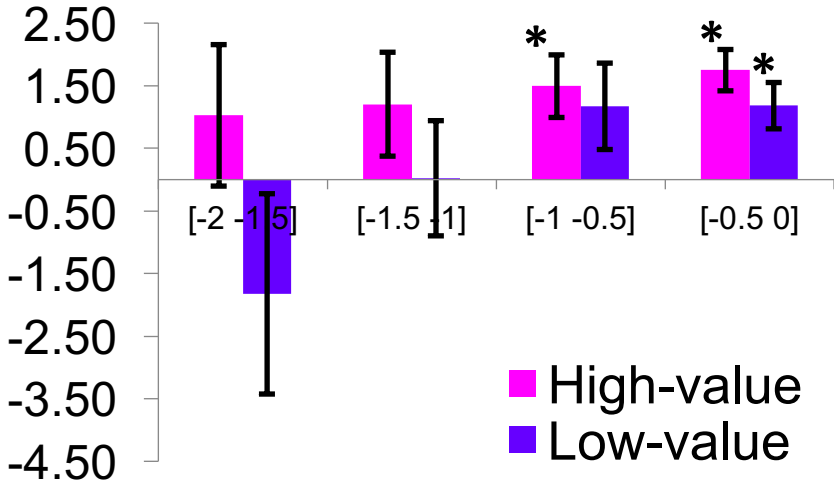
There is a significant different between high-value self-initiated and high-value externally-triggered skip actions



There is a significant different between low-value self-initiated and low-value externally-triggered skip actions

Expt 3. Varying the value of volitional actions





- Higher skip value produces earlier onset of EEG convergence (stronger preparation?)

One-sample, one-tailed t-test, correction for 8 comparisons
Cluster-based permutation test: significance for high value skips

Interim conclusions

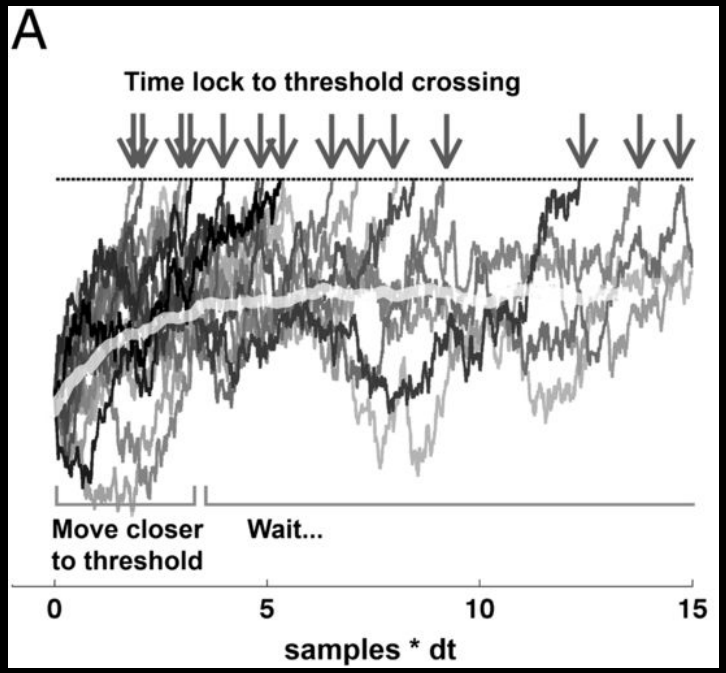
- New operational definition of volition and RP
  - Internally-generated *and* reasons-responsive

- Neural precursor:
  Consistent convergence of brain activity before volitional action

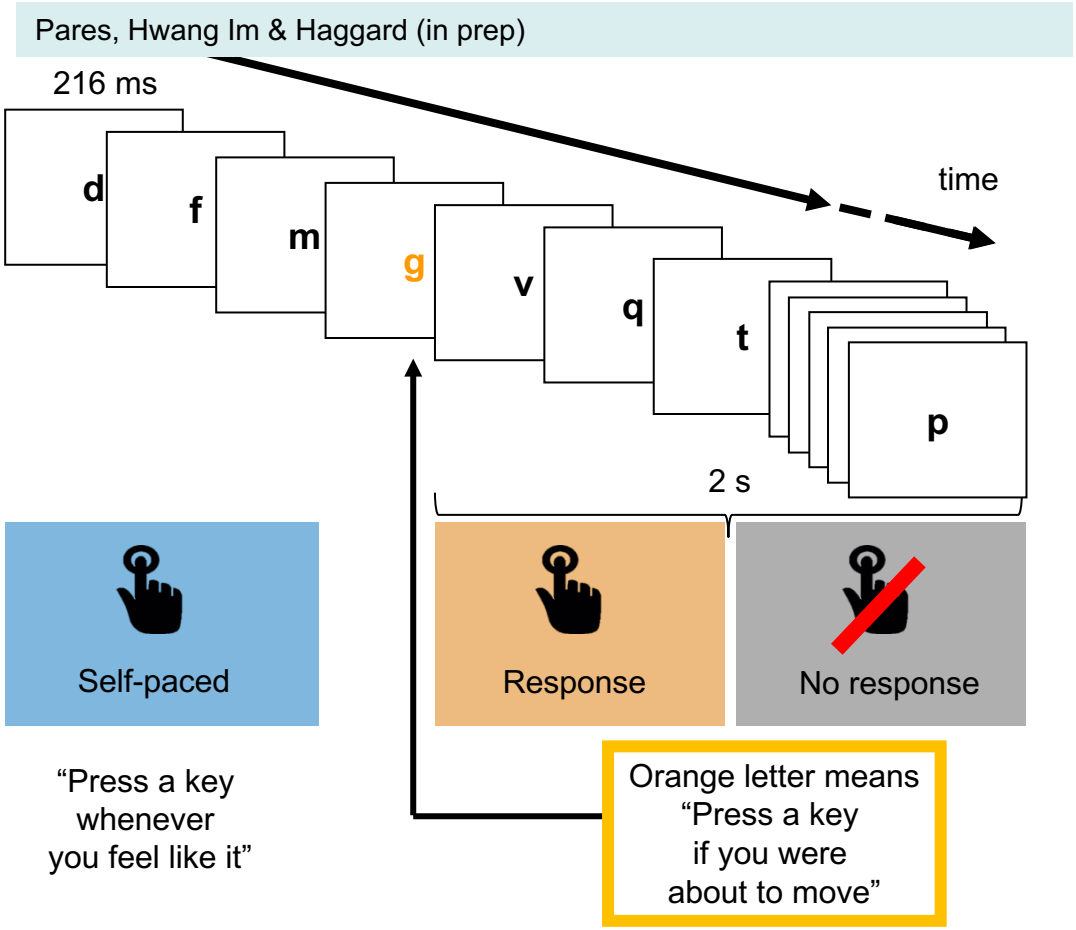
Roadmap

1. What brain events precede volitional action?

2. Are these events *uniquely* associated with the conscious intention to move?

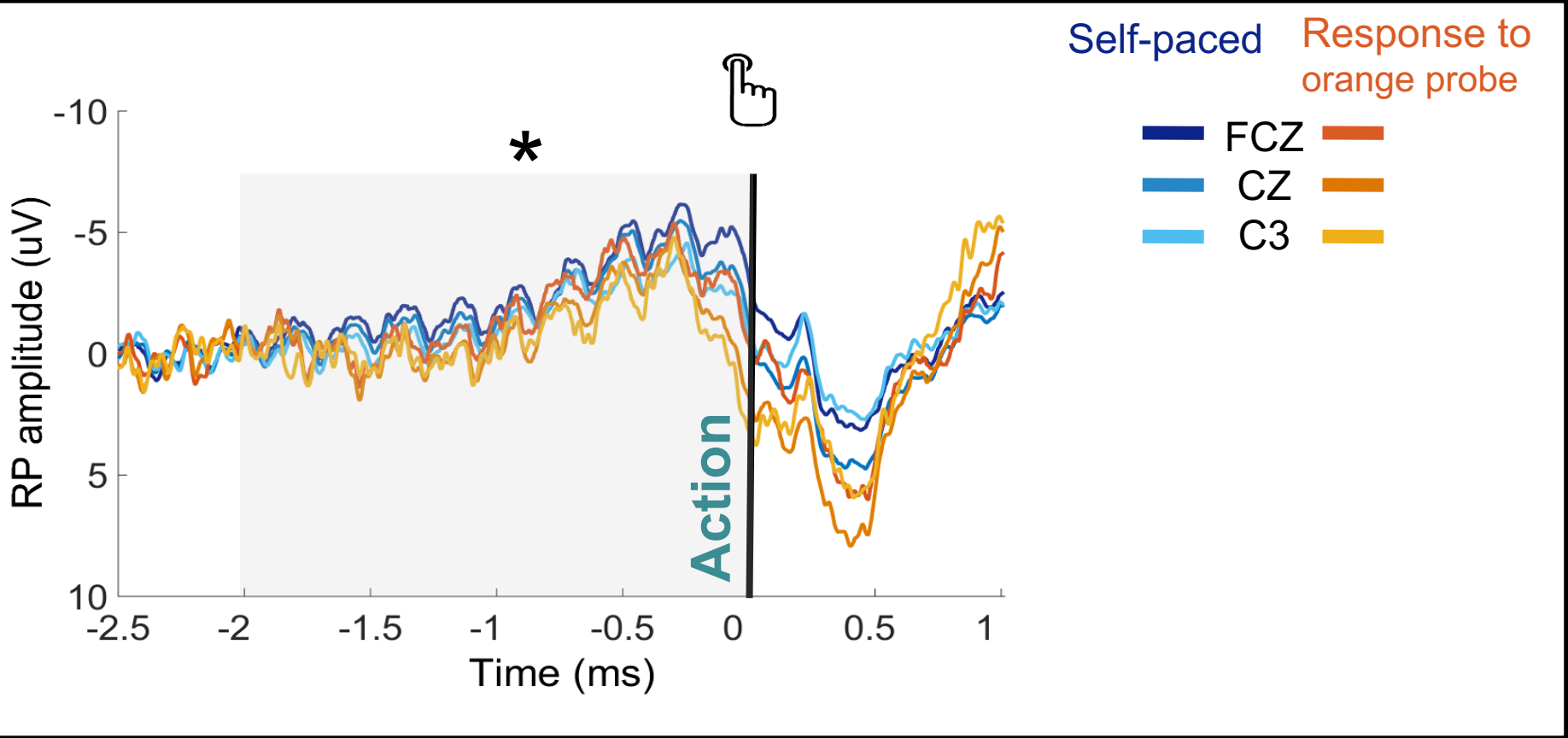


- RPs are based on biased sampling because we only show the brain activity time-locked to the action
- Are there “unconsummated” RPs happening all the time?
- In which case RPs cannot be a sufficient cause…



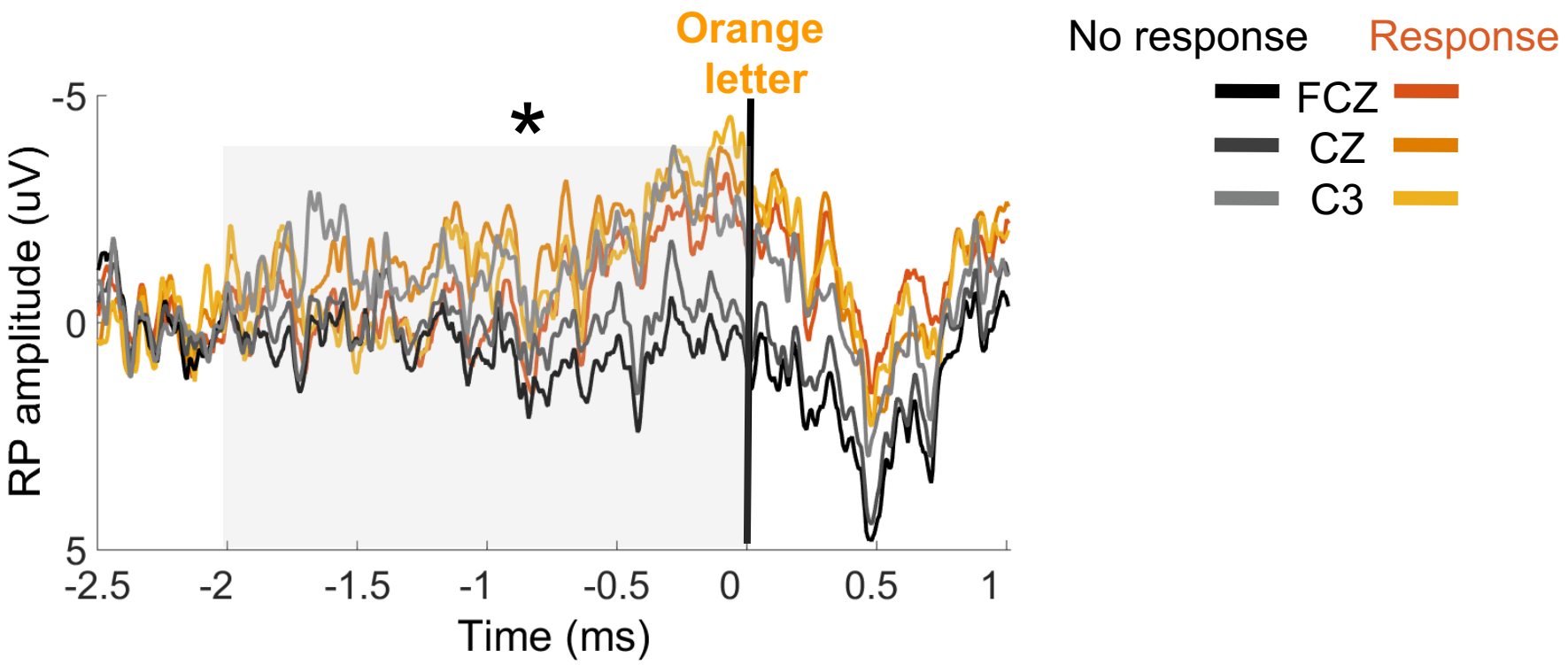
- Repetitive serial visual presentation
- Press the key when you feel like it (self-paced)
- "But if you see an orange letter *and* you were about to move, then move immediately, otherwise don't respond"
  cf Matsuhashi and Hallett, 2008

Action-locked analysis



- Some orange letters prompted early action, truncating the RP
- This interrupted a volitional premotor process partway through

Locked to (orange) probe letter



- Distinct and reportable experience of intention prior to spontaneous intention
- Dual thresholds for conscious intention: latent threshold & spontaneous threshold
- RP like signals are largely absent in the absence of an (at least latent) intention RP-like signals are specifically associated with experience of being about to move
- Latent awareness is associated with RP

Conclusions

- Consistent neural precursors of volitional action
- Are these precursors specific to volition? *Maybe*
- Conscious volition is not only retrospectively confabulated post hoc, but may involve real-time readout of neural precursors
- The will may not be free, but there is a *bona fide* neurocognitive process of volition, with some associated phenomenology

Precursors of voluntary action




Nima Khalighinejad Aaron Schurger Leor Zmigrod Andreas Desantis

+ Alex Dorgham, Emma Cawley, Elisa Brann http://biorxiv.org/content/early/2017/03/24/120105

Latent awareness

Elisabeth Pares

Haggard P (2017). Sense of agency in the human brain. *Nature Reviews Neuroscience*

Thank you