

# Uncovering the neural mechanisms of volition

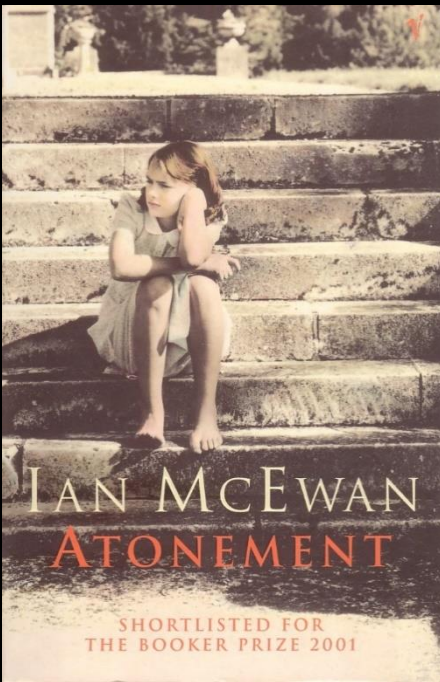
Patrick Haggard  
Institute of Cognitive Neuroscience  
University College London

Reimar Lüst Prize Fellowship 2022



Alexander von Humboldt  
Stiftung/Foundation





# Outline

---

1. Volition: an important but elusive mental state
2. Meaningful volition: planning goal-directed actions
3. Volition as generative consciousness

# Outline

---

1. **Volition: an important but elusive mental state**
2. Meaningful volition: planning goal-directed actions
3. Volition as generative consciousness

# Who cares? Societal importance of volition

---

- All human societies have a concept of responsibility
- Attribution of responsibility is based on a *cognitive* theory of volition: that conscious thought underpins choosing whether and how to act
- Therefore “*Mens rea*” (intentionality) must be established to prove guilt

# Agents are held responsible for voluntary actions, but not for involuntary movements

1. M’Naghten Rules  
“loss of control” defence  
insanity/automatism



*“a defect of reason, from disease of the mind, as not to know the nature and quality of the act he was doing”*

2. Coercion



Caspar et al., Curr. Biol. (2016)

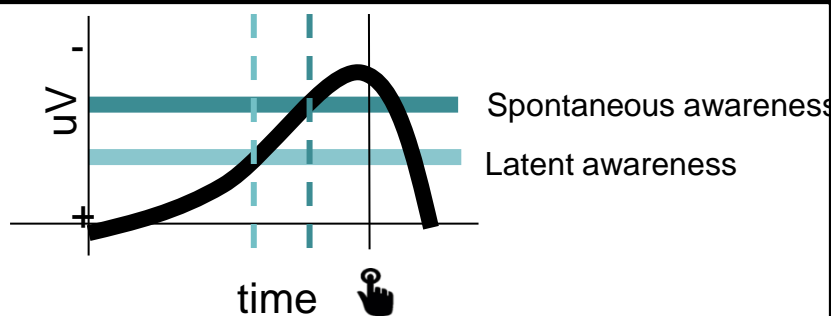
3. “Freezing” in sexual assault



Dhawan & Haggard, Nat. Hum. Behav. (2023)

# Volition vs. Agency

- Volition → generative problem
  - What causes voluntary actions?
  - When does consciousness occur?
- Agency → attributive problem
  - “Did I do that?”
  - Link voluntary actions to outcomes

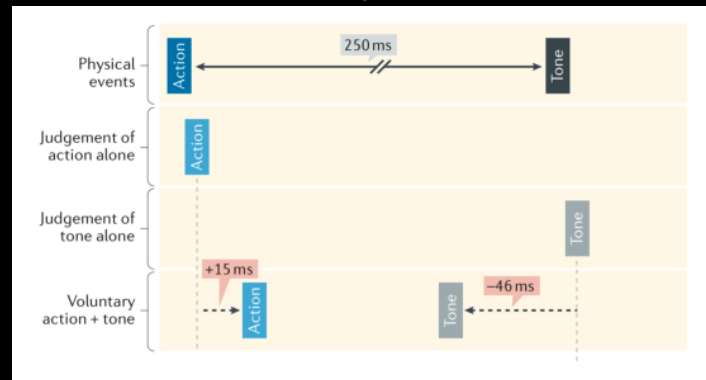


Two-threshold model of intention awareness.

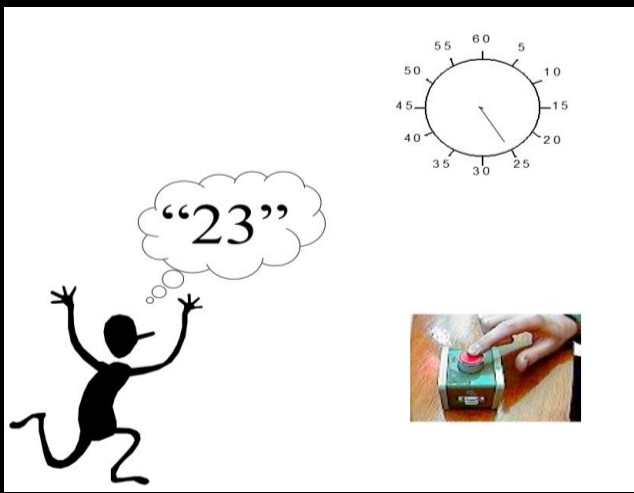
- Focus is *before* action onset

Libet et al., *Brain*, 1983

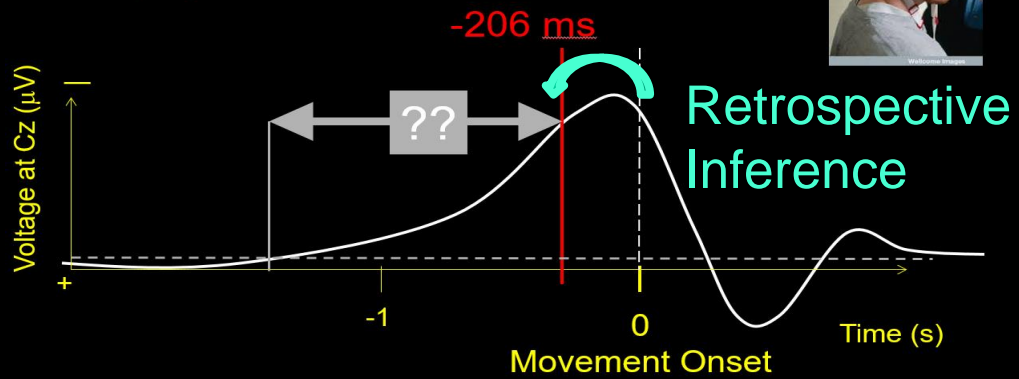
Matsushashi & Hallett, *EJN*, 2006



- “Intentional binding”
  - Focus is *after* action onset
- Haggard, *Nat Rev Neuro*, 2017



- Readiness potential: EEG signal preceding voluntary action
- **W judgement:** moment of conscious intention



## Critiques

- Experimental instructions are bizarre: “Be voluntary, now-ish!”
- Actions are meaningless and lacking context
- Biased sampling of brain and awareness, with low data rates
- Phenomenal experience of “urge to move” is weak and unclear
- Phenomenal experience could just be retrospective inference or confabulation, and unrelated to mechanisms of action generation
- “Free will illusionism”

Libet et al., 1983  
 Fried, Haggard, He, Schurger, J Neurosci 2017  
 Haggard, Ann. Rev. Psych. 2019  
 Frith & Haggard, TINS, 2019



# Volition as a cluster/network concept

<b>Volition: Key features (Explanandum)</b>	<b>Neuroanatomical constraint (Explanans)</b>
Leads to movement	Strong connections with motor areas
Involves consciousness	Prospective, pre-movement awareness
No external trigger	Weak connections with sensory areas
Innovative/spontaneous	Independence from “habitual” circuits
Reasons-responsive	Connections with valence/reward circuitry
Outcome/goal-directed	Connections with planning and monitoring circuitry

No single feature is necessary, but some subset(s) may be jointly sufficient for volition

# Volition as a cluster/network concept

<b>Volition: Key features (Explanandum)</b>	<b>Neuroanatomical constraint (Explanans)</b>	<b>Tower of London</b>	<b>Verbal Fluency</b>
Leads to movement	Strong connections with motor areas	✓	✓
Involves consciousness	Prospective, pre-movement awareness		✓
No external trigger	Weak connections with sensory areas	✓	✓
Innovative/spontaneous	Independence from “habitual” circuits		✓
Reasons-responsive	Connections with valence/reward circuitry	✓	
Outcome/goal-directed	Connections with planning and monitoring circuitry	✓	

No single feature is necessary, but some subset(s) may be jointly sufficient for volition

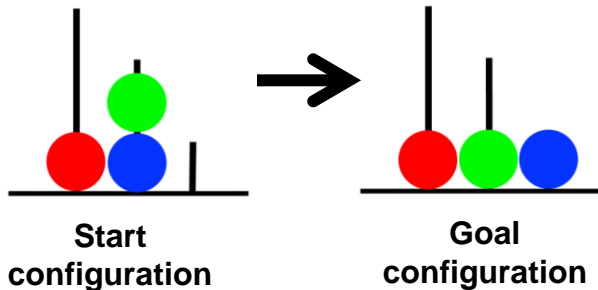
# Outline

---

1. Background: definitions and importance
2. **Meaningful volition: goal-directed actions**
3. Volition as generative consciousness
4. Understanding the sense of agency

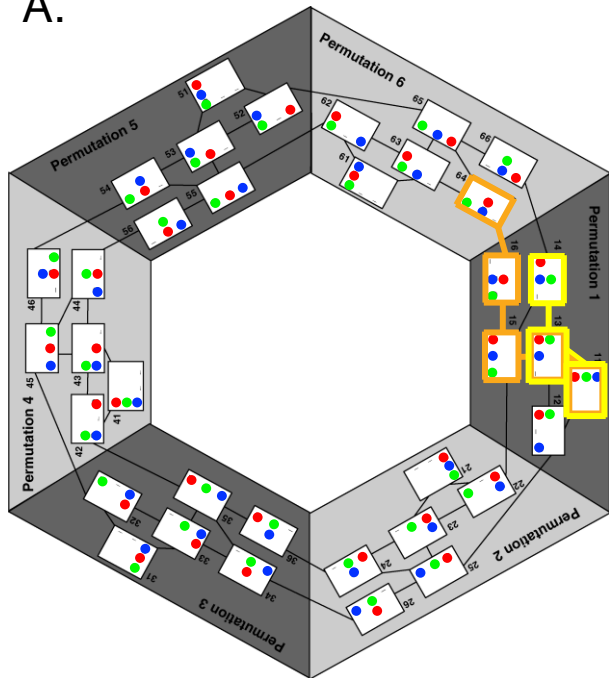
## Voluntary actions for goal-directed problem-solving

### Tower of London (ToL) task Shallice (1982)

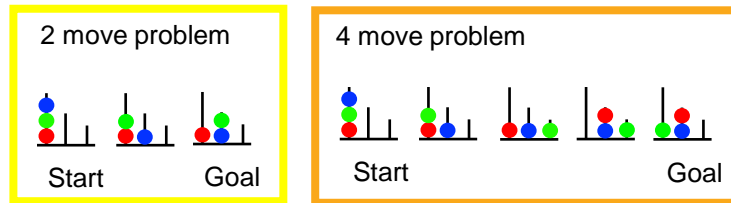


- Choose and execute actions to transform the Tower into the goal configuration
- Actions are internally-generated, and self-paced
- Actions are goal-directed and reasons-responsive
- Actions involve complex means-ends structures
- Some problems allow many equivalent means of solution
- Key cognitive elements of volition are present

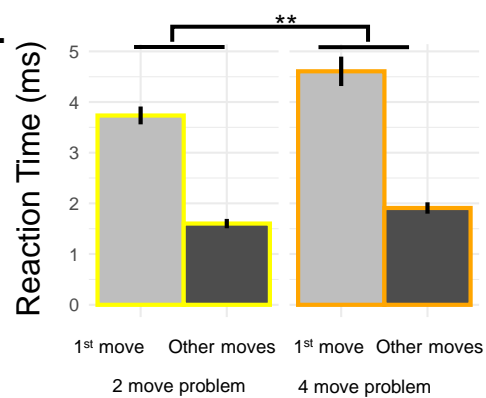
A.



B.

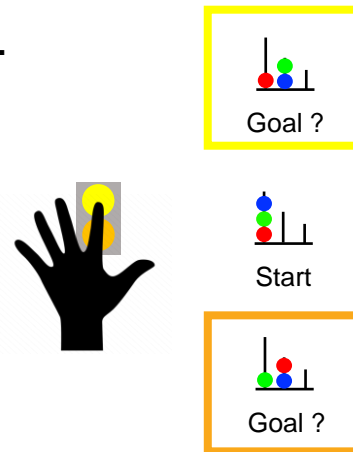


C.



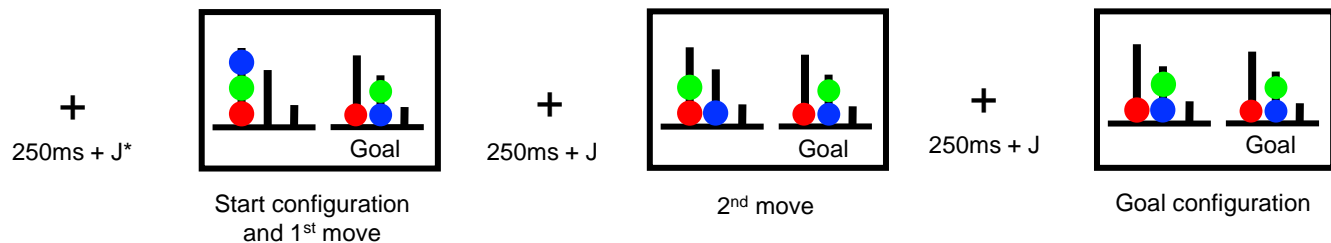
Sequence length

D.

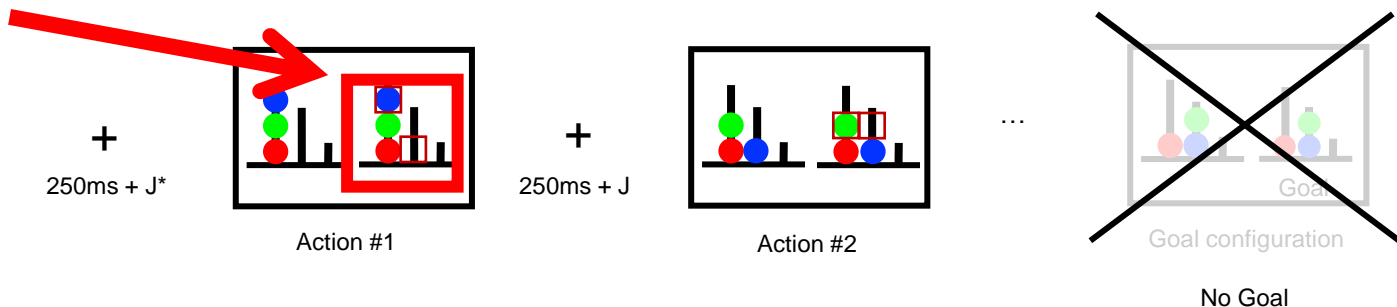


# fMRI design: Goal-directed self-generated actions vs. series of instructed movements

## Goal-directed self-generated actions

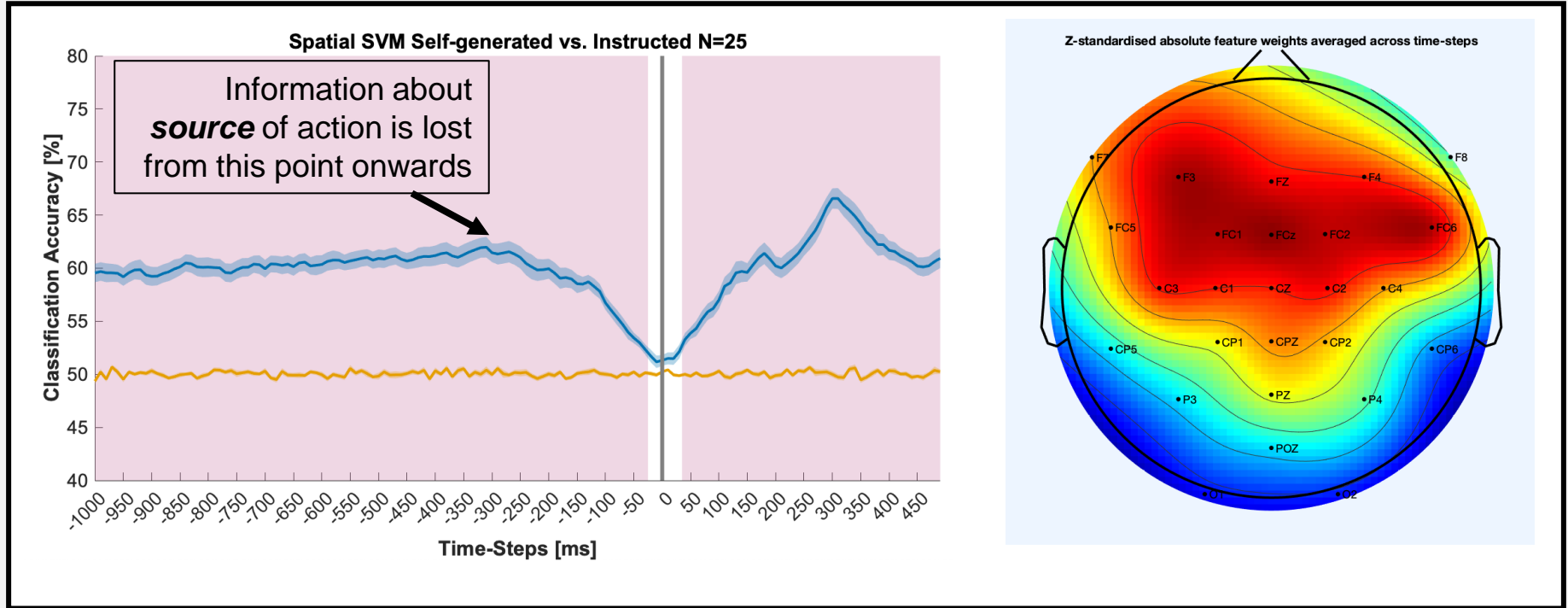


## Control condition: series of instructed movements



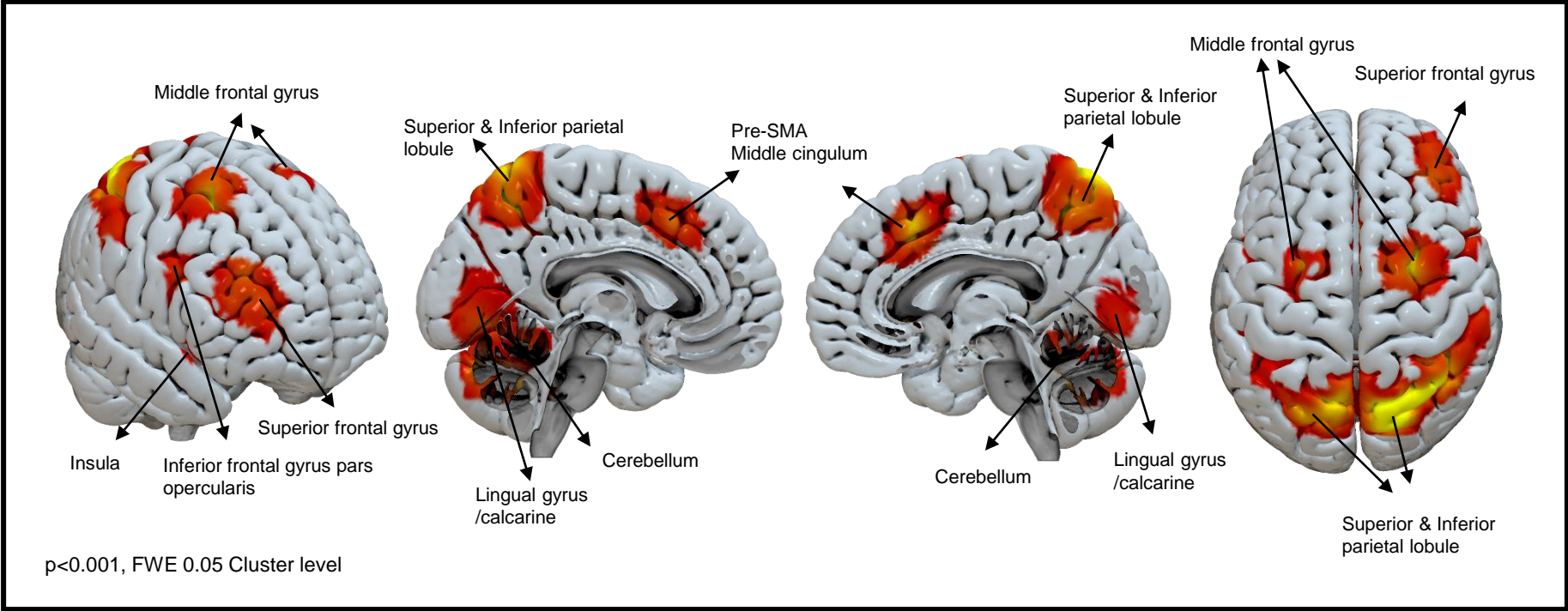
## EEG of Enriched volition:

## SVM Classification: endogeneity of goal-directed action involves medial frontal cortex



- Data-driven search for neural correlates of endogenous goal-directed action
- No a priori definition of “Readiness Potential”

# fMRI Results: Self-generated sequential actions > series of instructed movements

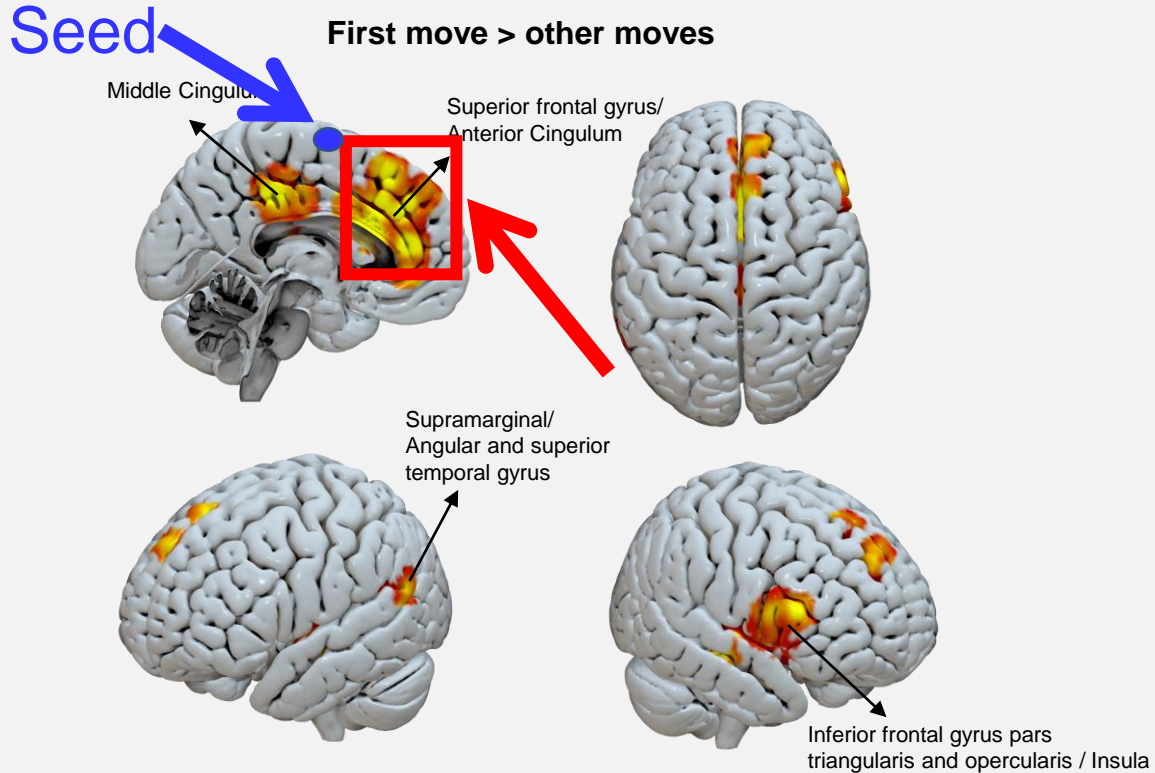




# fMRI Results: Pre-SMA-seeded



# Functional connectivity (gPPI)



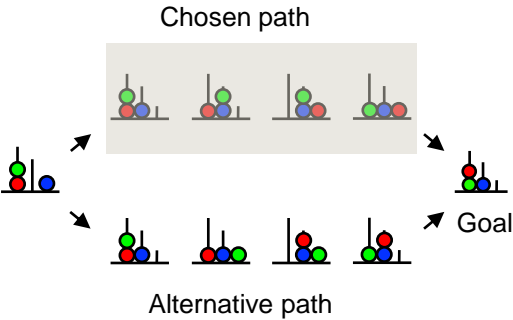
“Enriched volition” connects MFC to a wider prefrontal goal/planning network

# Means-ends structure and conscious access to unchosen alternative actions

Some ToL problems have two alternative optimal solutions

Does the agent represent the unchosen alternative path?

Does this representation remain accessible to consciousness?



Immediate recognition memory test:

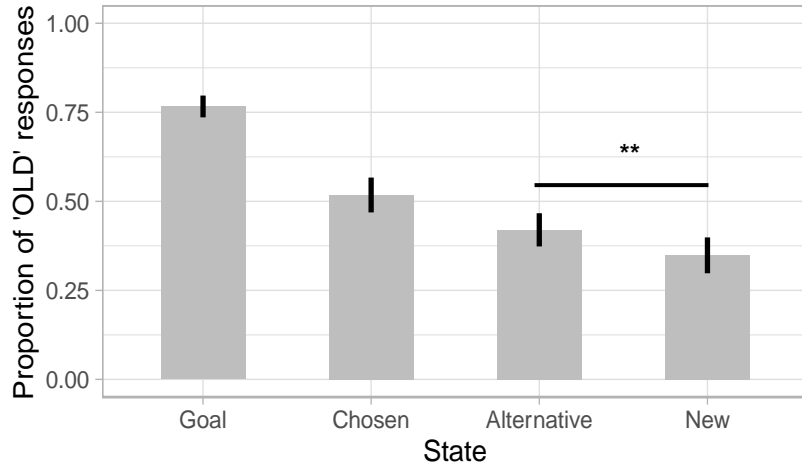
Did you see this state during the problem just completed?

Responses: "Yes, I saw it" (OLD) "No, I didn't see it" (NEW)

Stimulus Classes



## Memory recognition test after each ToL trial



**Logistic regression: proportion of “OLD” responses**

**Higher proportion of memory false positives for unchosen alternative paths compared to other new configurations that are visually-matched**

**Unchosen actions are mentally represented and available to consciousness**

**Deliberate → Choose → Plan → Act**

# Outline

---

1. Volition: an important but elusive mental state
2. Meaningful volition: planning goal-directed actions
3. Volition as generative consciousness

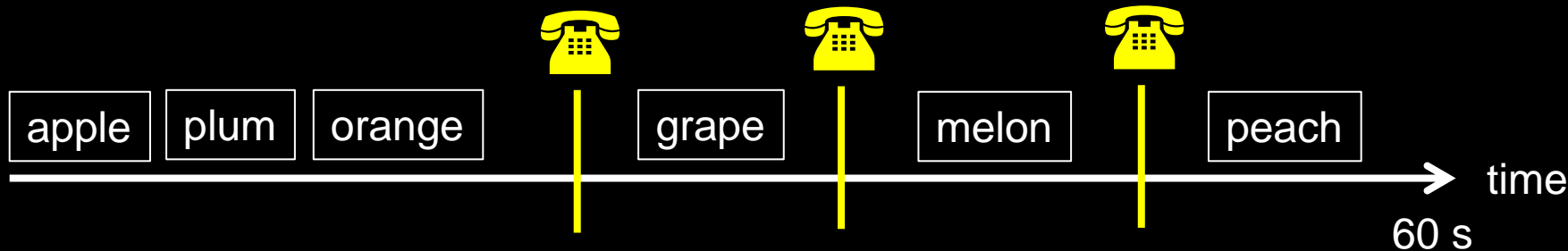
# Verbal Fluency

Example instruction: Type the names of as many different fruits as you can in 60 s



- Effortful process of searching verbal LTM
- High rate of generating voluntary actions
- Distinctive subjective experience of finding the next word

# Verbal Fluency



Randomly-timed probe sounds interrupt the process of action generation

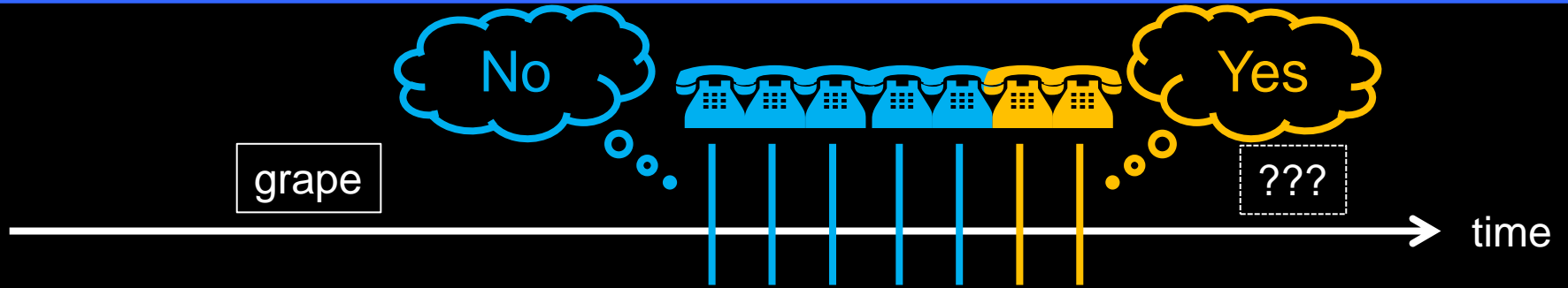
Probe question: “Did you know what word you were going to type next?”

Answer: “No”, or “Yes”

Follow-up if yes: “OK, please tell us what word you were about to type”

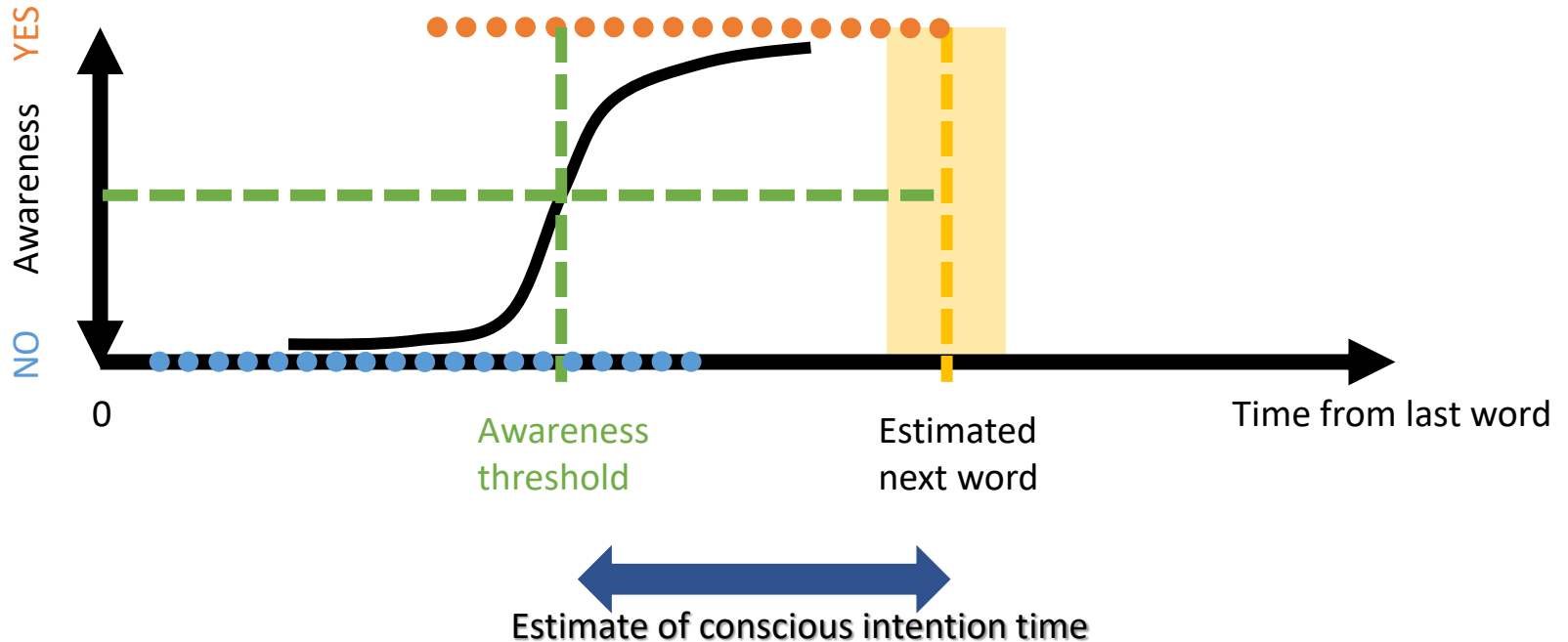
Trial continues until 60 s of generation completed... (approx. 10-30 words, 2-8 probes)

# Verbal Fluency



- Participants should be more likely to report awareness of the forthcoming action when the probe occurred closer to the estimated onset of the next action
- This method can be used to estimate the time of **prospective** awareness of intention to act, avoiding the bias and retrospectivity of some other methods

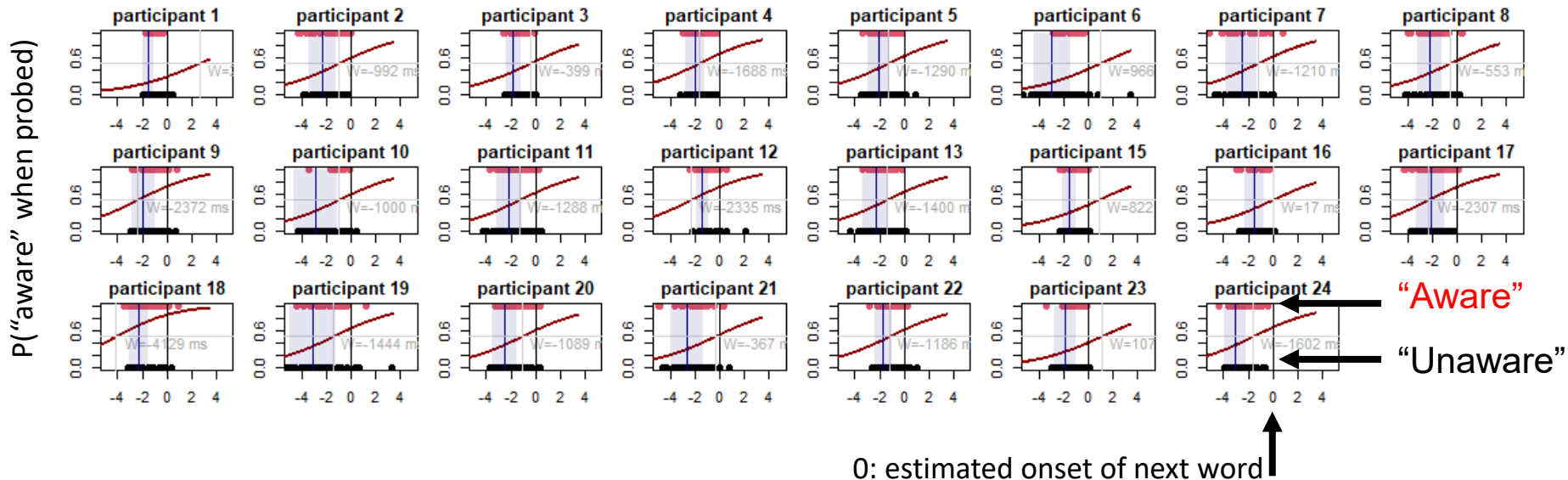
# Predictions from theories of prospective awareness of intention





# Results (n=23)

End of preceding word (mean/SD)  
 Awareness threshold



W' time (mean/sd): -916 ms (1402 ms)

Cf. Libet (1983): -206 ms

Matsuhashi & Hallett: -1800 ms

# Conclusions

---

- The brain generates voluntary actions, based on goals
- Volition involves a distinctive subjective experience
- This experience is not merely an illusion, but arises from specific brain networks centred on medial frontal cortex
- Experience of volition may include both prospective and retrospective influences
- Volition is a neurocognitive state with high societal importance, since it is essential for social/moral responsibility



Silvia Seghezzi



Zheng Huang



Stefan Bode

Earlier agency work: James Moore, Michiko Yoshie, Emily Caspar

Earlier funding: Experimental Psychology Society, John Templeton Foundationm, European Research Council

# Future perspectives

- Scientific study of volition needs richer experimental models
  - The main problem is that we cannot manipulate the input: it's up to you!
  - Need to capture high generativity and means-ends structure
- Middle ways may exist between “free will illusionism” and ghost-in-the-machine dualism
- High societal value, and strong relevance for neuropsychiatry



Silvia Seghezzi



Zheng Huang



Stefan Bode

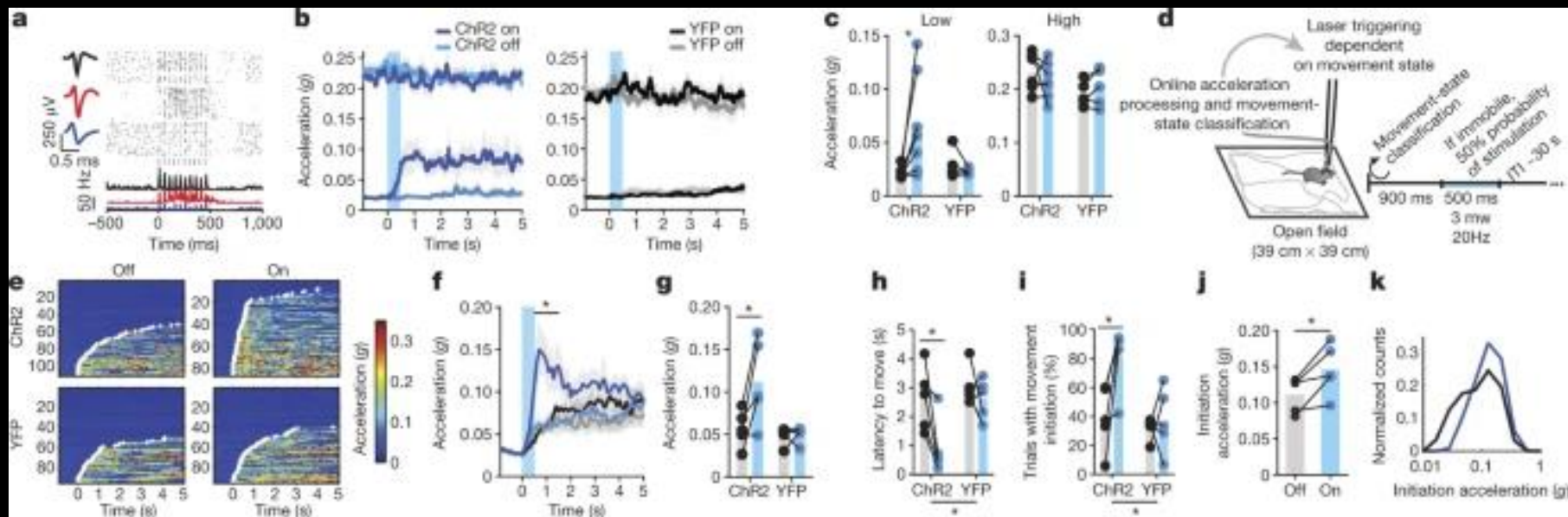
Funding: Experimental Psychology Society, John Templeton Foundation  
Alexander von Humboldt Foundation

Thanks for your attention

# Motor Vigour

# Motor Equifinality

# Intentional Binding

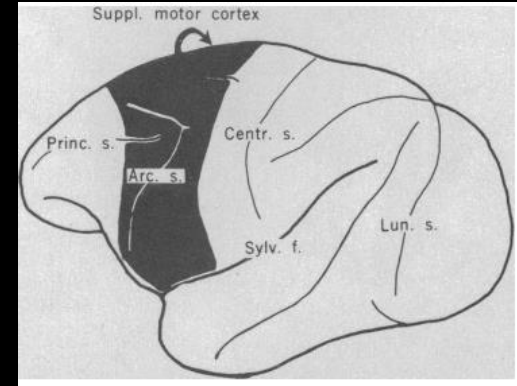
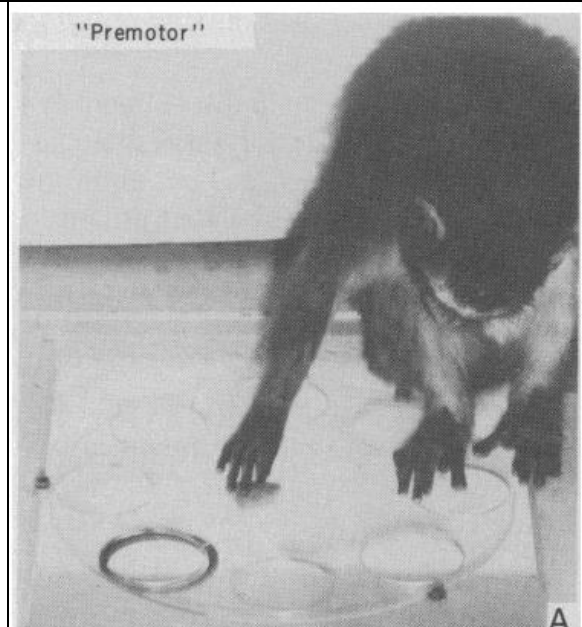
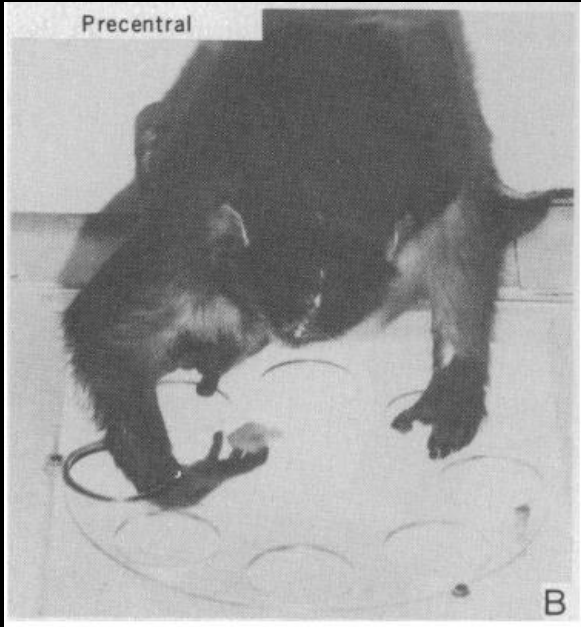


SNC Phasic dopaminergic neurons  
<https://doi.org/10.1038/nature25457>

# Motor Vigour

# Motor Equifinality

# Intentional Binding



these frontal areas. The present report demonstrates that in keeping with this expectation, ablation of these frontal areas impairs the capacity of the animals to reach around an obstacle with the contralateral arm in order to obtain a visible food reward, and results in a tendency of this arm to reach straight to where the food is visible.

Detour Reaching: Many ways to achieve the goal. Key computation of frontal/prefrontal cortex

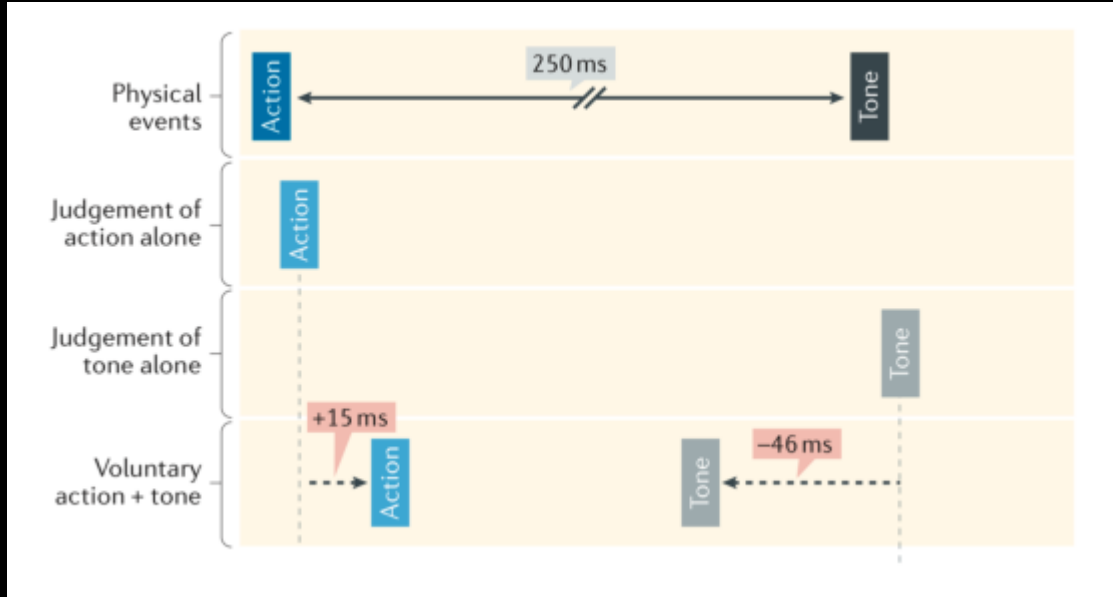
<https://doi.org/10.1126/science.410103>



# Motor Vigour

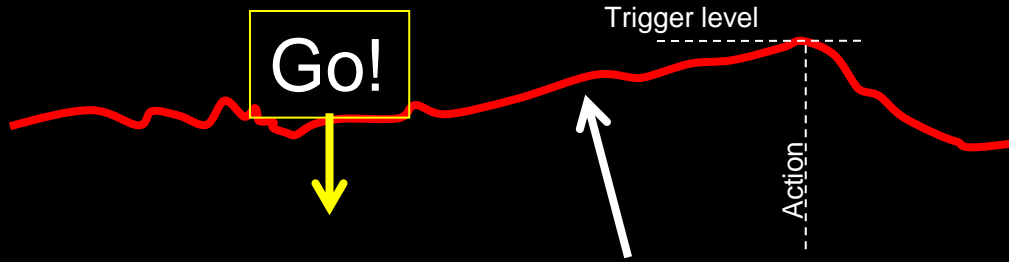
# Motor Equifinality

# Intentional Binding



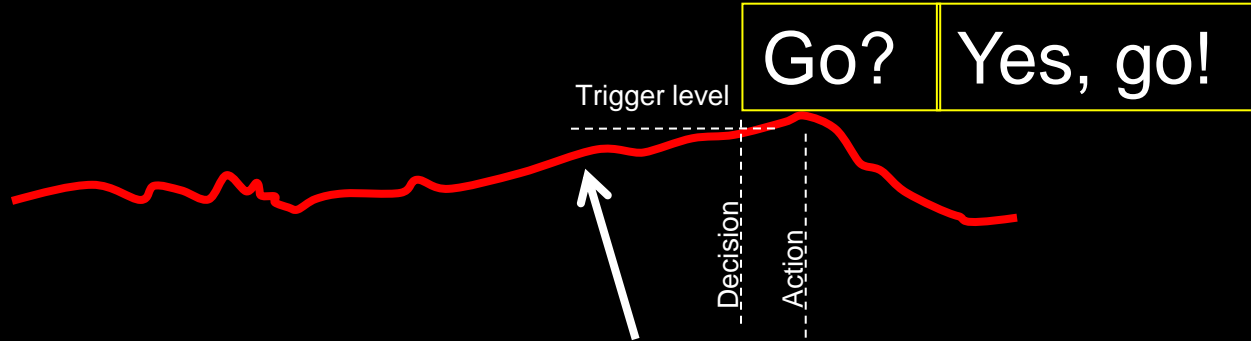
The capacity to link voluntary actions to arbitrary outcomes underpins sense of agency  
Sense of agency potentially creates a transformative individual power to change the world  
<https://doi.org/10.1038/nrn.2017.14>

# Early decision model: conscious decision triggers RP



RP-like signal: cause of action

# Late decision model: consciousness has no role or veto role



Averaged noise, not a signal

