Cordula Vesper
BSc in Cognitive Science
Fall 2022

Mouse-tracking

Freeman, J. B. (2018). Doing Psychological Science by Hand. *Current Directions in Psychological Science, 27* (5), 315–323. https://doi.org/10.1177/0963721417746793

Today's topics

- Constraints of RTs
- Cognition as continuous
- Experimental logic of tracking decisions with mouse-movements
- Neural basis
- Introduction to OpenSesame and the Mousetrap R package

Looking back: Part I

Part	Week	Date	Topic
I	35	1.9.	Chapter 1: Why perception and action?
		2.9.	Getting to know each other, group discussions, and practical exercises
	36	8.9.	Chapter 2: Principles of multisensory integration
		9.9.	Crossmodal data, group discussions
	37	15.9.	Chapter 3: Experimental psychophysics
		16.9.	SDT exercise, matrix and group discussions
	38	20.9.	Guest: Peter Keller
II	39	29.9.	Chapter 4: Mouse-track
		30.9.	Mouse-tracking with Op group discussions
	40	6.10.	Chapter 5: Neurobiologi
		7.10.	MouseTrap analysis I
	41	13.10.	Chapter 6: Common rep
		14.10.	MouseTrap analysis II, p term evaluation

Kahoot!

LEARNING MILESTONE I

At this stage in the course, you should be able to

- explain basic principles of multisensory integration,
- design a simple (maybe low-tech) way to study crossmodal correspondence task,
- explain the main contributions of the field of Psychophysics,
- introduce Signal Detection Theory and its use,
- analyze a data sample using the SDT methodology.

From perception to action

Perception as a decision-making process

SDT usable for **all kinds of decisions**

Actions (SDT: button-press responses) express not just the decision but often also something about the process leading to it

- e.g. bias

Let’s take a step back: Measuring reaction times

Can we learn something about the underlying cognitive processes when measuring reaction times (RTs)?

Stimulus → **Black box ?!** → RT response

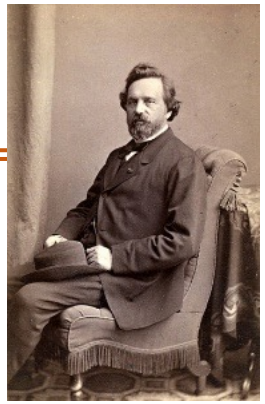
Thought exercise

In what way do reaction times relate to mental processes?

Donders proposed an influential stage model and the subtraction method, allowing to estimate

1. the time of different stages and
2. the process on which a task manipulation has an effect

Donders' subtraction method: How fast are mental processes?



Franciscus Donders, 1818-1889

"Mental chronometry"

Simple reaction time task	Go/no-go task	Choice reaction time task
Signal perception	Signal perception	Signal perception
Motor response	Stimulus discrimination	Stimulus discrimination
	Motor response	Response choice
		Motor response

General assumption:
Motor response is constant as it depends (only) on neural transmission speed

Donders' subtraction method: How fast are mental processes?

Donders, On the speed of mental processes, 1869 (1969)

Method a. *Ki* to be responded to with *ki*.

Serial number	Stimulus	Response	Number of vibrations	
1	*ki*	*ki*	45	
2	*ki*	not forthcoming		
3	*ki*	*ki*	54	average = 51.5
20	*ki*	*ki*	53	minimum = 45.
21	*ki*	*ki*	60	
22	*ki*	*ki*	45.5	

Simple reaction time task

Method b. Unknown sound, to be responded to with the same sound.

Serial number	Stimulus	Response	Number of vibrations	
4	*ko*	*ko*	77.5	
5	*ke*	*ke*	72	
6	*ki*	*ki*	72	average = 74.33
17	*ki*	*ki*	76	minimum = 72
18	*ku*	*ku*	74.5	
19	*ke*	*ke*	74	

Choice reaction time task

Method c. Of the sounds only *ki* has to be responded to.

Serial number	Stimulus	Response	Number of variations	
7	*ku*	—		
8	*ki*	*ki*	71.5	
9	*ki*	*ki*	61	
10	*ka*	—		average = 63.37
11	*ku*	—		minimum = 59
12	*ki*	*ki*	62	
13	*ke*	—		
14	*ki*	*ki*	59	

Go/no-go task

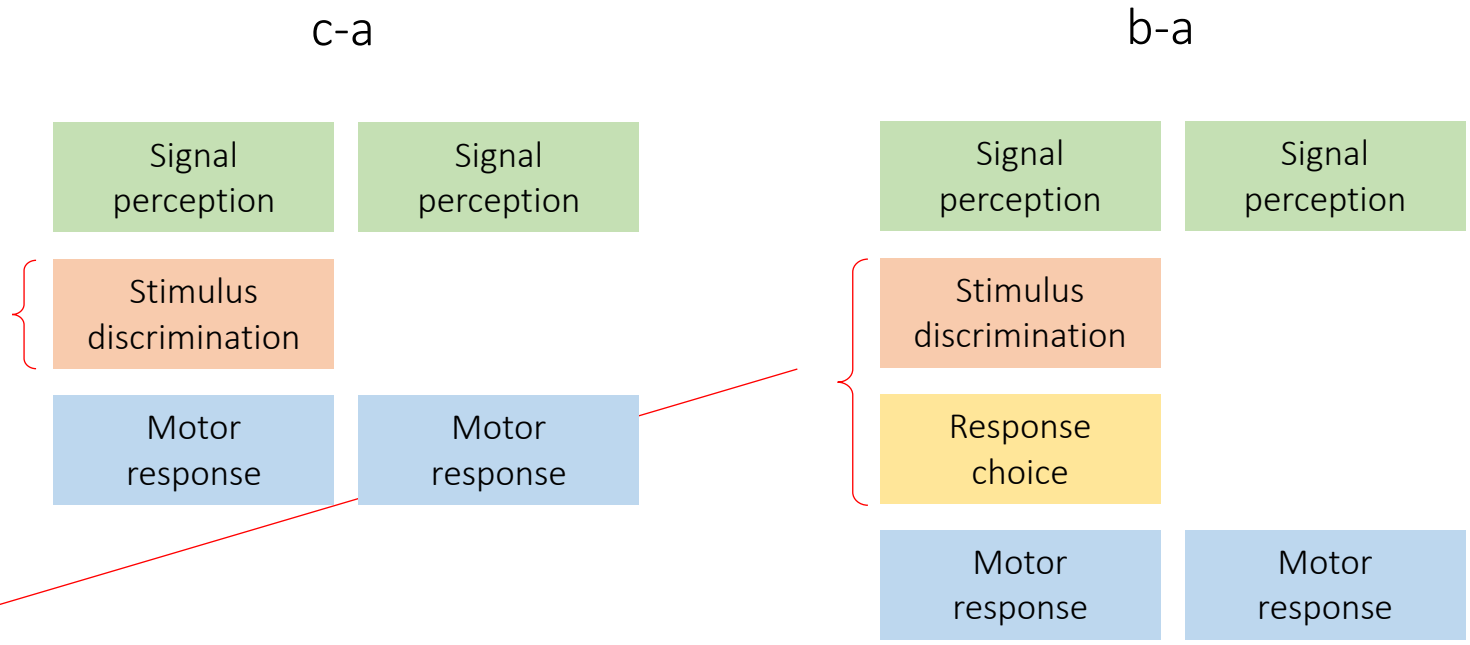
Donders' subtraction method: How fast are mental processes?

Donders, On the speed of mental processes, 1869 (1969)

Methods	average of the observations
a.	52.41
b.	74.08
c.	61.89

Now one

	from the averages of all observations
b-a	21.67
c-a	9.48
b-c	12.19



This subtraction idea still underlies – more or less explicitly – all speeded RT tasks.

So …

Reaction times

- gives indications about how long a task takes
- and, using clever designs, how a manipulation affects cognitive processing
- but not how a decision-making process unfolds

SDT

- informs about sensitivity and bias in decision making
- and how particular manipulations shift these factors
- but nothing about the timing and dynamic interaction of these processes

EEG and eye tracking

- show there is a “story” behind behavioral responses
- and that dynamic and continuous processes lead to diverse motor responses
- but effortful setup and restricted to particular tasks and modalities

Thought exercise

What are specific advantages of mouse tracking?

Why mousetracking?

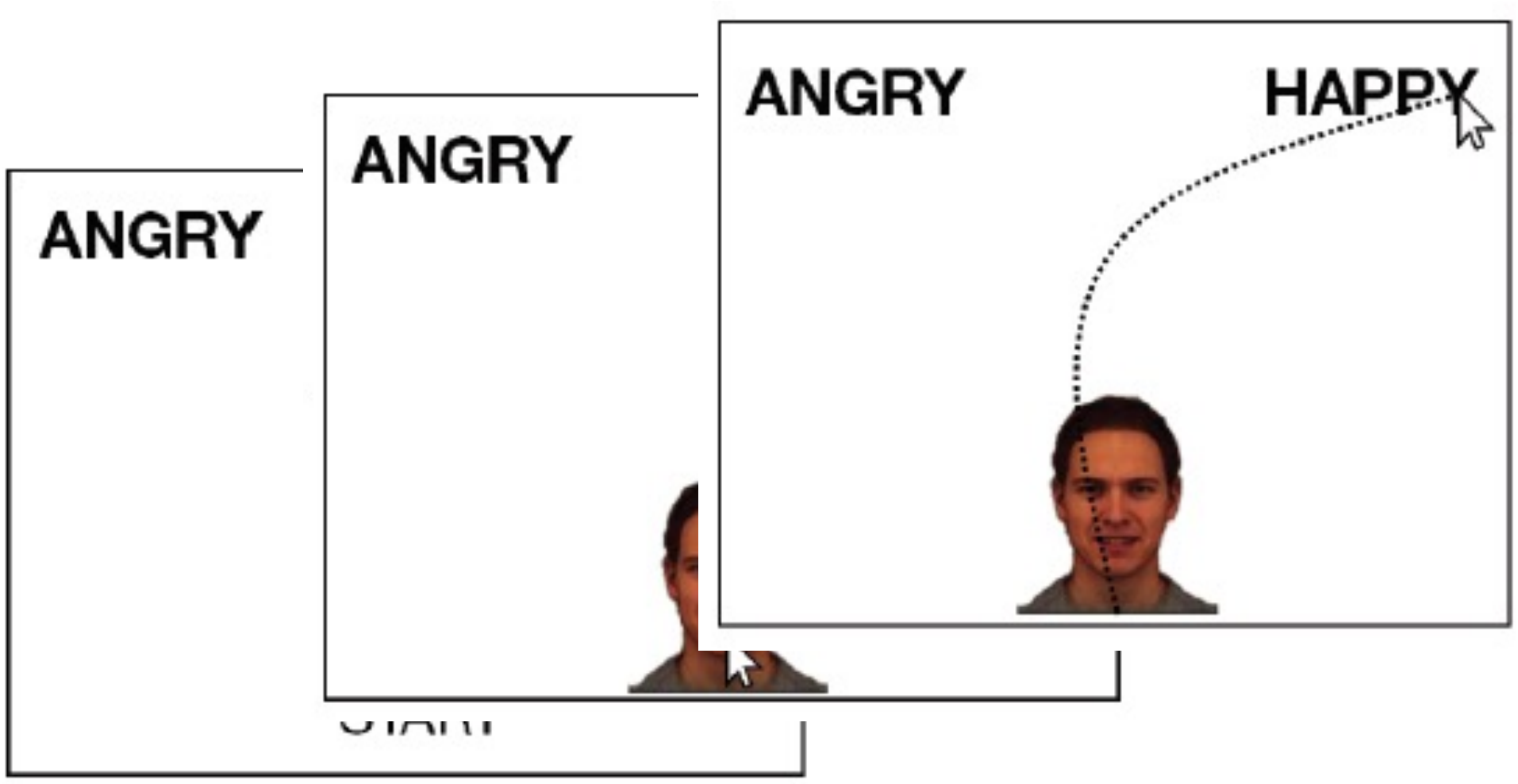
"This more recent work demonstrates that mouse tracking is a widely applicable measure across the field, capable of exposing the microstructure of real-time decisions, including their component processes and millisecond-resolution time course, in ways that inform theory."

Freeman, 2018, p. 1

Major advantages

- Applicable to all kinds of cognitive science research
- Fine-grained measure of decision microstructure, capturing in-between states
- Neurophysiological support for hand movements as valid index of evolving decisions
- High temporal resolution (depending on devices)
- Freely available and easy to use: standard computer + mouse
- Freeware (for both running and analyzing)

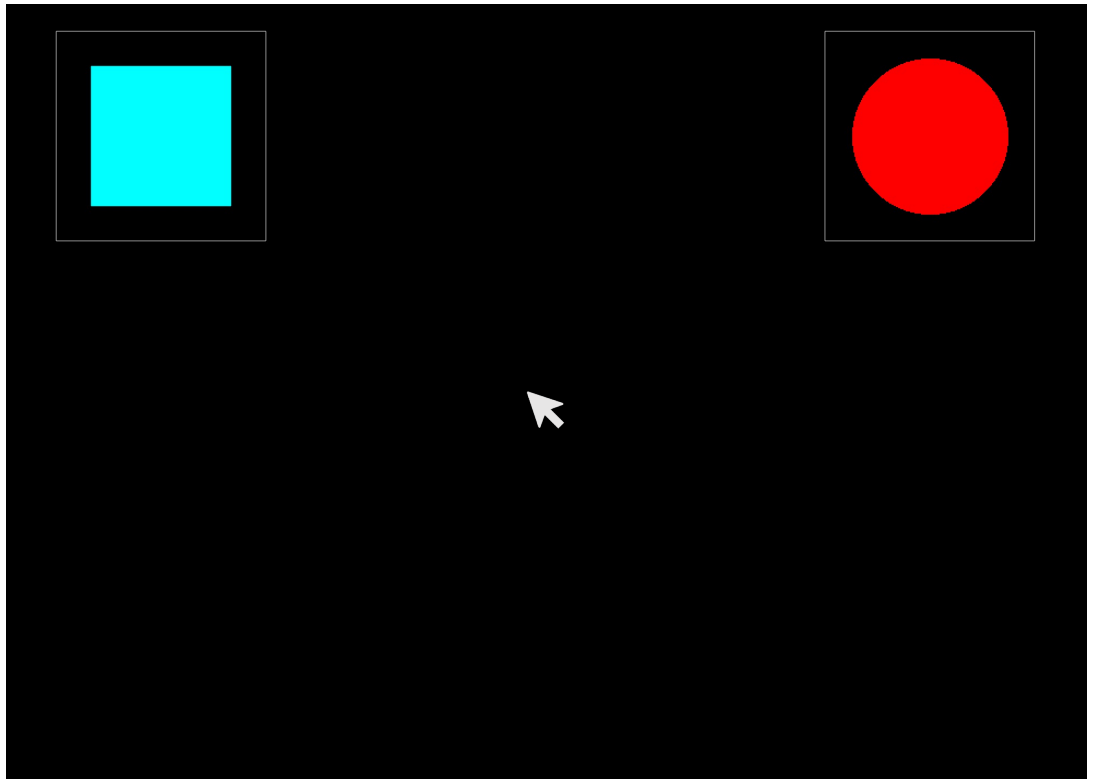
A simple example

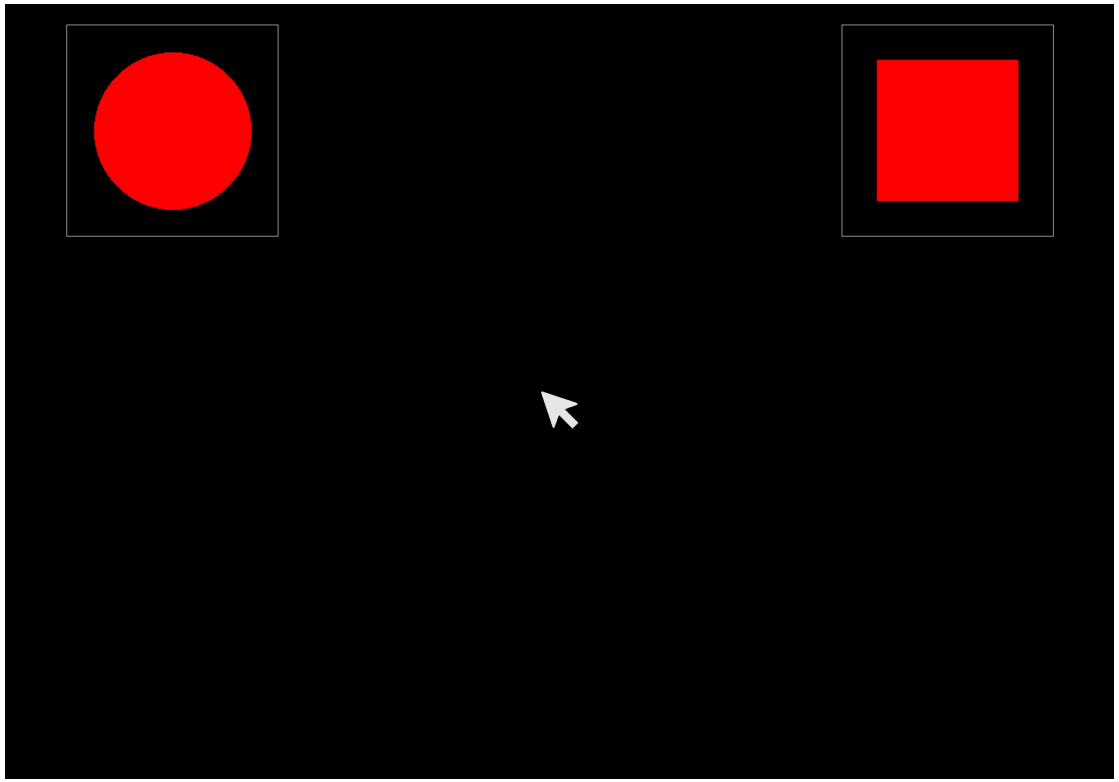


Another simple example

Thought exercise

What could be the important difference between these two trials here?





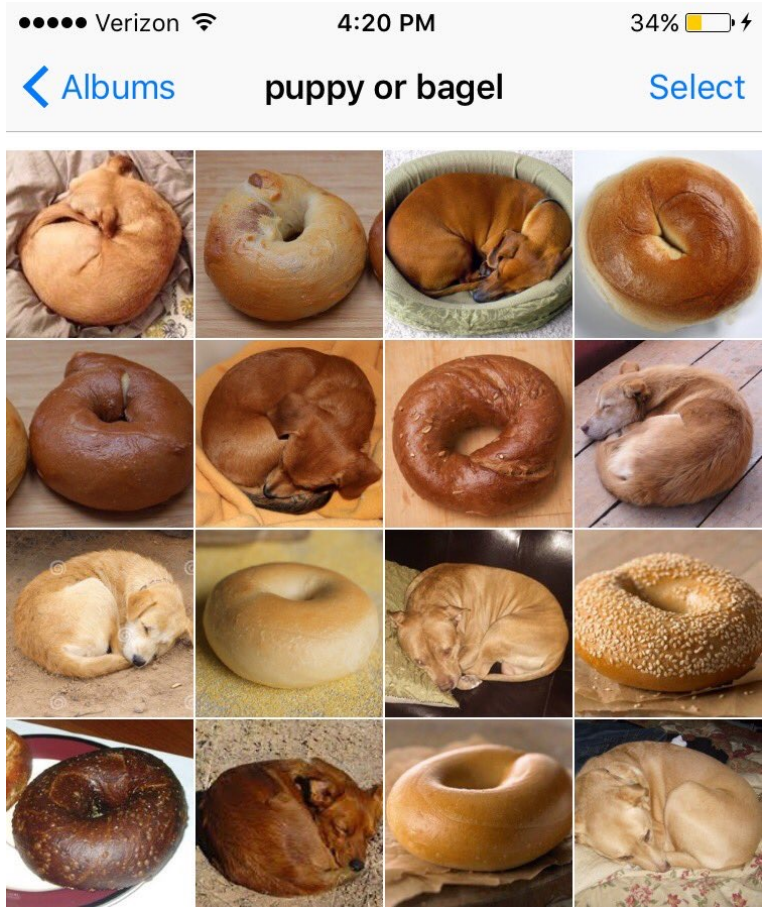
Circle and square experiment

Hypothesis:

Similar trials are more difficult to discriminate perceptually and lead to temporarilly visible conflicts.

- Longer overall duration
- Stronger curvature towards distractor item
- More short-term flipping between response options

For your inspiration …



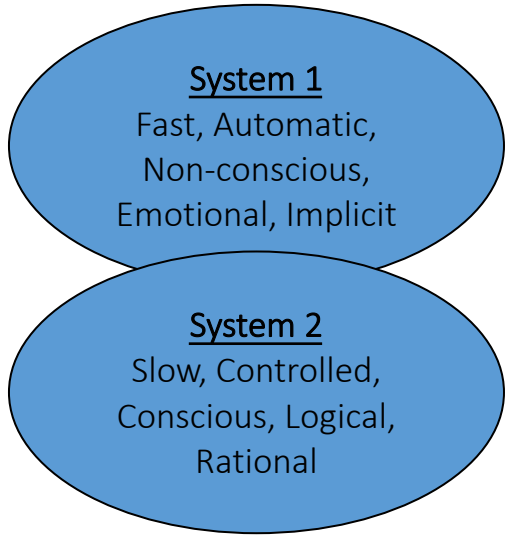
Different predictions for different theories

Dual systems models: ”switch” from one system to another system

Stage-based:

Dual-systems:

→ Discrete midflight corrections
Flip-flopping
Bimodal distribution

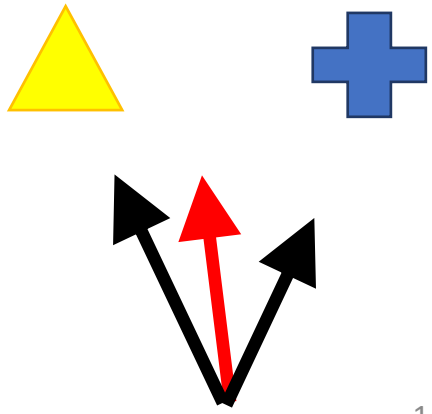


Kahneman, 2011, Thinking Fast and Slow

Dynamic models: continuous attraction by multiple systems

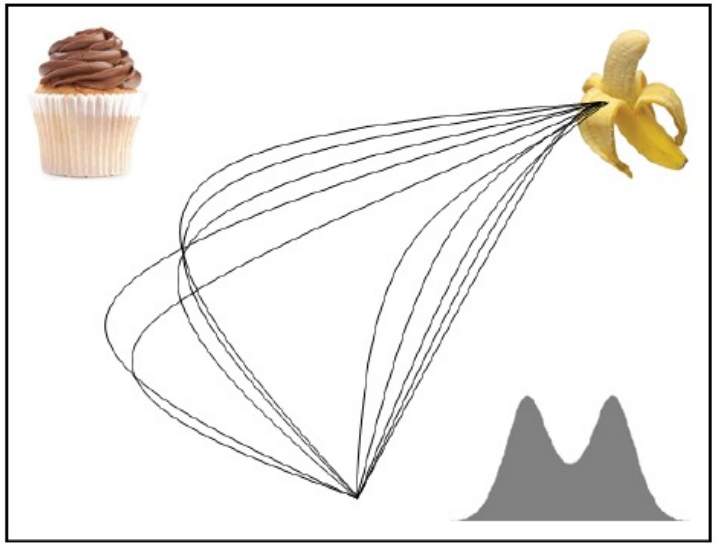
Dynamic:

→ Continuous attraction
Coactivation
Unimodal distribution



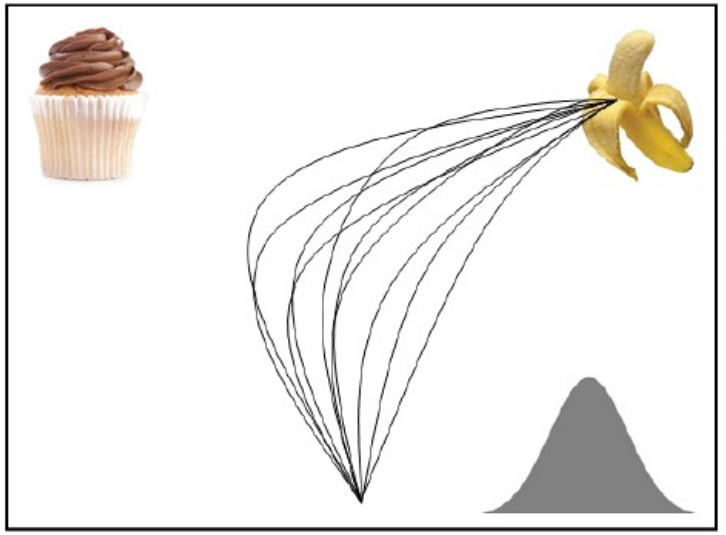
Dynamic responses made visible

Prediction of dual-systems models with a “sudden” intervention on the impulsive response:



Bimodal distribution of trajectories

Prediction of dynamic models where the two responses are co-activated:

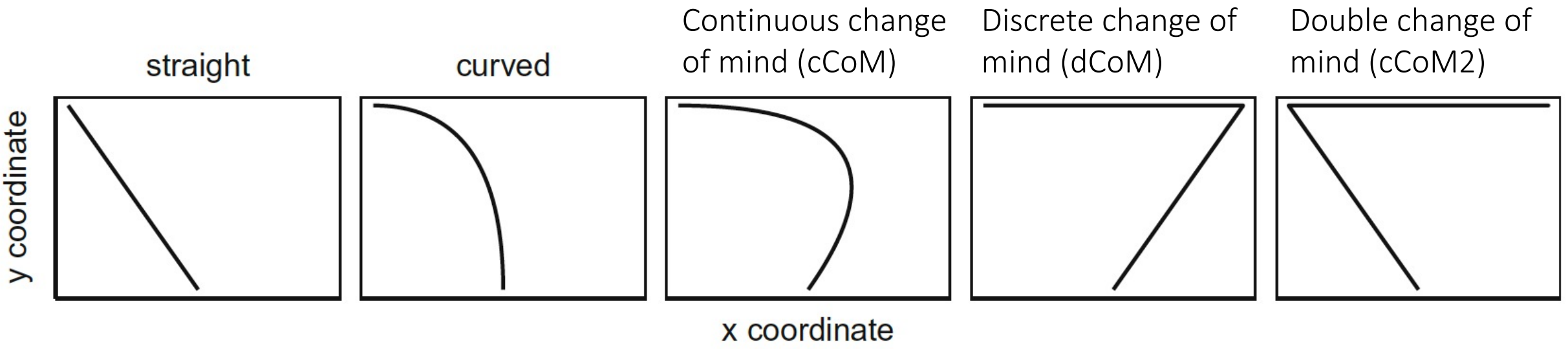


Unimodal distribution of trajectories

Mixed processes

Kieslich et al., 2020. Design factors in mouse-tracking: What makes a difference?

Different patterns are possible and might be intermixed: probabilistic activation

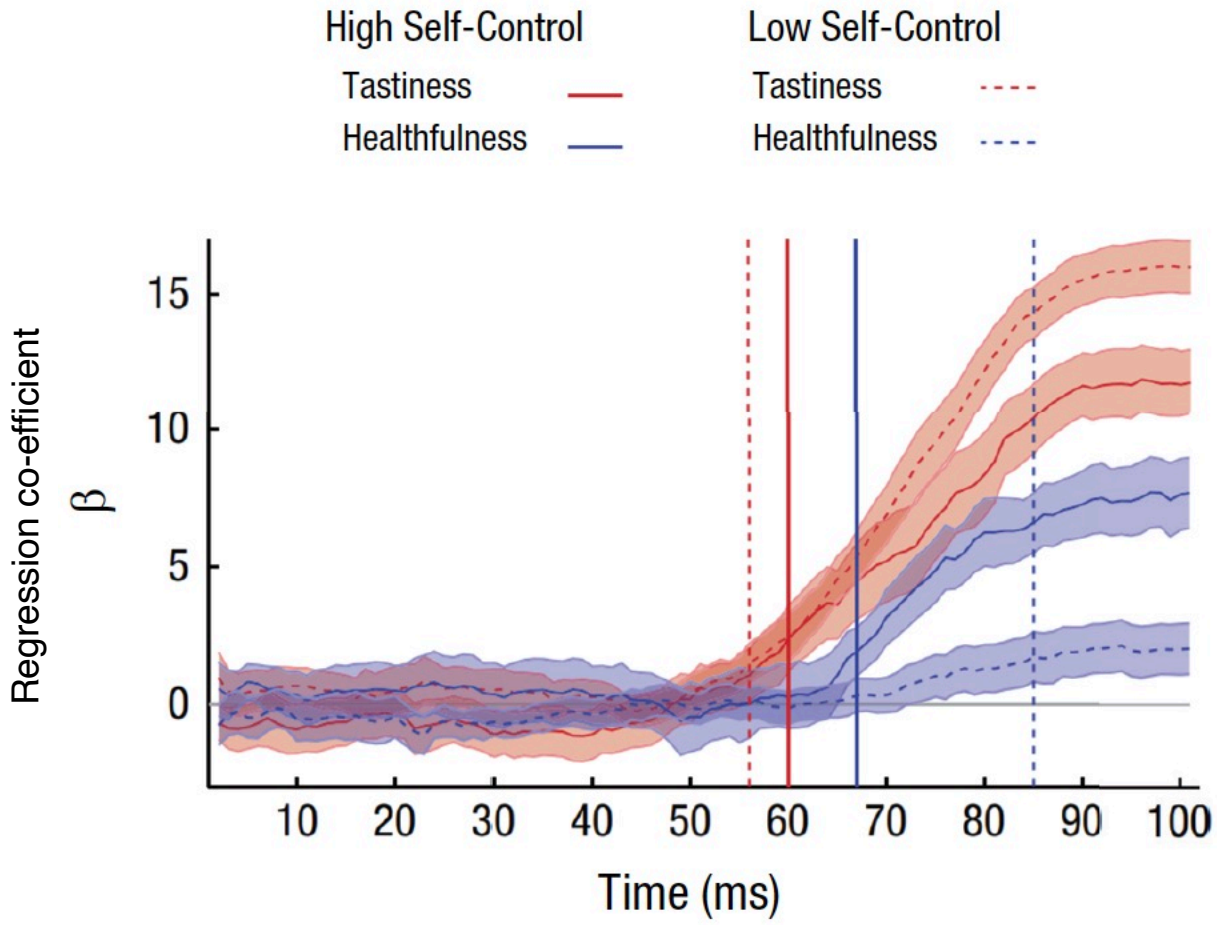


Self-control revealed

How much does explicit self-report correlate with behavior?

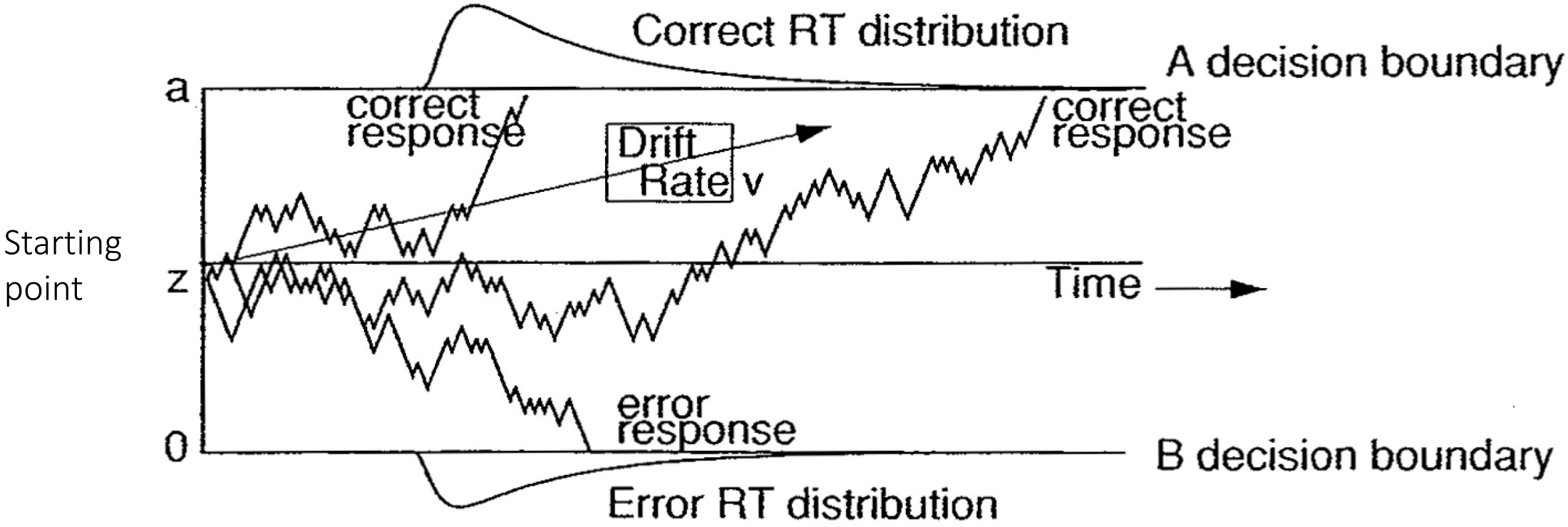
- High self-control group:
  tastiness and healthfulness correlates with mouse trajectories at the same (early) time during the decision process

- Low self-control group:
  healthfulness correlates with mouse trajectories considerably later in time than tastiness



Ratcliff & McKoon, 2008, The Diffusion Decision Model

The Diffusion Decision Model

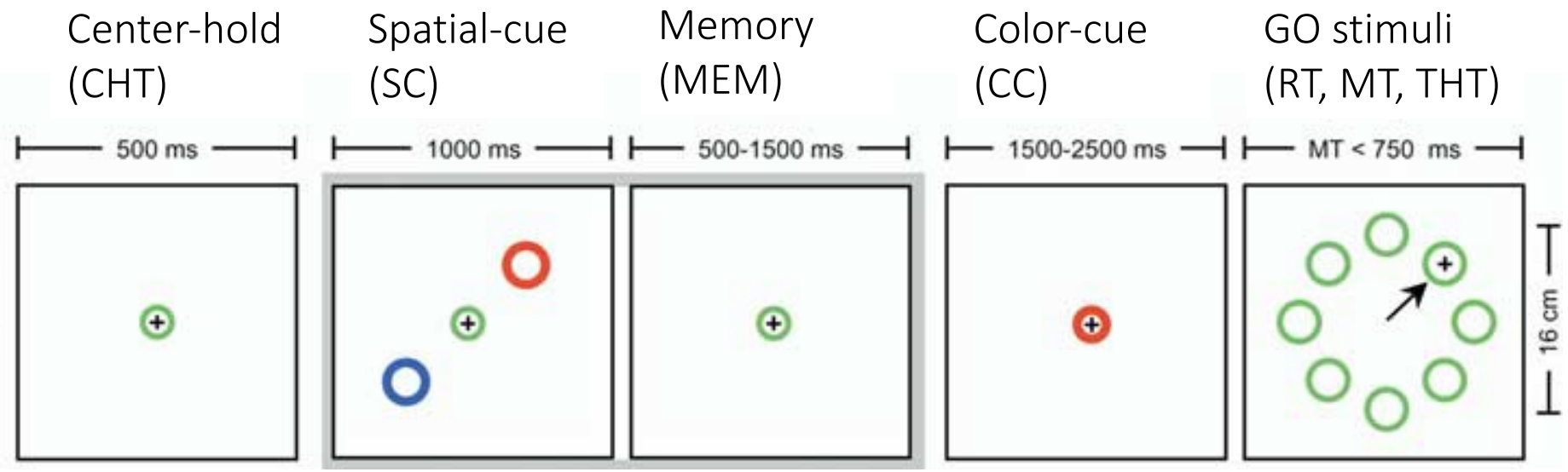


Underlying neural processes

Cisek & Kalaska, 2005

Two-target task

Measured cells in dorsal premotor cortex (PMd) and primary motor cortex (M1)

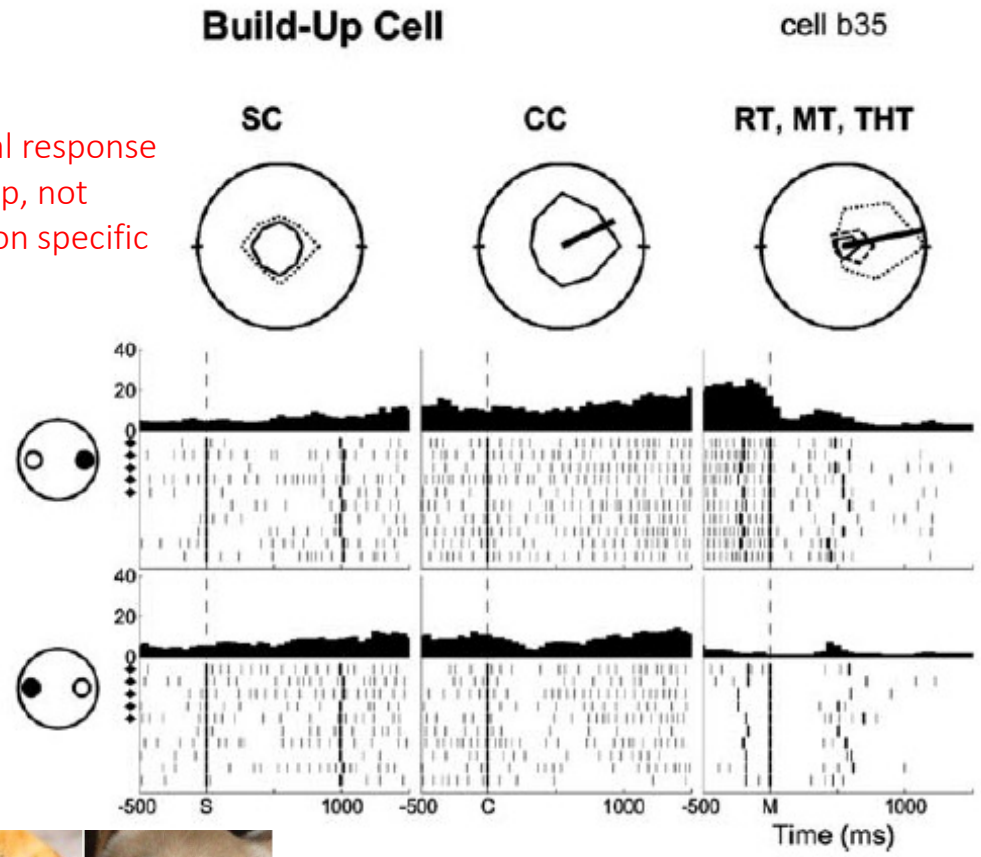


Underlying neural processes

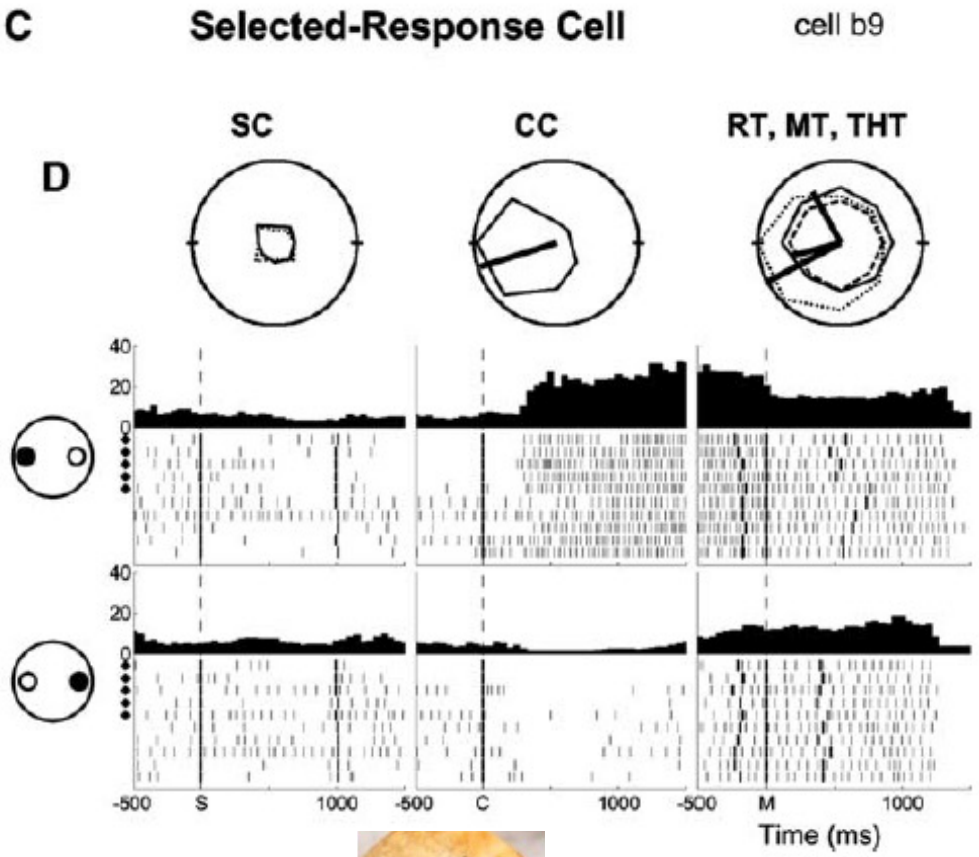
Cisek & Kalaska, 2005

Four types of cells identified

Gradual response build-up, not direction specific



Get ready for whatever will come!



Indifferent to options until cue

Yeah, it's a muffin!

Underlying neural processes

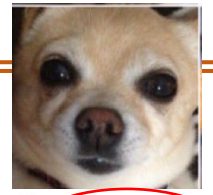
Cisek & Kalaska, 2005

Potential-response cells

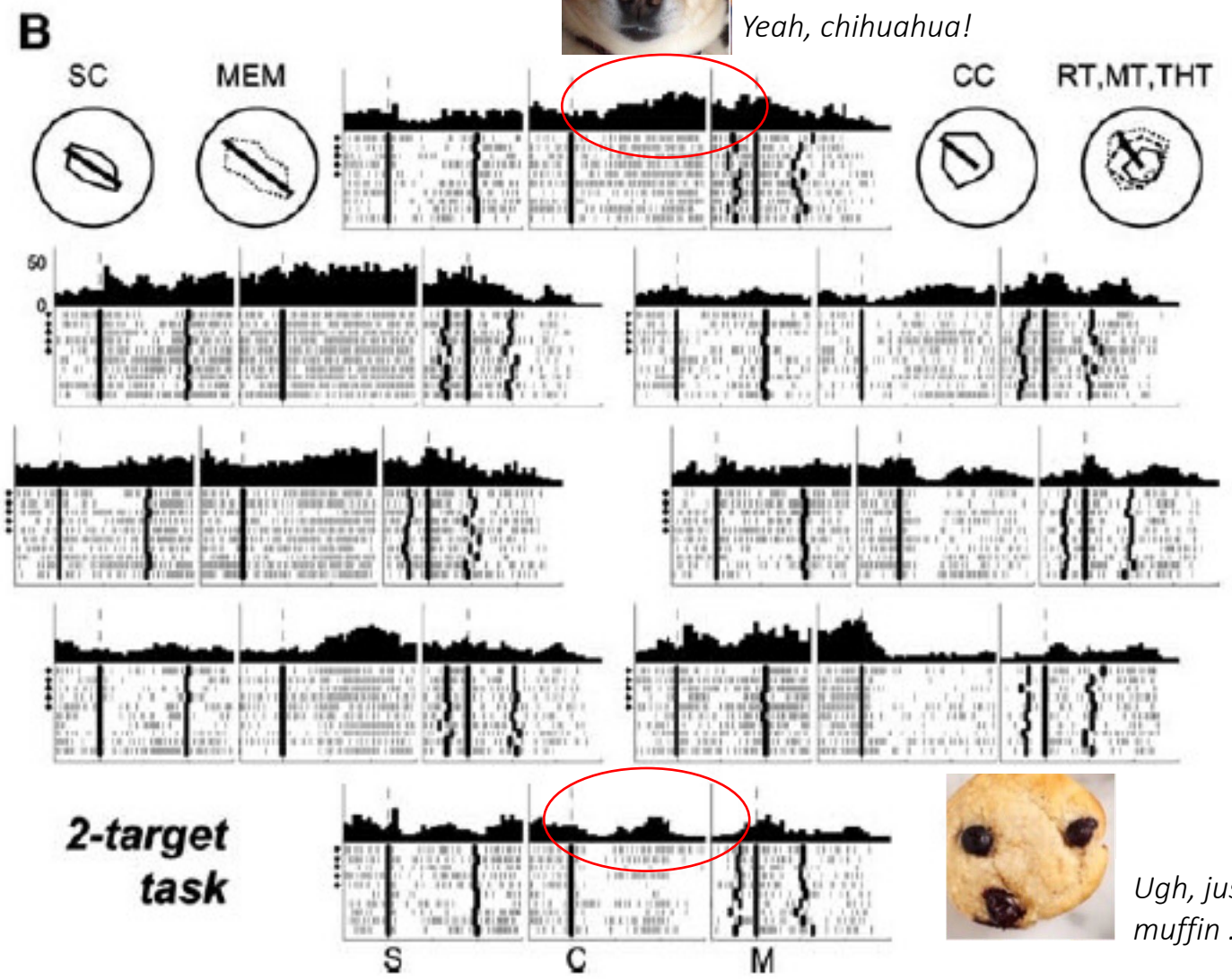
So excited to see whether it'll be a muffin or a chihuahua!

Simultaneous activation of all options until cue is given

Then activity according to preferred direction



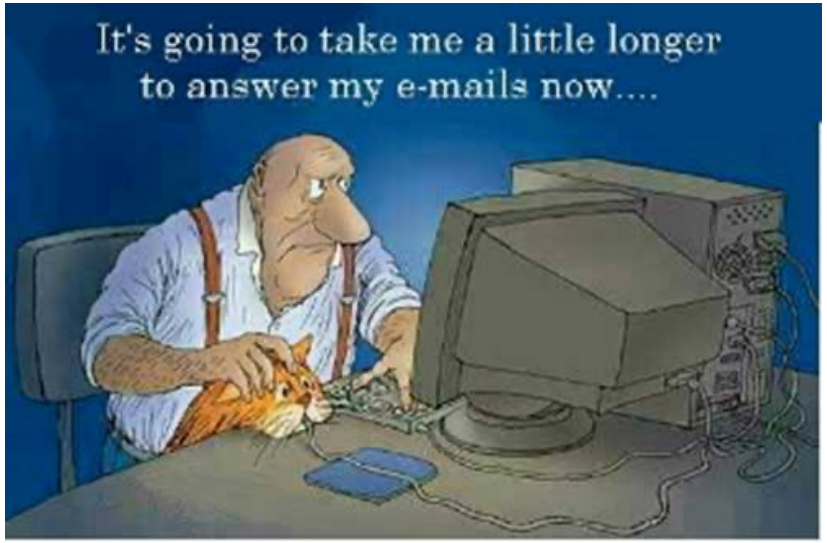
Yeah, chihuahua!



Ugh, just a muffin …

Also: **Movement cells**

How to set up a perceptual discrimination mouse-tracking experiment?



Thought exercise

What are important features if you want to set up a mouse-tracking experiment on a perceptual decision-making task?

Essentials

- Topic with a decision-making component
- Well-balanced stimulus set, accounting for differences and similarities between items
- Start button for participants to initiate trial
- Specified region around stimuli where final mouse click should happen
- Possibly, some filler stimuli to distract from research question
- Counterbalanced ordering of stimuli (on left and right sides)

How to set up a mouse-tracking experiment?

Further recommendations

- Practice trials to familiarize participants with the paradigm
- Ensure that participants understand the importance of initiating movement early
  E.g., set limit for movement initiation to 400 ms and display a warning message
- Movement-triggered stimulus presentation

Thought exercise

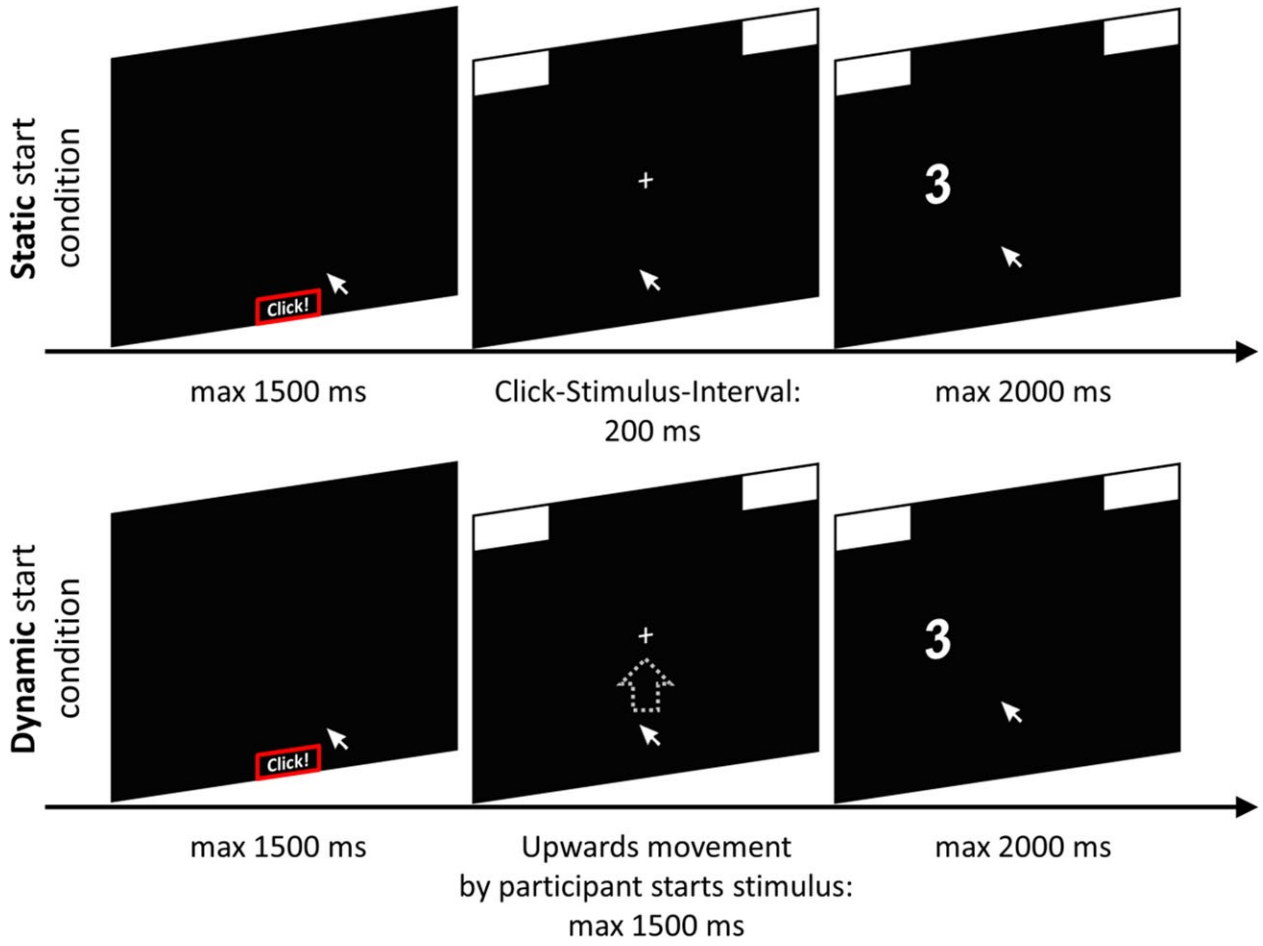
Why is an emphasis on speed important in the instructions?

"Without having an initiation time, participants may be tempted to begin moving only once a decision has been completely finalized, thus rendering the measure off-line."

When to start?

Scherbaum & Kieslich, 2018, Stuck as the starting line.

Static or movement-triggered stimulus presentation?



When to start?

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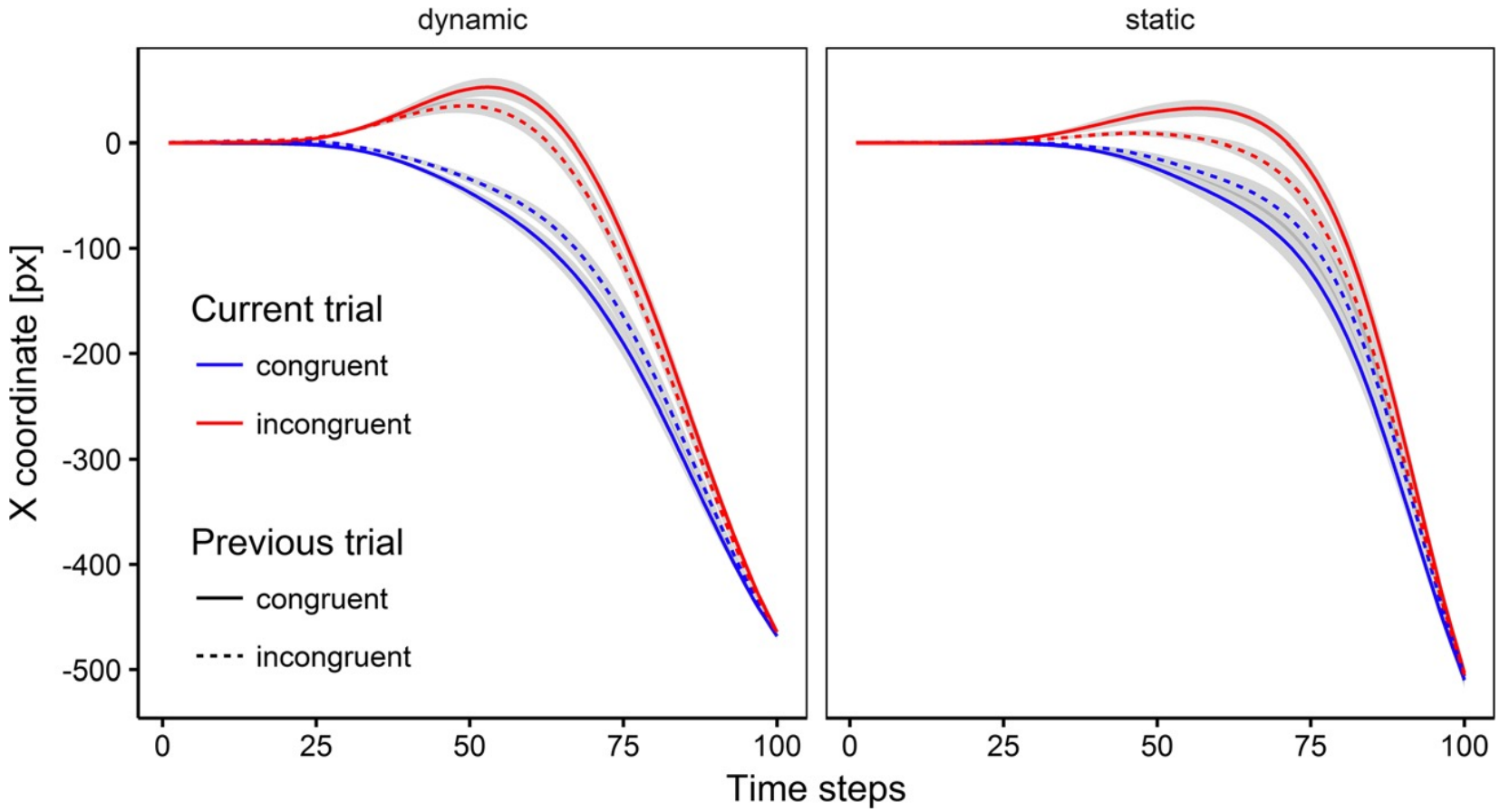


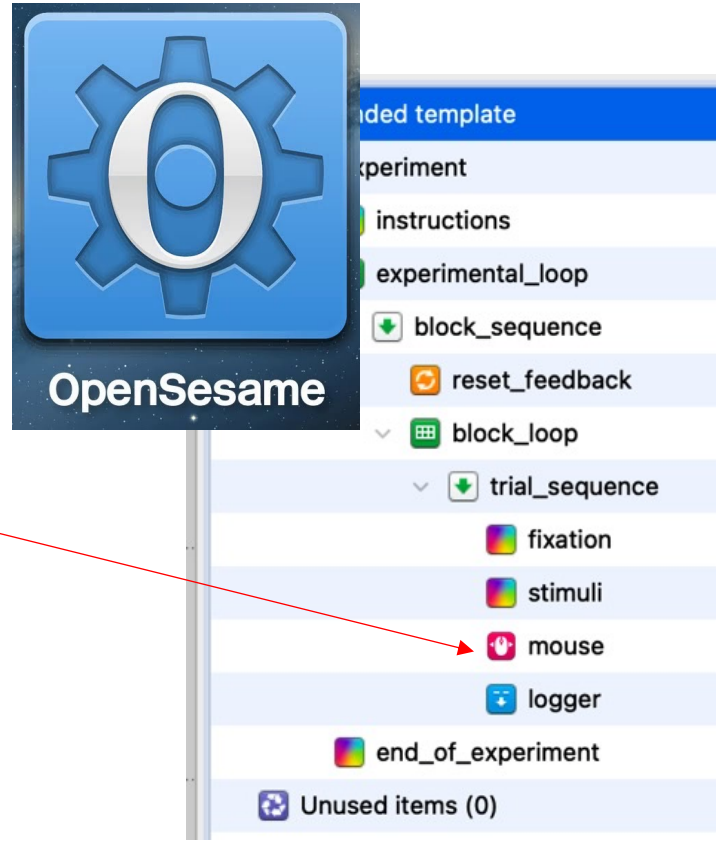
Software packages

Mousetrack (R) Coco & Duran, 2015

- Mainly developed to analyze data coming from mouse-tracking experiments
- 40 DVs

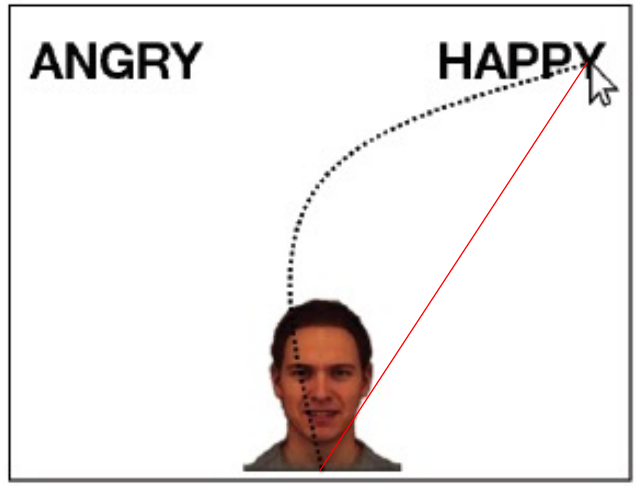
MouseTrap (OpenSesame, R) Kieslich, Wulff, Henninger, Haslbeck, Brockhaus, 2019

- Own open source software for experiment design and data collection
- Corresponding data structures
- Functions for importing, preprocessing, analyzing, aggregating, and visualizing mouse-tracking data
- Steeper learning curve but useful and flexible



Some often-used measures

Measure	Description
X-flips	Number of directional changes along x-axis
Y-flips	Number of directional changes along y-axis
MAD (Maximum Absolute Deviation)	Maximal deviation between real path and hypothetical direct path
AD (Average Deviation)	Average deviation from direct path
Curvature	Area between real path and direct path
Idle time	Amount of time when the cursor is paused
Motion time	Amount of time when the cursor is moving
Latency	Latency at the start of the movement
Dwell time	Dwell time before committing to the final response
MaxVel	Maximum velocity
MaxAcc	Maximum acceleration
MaxPull	Maximum pull towards non-chosen option
MaxAng	Maximum severity of angle towards non-chosen option while in motion



Mouse-tracking & other measures

Eye-tracking

- MT continuous measure, ET discrete saccades
- ET more sensitive to preattentive processes, before movement
- Combining the two can be a good idea

ERP

- ERPs clear time lock, exact timing of interest
- MT exact timing has no meaning, relative differences of interest
- Combining both -> more meaningful interpretation of MT timing
- Combining ERP with MT -> problem with ERP artifacts

fMRI or TMS

- Allows for combining neural representational patterns with trajectories

What does decision-making have to do with perception and action?

Looking ahead: Action selection as an essential decision-making problem

"Animals evolved in a world of real-time situated activity, and the appropriate selection of actions was likely the primary context and driving force within which decision-making processes evolved. Even the abstract cognitive abilities of humans do not appear to be completely free from the influence of an action-centered heritage."

Cisek & Kalaska, 2005, p. 801

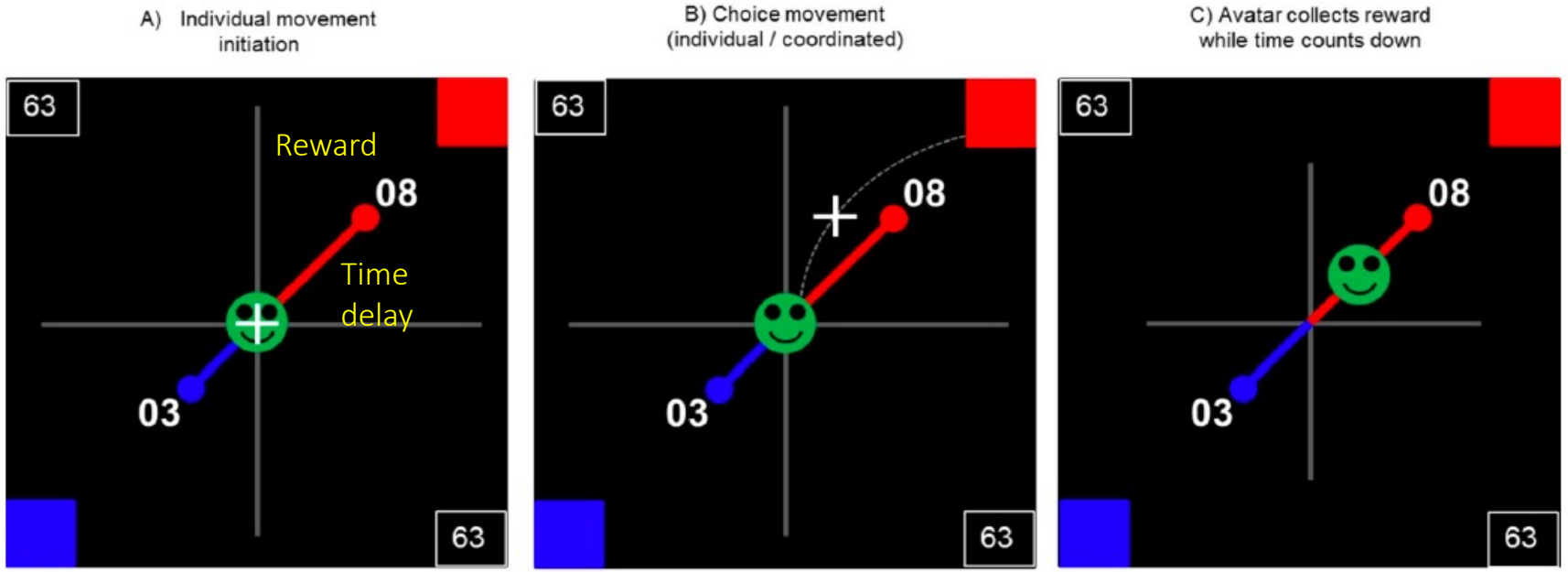
A bit now or a lot later?

Schwenke et al., PLOS ONE, 2017

Choices between sooner-but-smaller and later-but-larger rewards

Known human bias towards sooner rewards – how about social context?

The Stanford Marshmallow Test



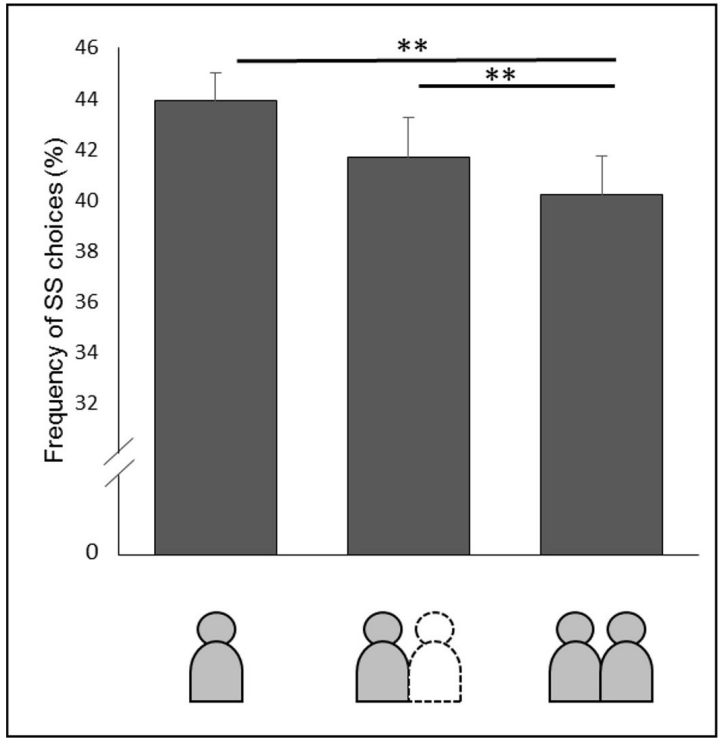
Joint Delay-Discounting

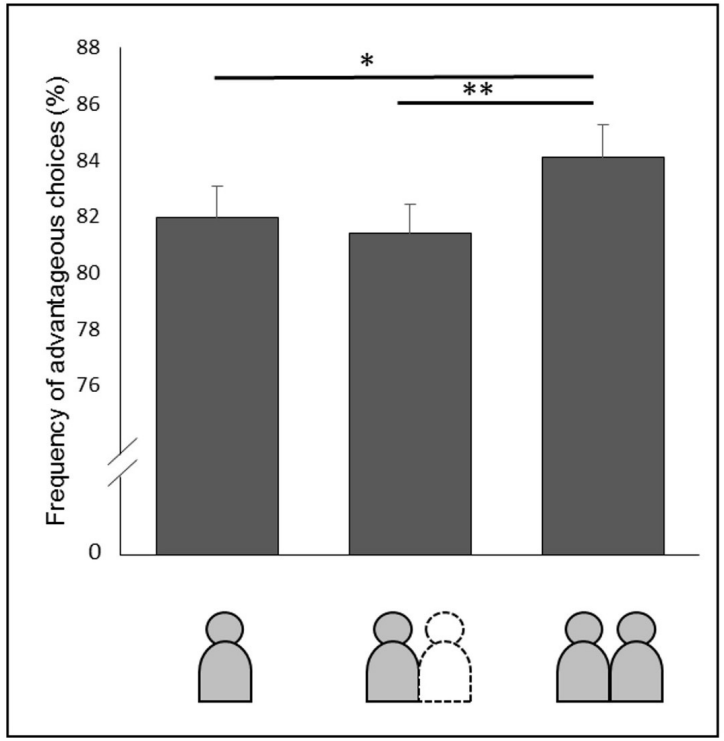
Schwenke et al., PLOS ONE, 2017

Results

- Fewer soon-but-small choices in joint context
- More advantageous decision-making when required to negotiate through movement

Mouse-tracking allows visualizing decision-making processes also in social context





Take-home messages

- ✓ Mouse-tracking is an easy to use method that captures the micro-structure of decisions.
- ✓ Originally applied to distinguish between theories of cognitive processes: stage-based / dual-systems / dynamic systems
- ✓ Now applied in all areas of research, e.g. language processing, value-based decisions, moral cognition, self-control, social cognition
- ✓ Offers clear advantages over discrete measures such as reaction times as it can reveal different dynamic patterns that link to predictions of different theories.

Class tomorrow

OpenSesame exercise with Laura

Matrix discussions

Install OpenSesame