TECHNISCHE UNIVERSITÄT DRESDEN

Professur für
METHODEN DER PSYCHOLOGIE
UND KOGNITIVE MODELLIERUNG

DRESDEN concept

Stefan Scherbaum, Martin Schoemann

Tracking the embodied dynamics of cognition using computer mouse tracking

Interdisciplinary College 2023

Where can you find the slides?

https://github.com/mschoemann/ik2023_mc2

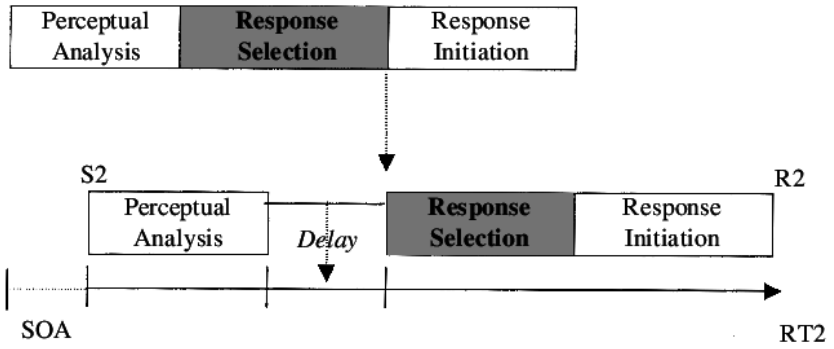
Who are you dealing with?

Stefan Scherbaum

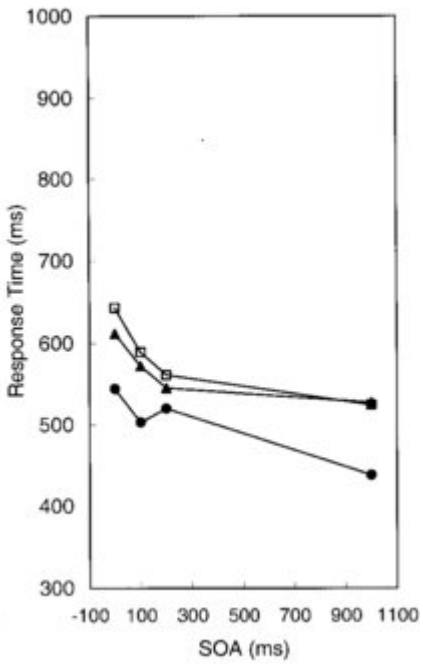
and a very versatile device
for behavioral research

Martin Schoemann

Stage-like linear approaches to cognition
→ Measures of final response



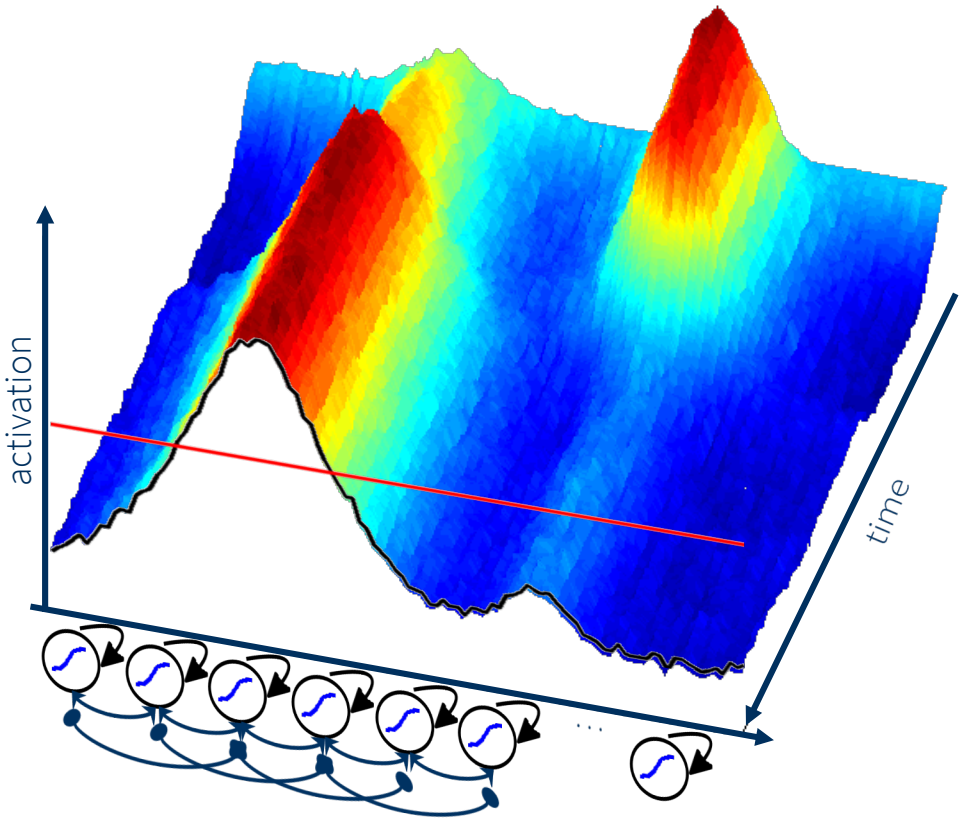
e.g., Lien & Proctor, 2002

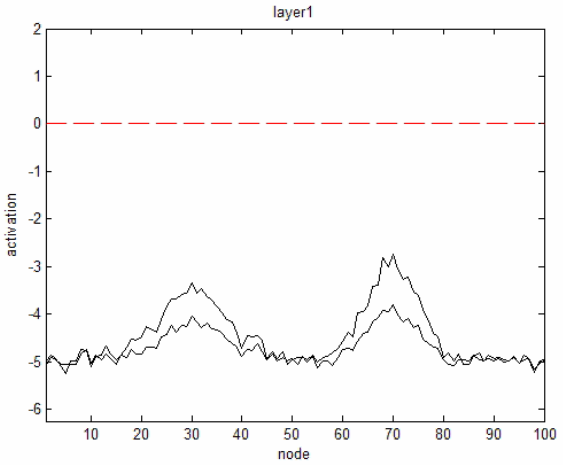


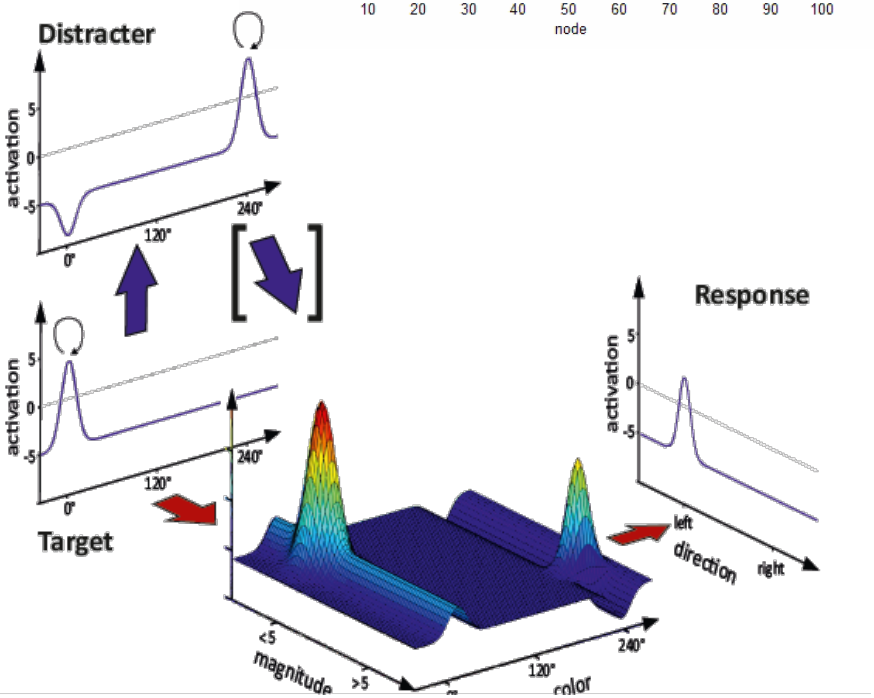
Infering stage components from RT and choices

e.g., Fellows 2004, Sugrue et al. 2005

Cognitive processes are inherently dynamic & interconnected & non-linear



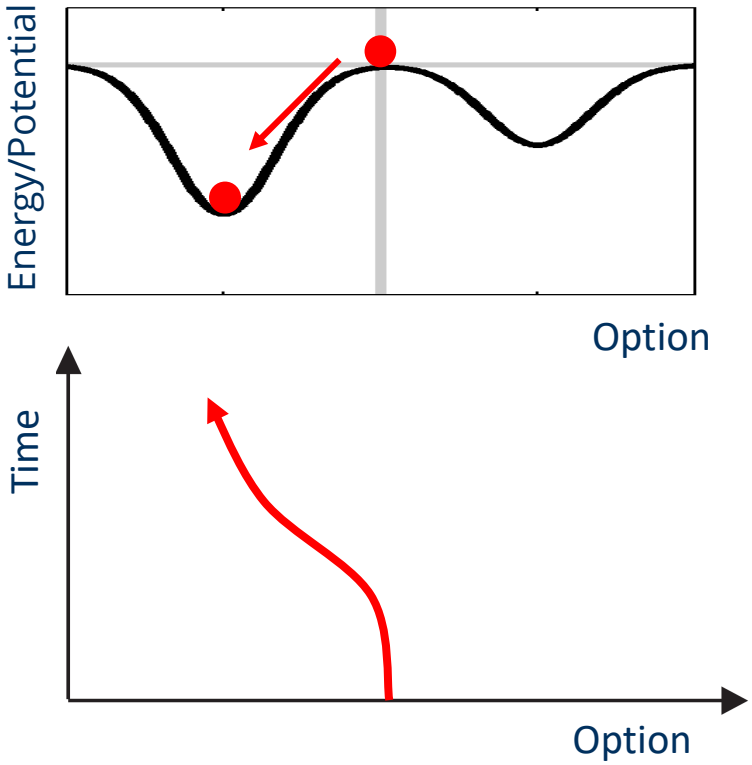




Cognition & embodiment:
Thinking and moving in the world are directly connected

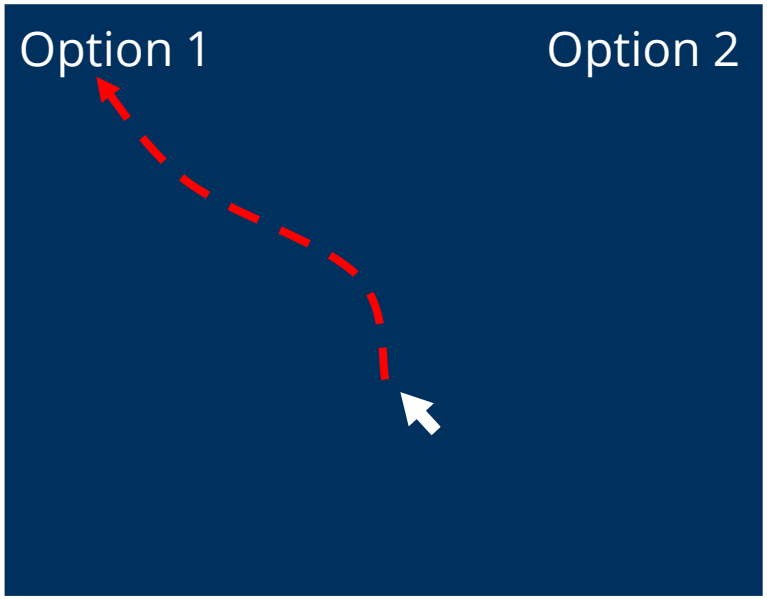
Tracing continuous processes continuously: by studying continuous movements

continuity within trials



Embodiment: Leakage of cognition into movements

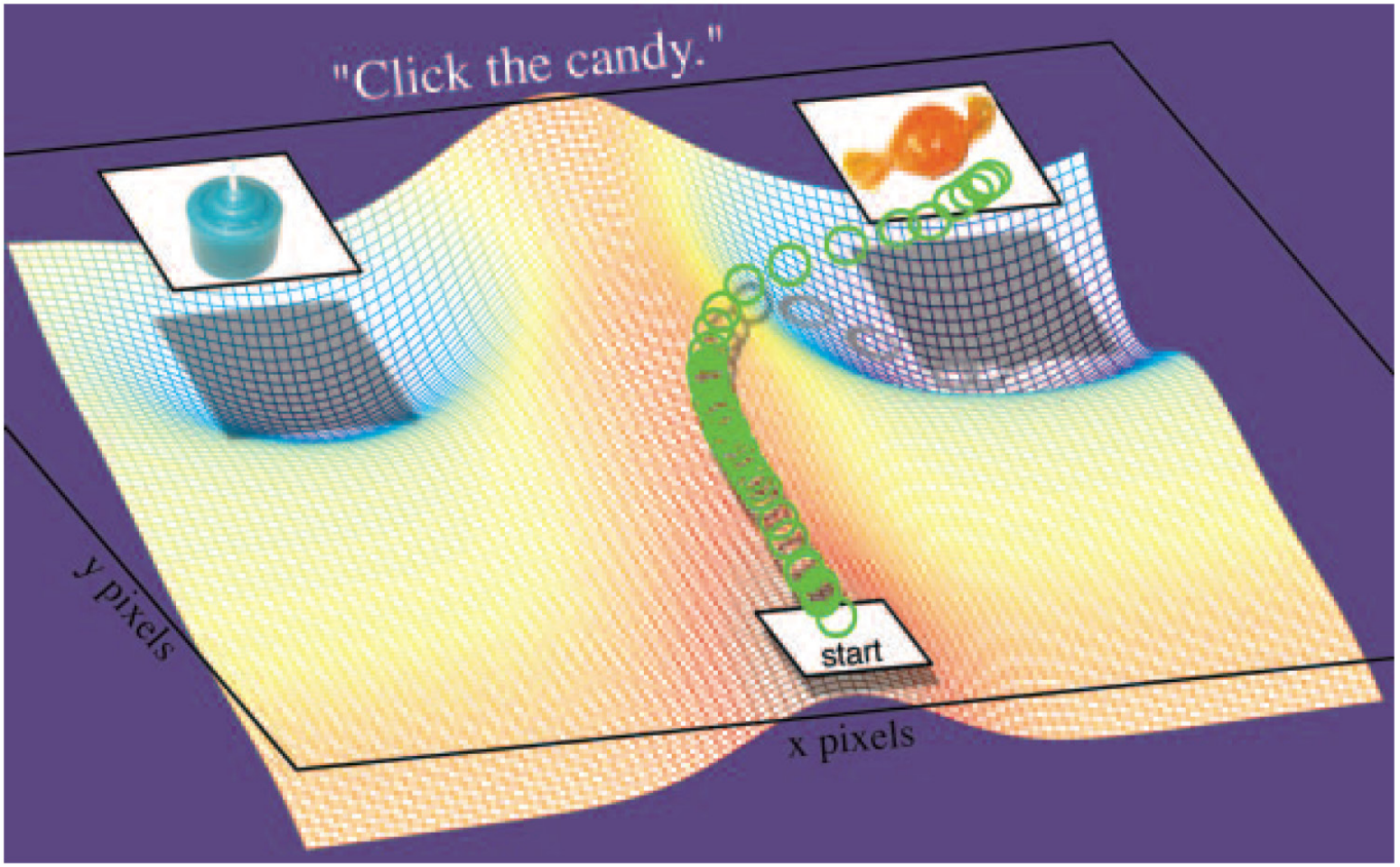
continuous tracing of responses



Computer mouse tracking!

Scherbaum, Dshemuchadse, Kalis, 2008

Observing cognitive processes by their „leakage“ into motor control

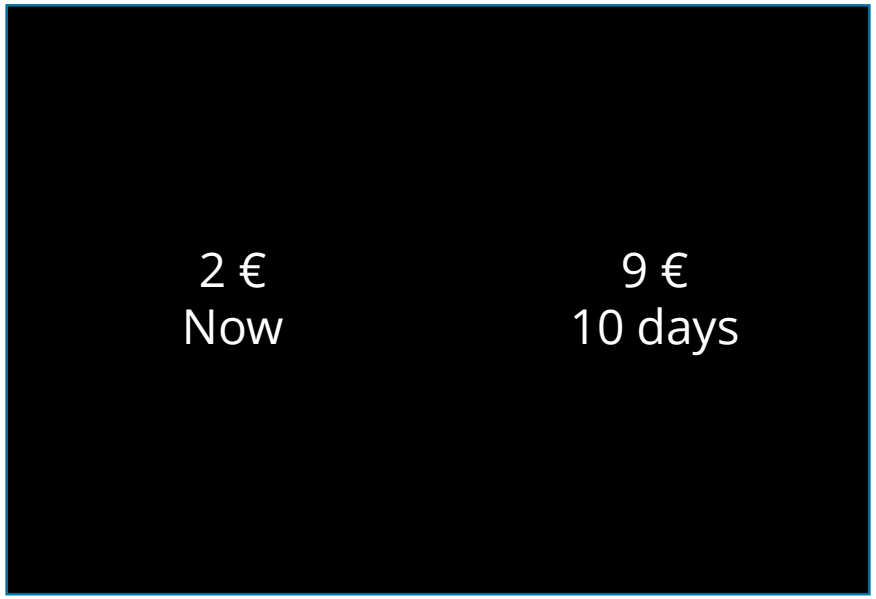


Spivey & Dale, 2006

A typical mouse tracking paradigm

Two alternative forced choice paradigms as most controlled variant

Example: Intertemporal Choice



A typical mouse tracking paradigm

Two alternative forced choice paradigms as most controlled variant

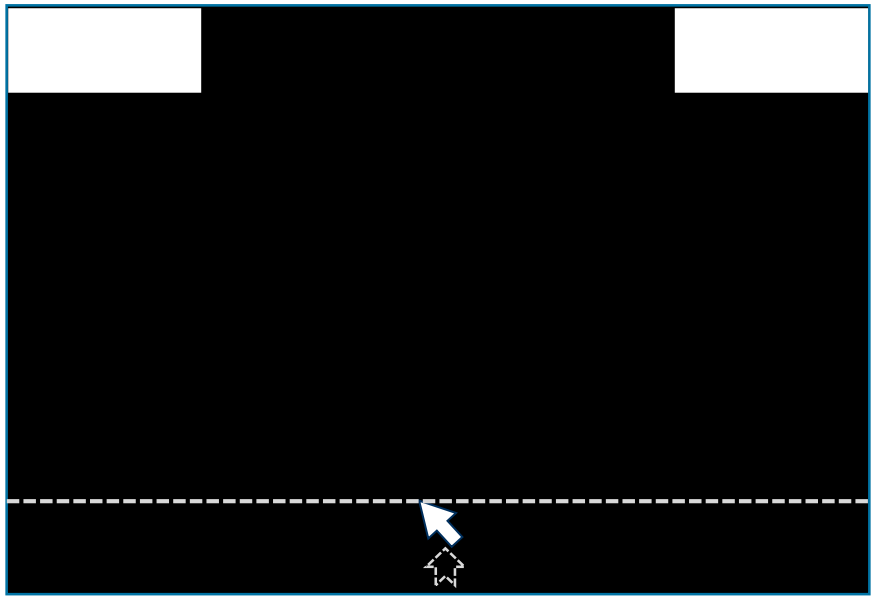
Example: Intertemporal Choice

clicking to start a trial

A typical mouse tracking paradigm

Two alternative forced choice paradigms as most controlled variant

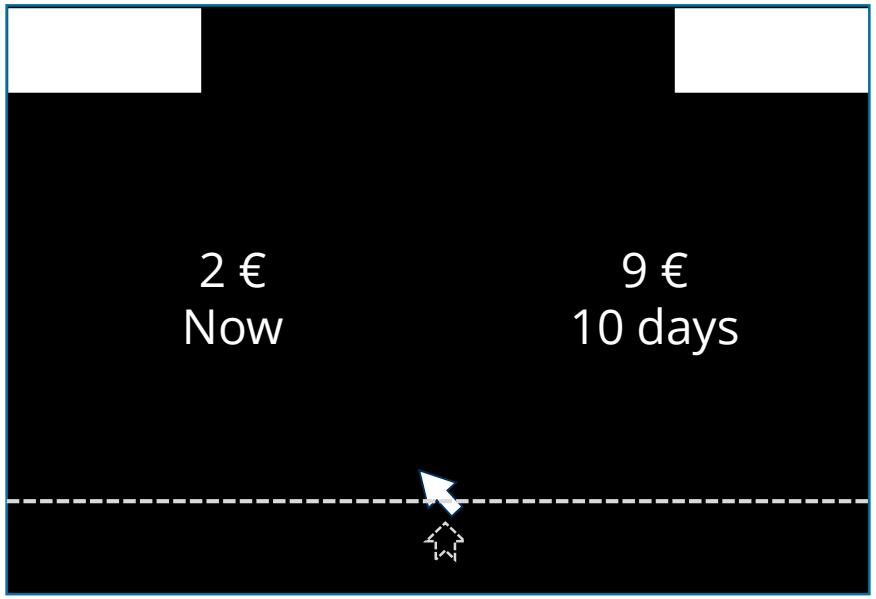
Example: Intertemporal Choice



A typical mouse tracking paradigm

Two alternative forced choice paradigms as most controlled variant

Example: Intertemporal Choice

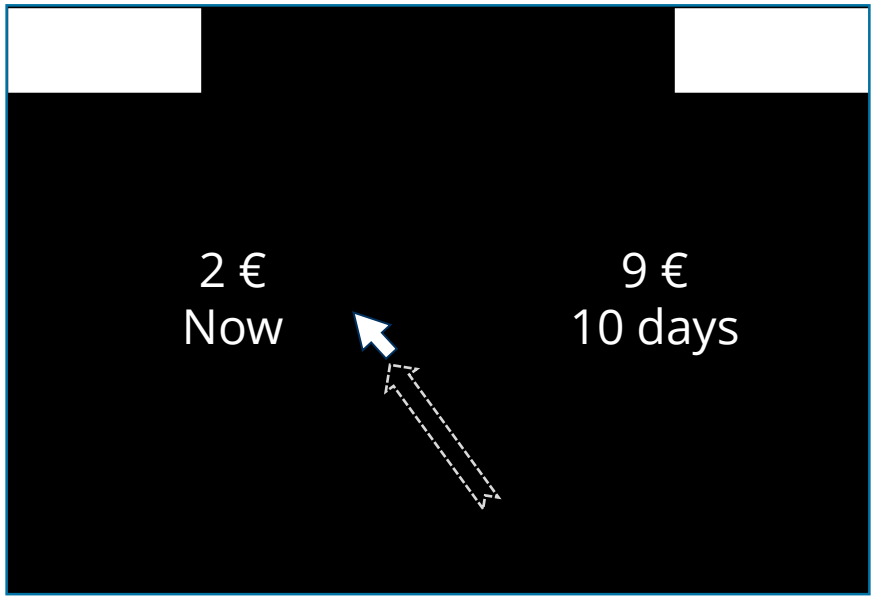


reaching presentation criterion (speed/time/position)

A typical mouse tracking paradigm

Two alternative forced choice paradigms as most controlled variant

Example: Intertemporal Choice

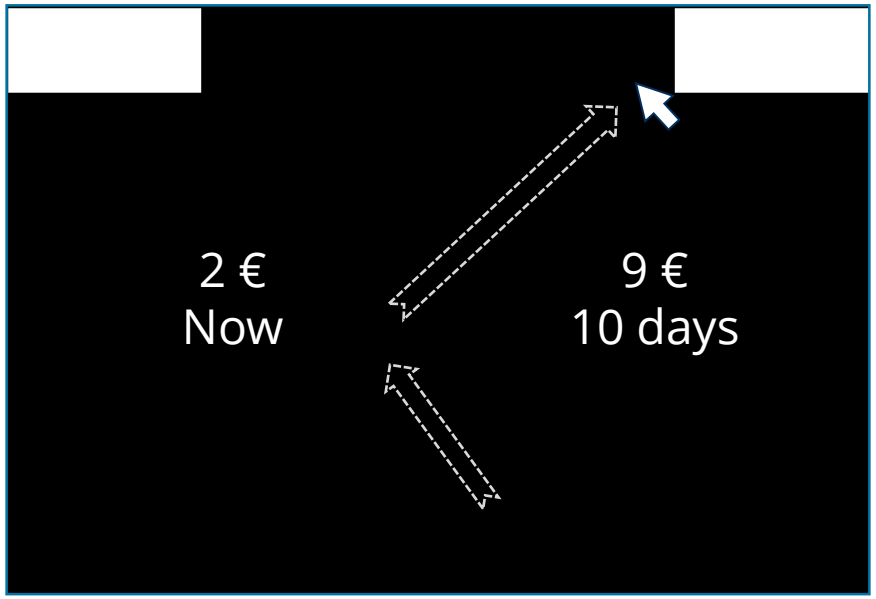


decision process

A typical mouse tracking paradigm

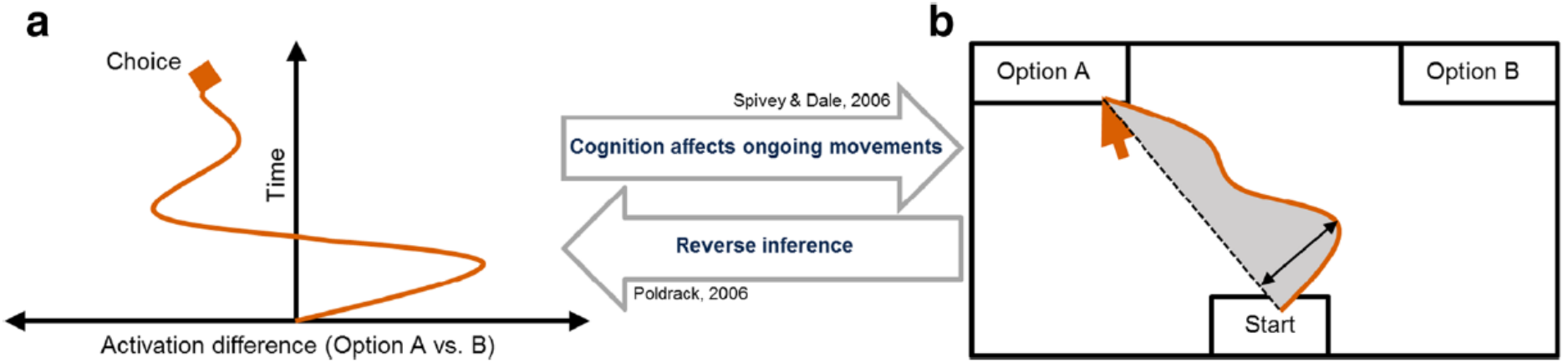
Two alternative forced choice paradigms as most controlled variant

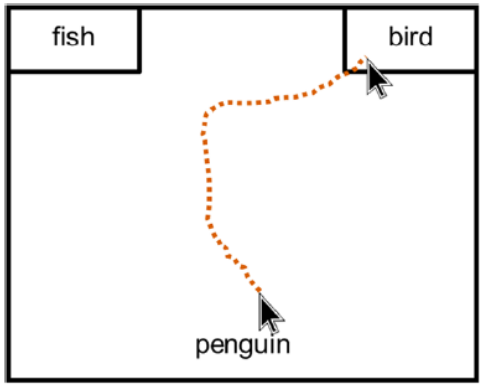
Example: Intertemporal Choice



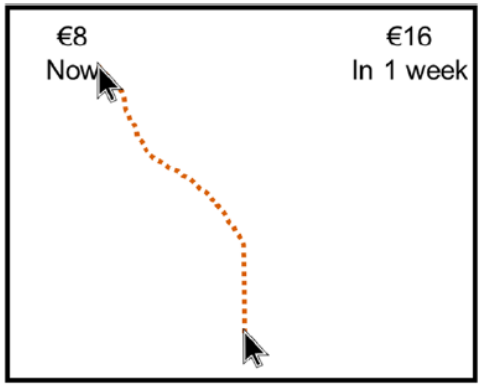
reaching response box for final decision

Using mouse tracking to infer processes

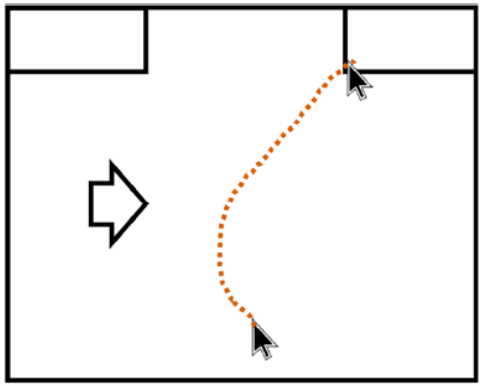




Dale et al., 2007



O'Hora et al., 2016

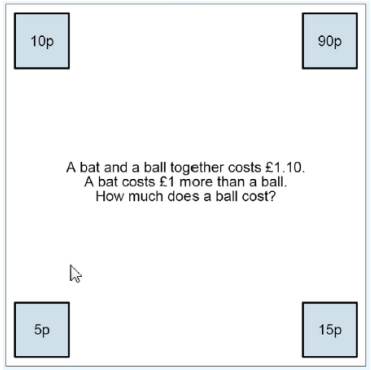


Scherbaum et al., 2010

Schoemann et al, 2020

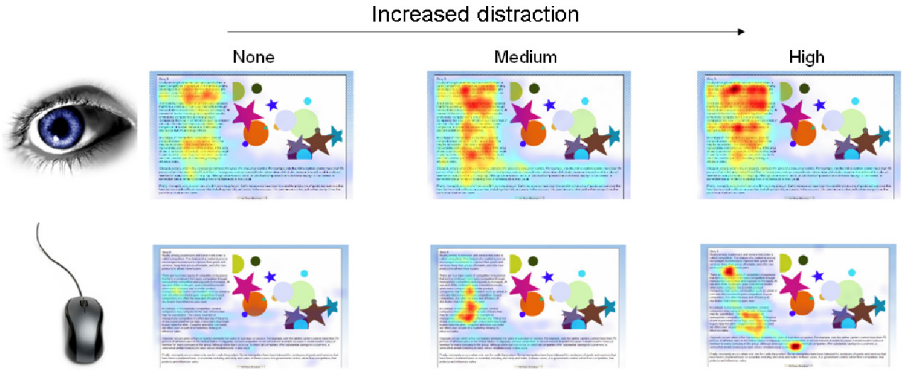
Other types of mouse tracking

More than 2 options



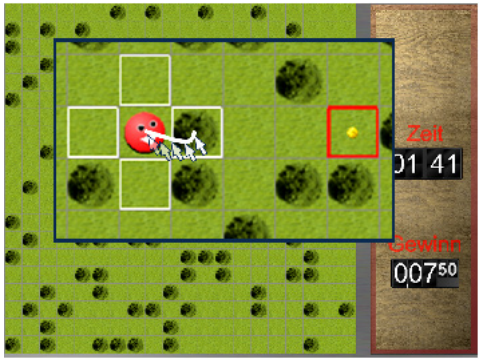
Travers, Rolison, Feeney, 2016

Mouse tracking as eye tracking



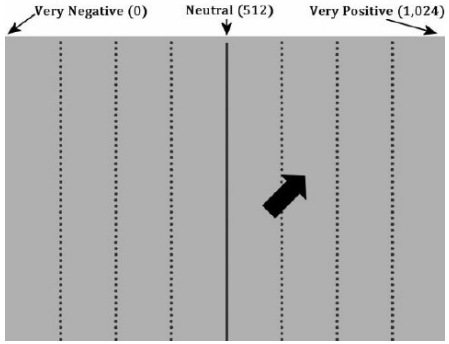
Navalpakkam, Churchill, 2012

Micro mouse tracking



Scherbaum et al., 2013

Long(er) term mouse tracking



Vallacher, Geert, Nowak, 2015

What we will look at today

- What will we do in the course?
- Where has it been applied?
- What can we look at?
- What do we need to keep in mind?

Course Syllabus

1. Introductory lecture (Monday, 14.30-16.00, i.e., now :))
2. Performing an experiment & discussing your ideas for experiments (Tuesday, 11.00-12.30)
3. Analyzing mouse-tracking data (Tuesday, 16.30-18.00)
4. Presentation of your experiment ideas & analysis results (Wednesday, 11.00-12.30)

Course Syllabus

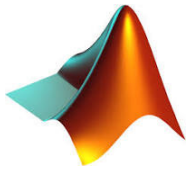
Performing an experiment & discussing your ideas for experiments (Tuesday, 11.00-12.30)

- We will present a task
- You will perform the task
- We will discuss your experimental ideas
  → Find groups and brainstorm ideas
  https://drive.google.com/drive/folders/14XsqqMNp_30vliT2osjegT-ocYrxYAVM?usp=sharing
- What you need: Laptop with Wifi & Google slides link (OpenSesame installed)
  (https://osdoc.cogsci.nl/)

Course Syllabus

Analyzing mouse tracking data (Tuesday, 16.30-18.00)

- We will analyze together the data of the measured task
- You can dig deeper into the data in groups



- What you need: Laptop with **Matlab** or **R** installed

(https://www.mathworks.com/campaigns/products/trials.html)
(https://www.r-project.org/ | https://posit.co/downloads/)

Course Syllabus

Presentation of your experiment ideas & analysis results
(Wednesday, 11.00-12.30)

- We will see and discuss your short presentations of
  - Your designed tasks
  - Your implemented tasks
  - Your additional results from analysis from Tuesday

- What you need: Laptop & Google slides

Course Syllabus

Paths through this course:

The starter package:

- Think about a potential experiment and what you might need to consider
- Follow the analysis and play around with the provided script(s)
- Present your finalized ideas

The data science package

- Think about a potential experiment and what you might need to consider
- Perform advanced analysis on the data provided
- Present your finalized task ideas and your additional results

The experimenter package

- Think about a potential experiment and implement it by adapting the provided task
- Follow the analysis and play around with the provided scripts
- Present your task, have someone test it live;
- Extreme: measure a few people and analyze

What do you pick?

Matlab vs R?

Which package?

https://www.menti.com/al8e1bqphr1d

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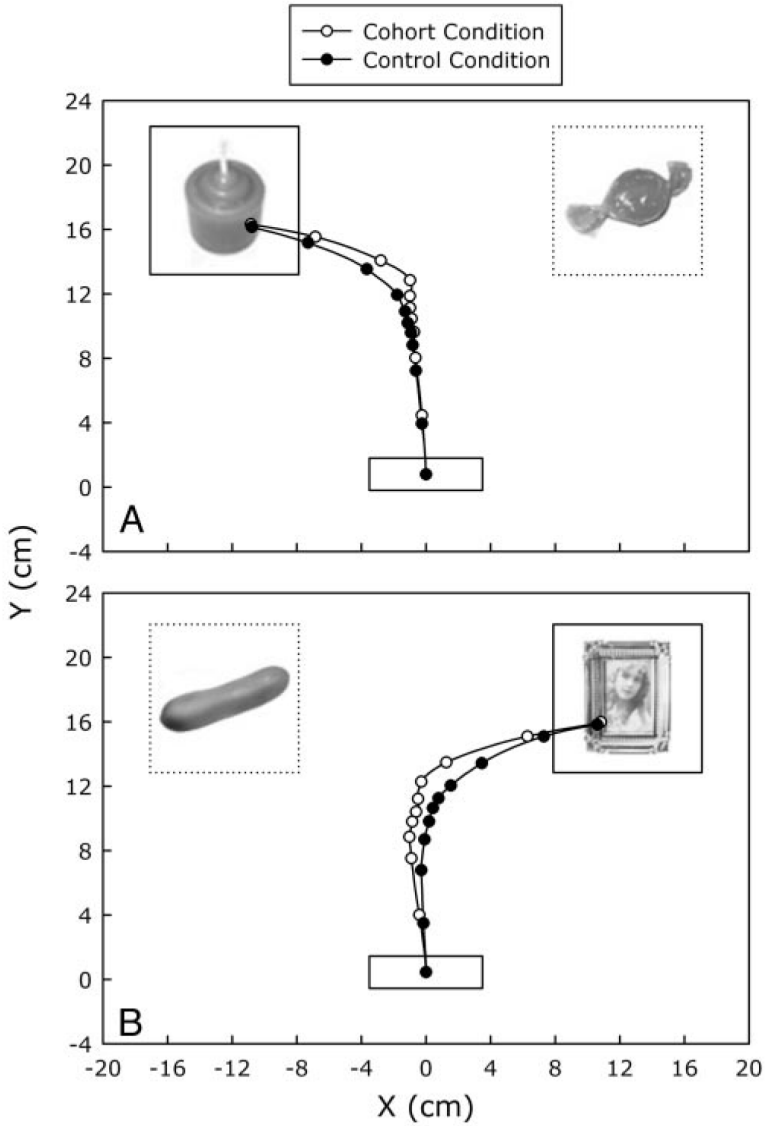
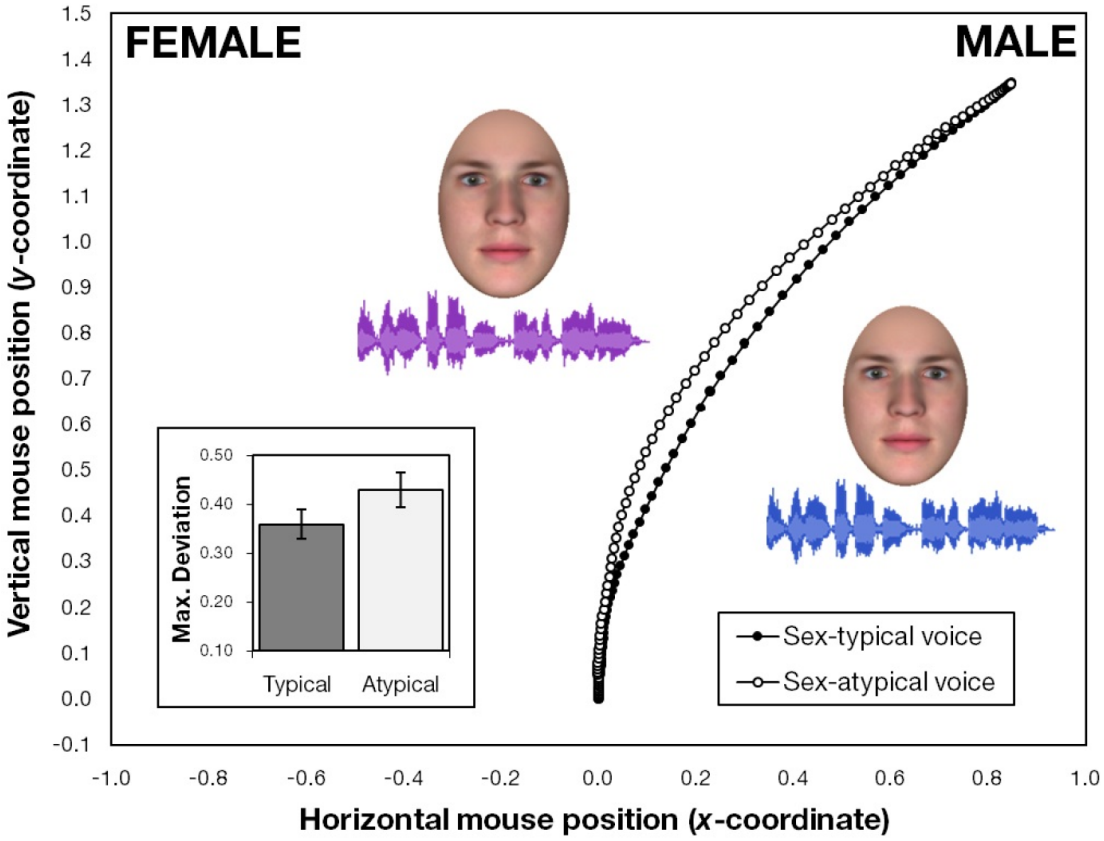
Areas of application
Spoken language



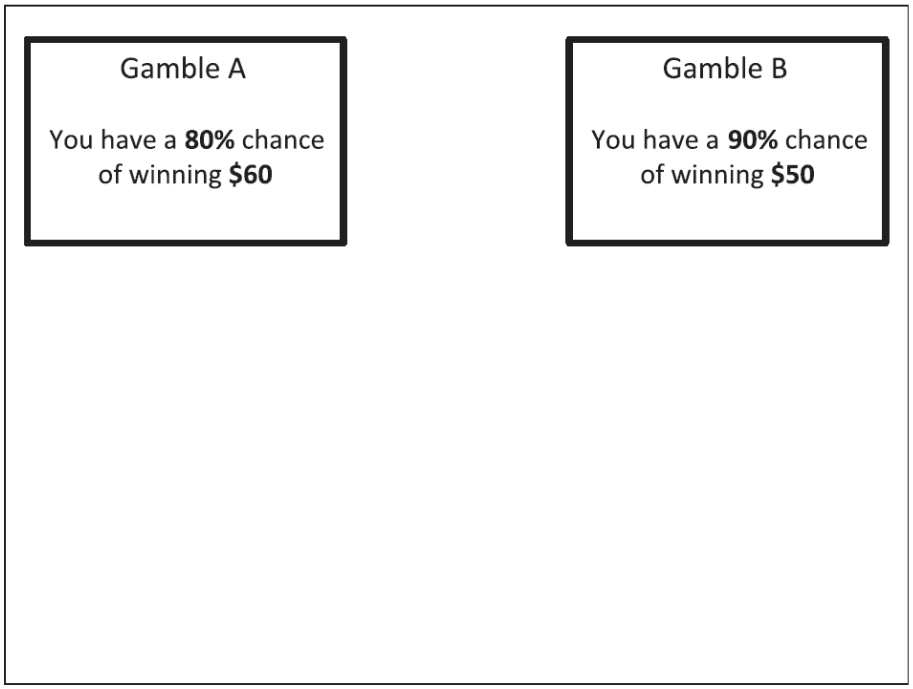
Spivey, Grosjean, Knoblich, 2005

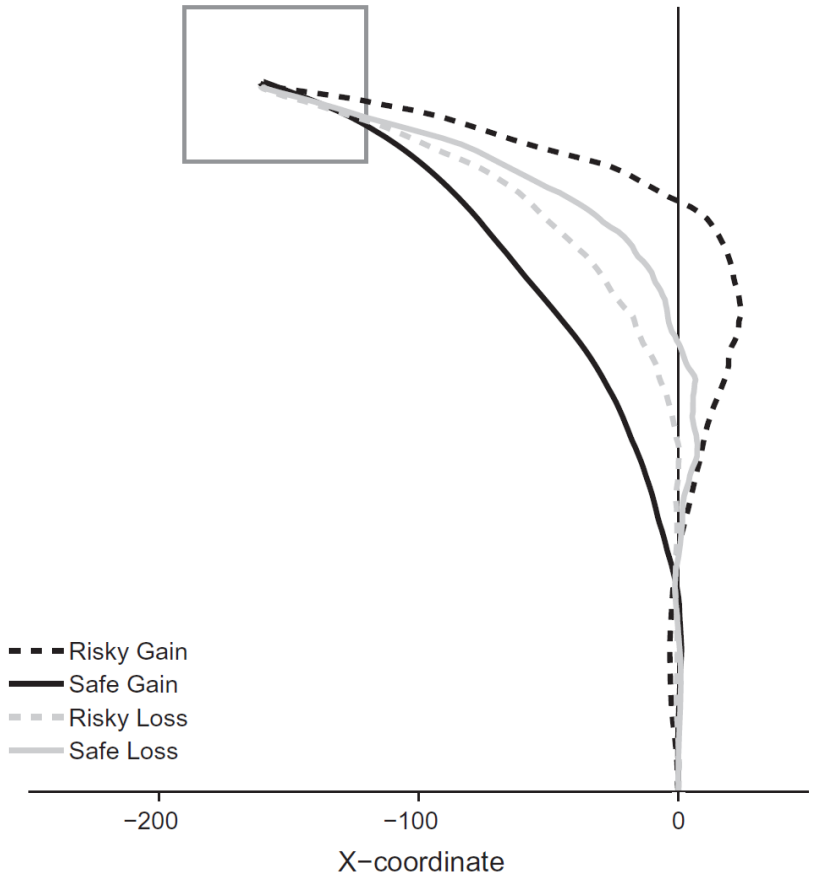
Areas of application
Stereotypes & face and voice



Freeman & Ambady, 2011

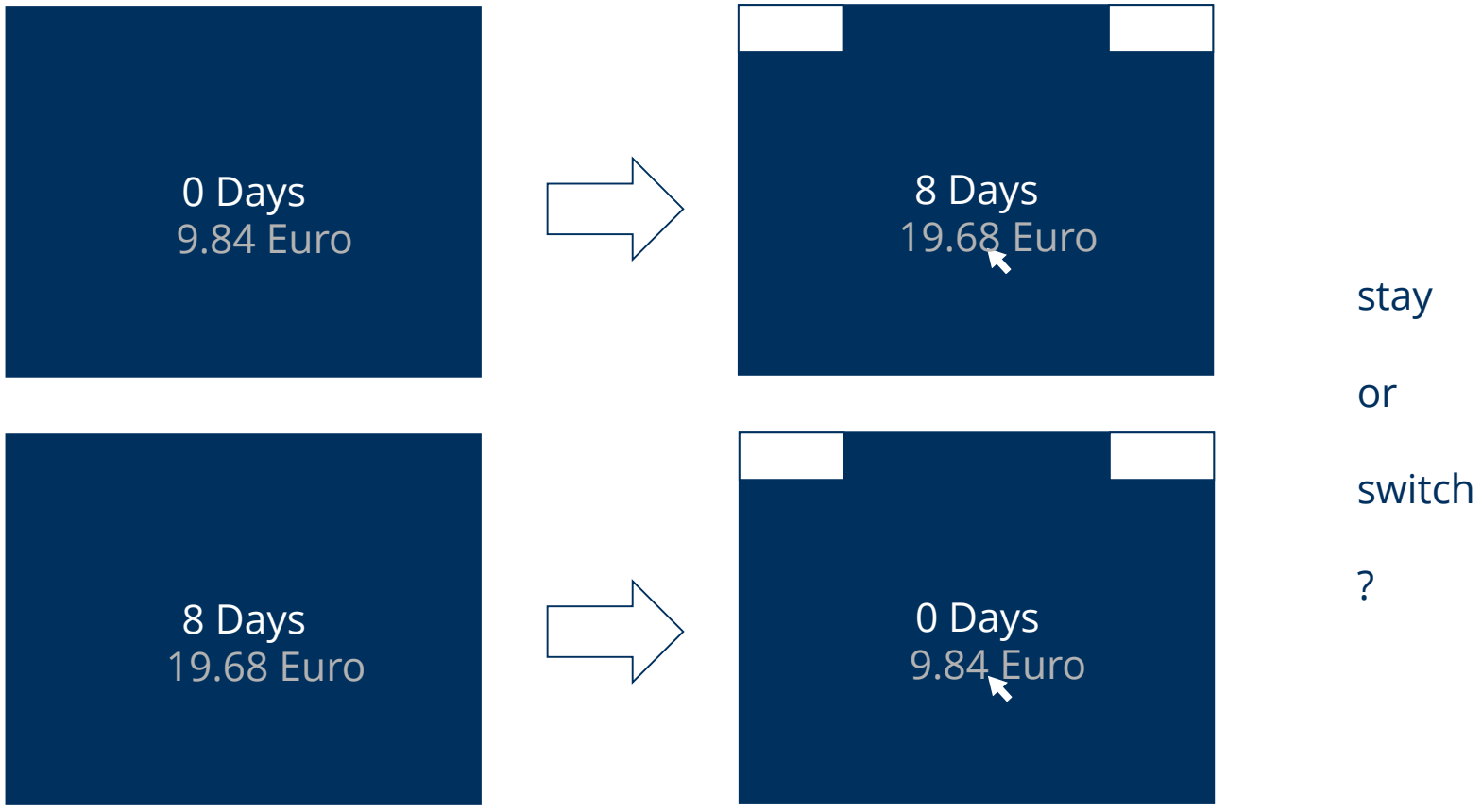
Areas of application
Decision making & risk aversion





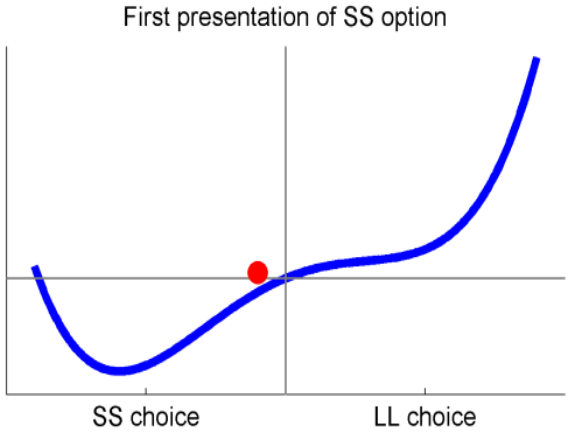
Koop & Johnson, 2013

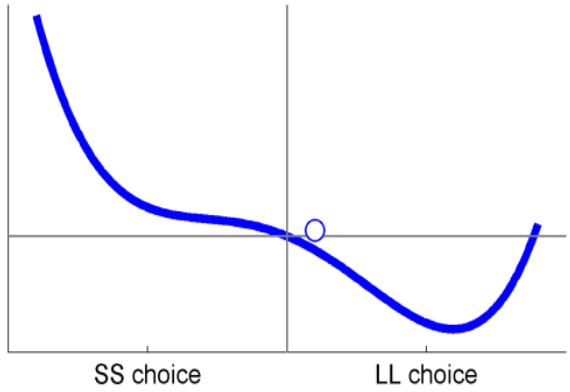
Areas of application
Decision Making & Status Quo Bias

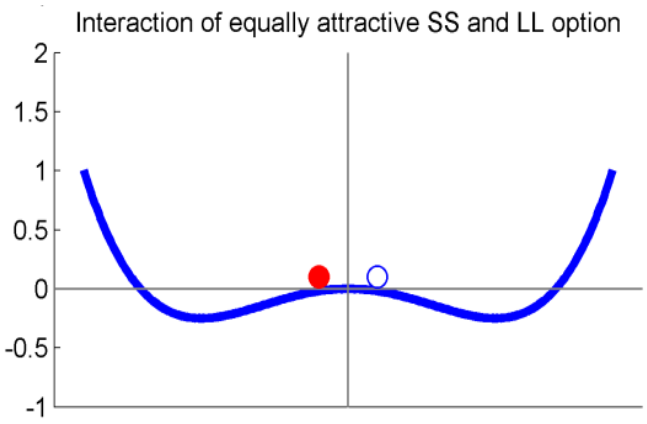


Areas of application
Decision Making & Status Quo Bias

SS = soon & small
LL = late & large

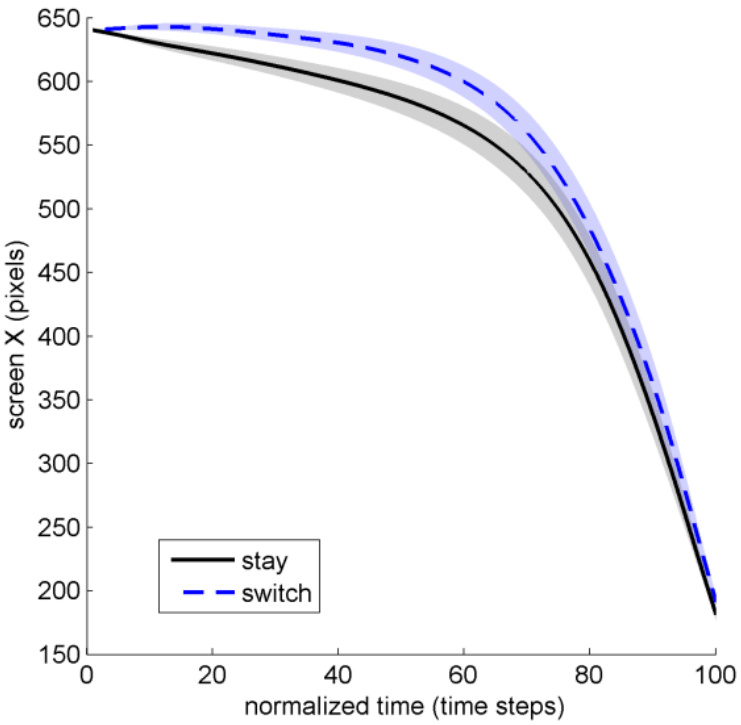






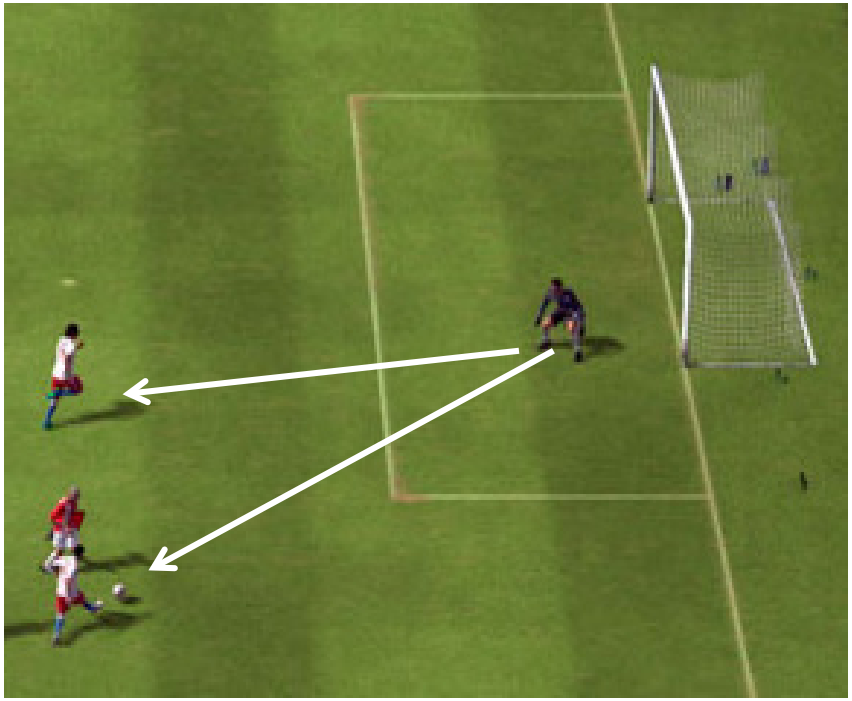
→ *Stay* easier than *switch*

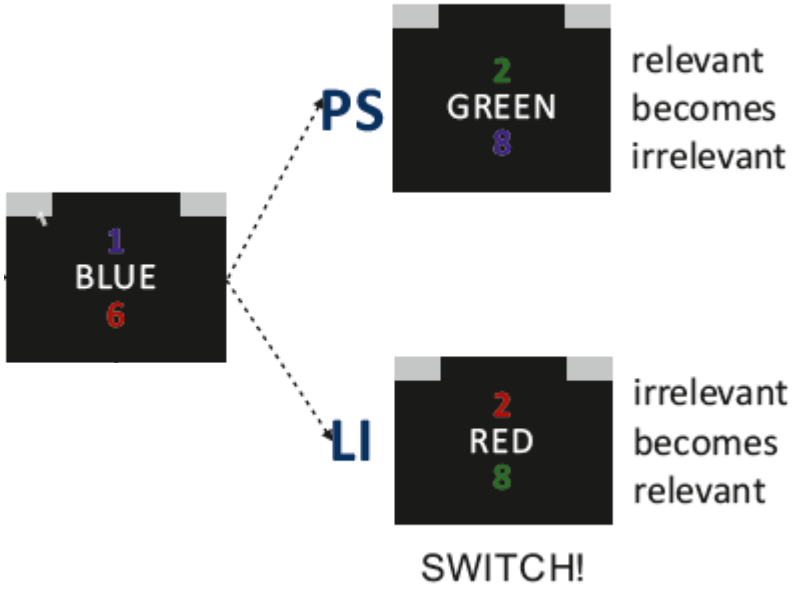
Order of presentation: Results



(Scherbaum, Frisch, Dshemuchadse, 2018)

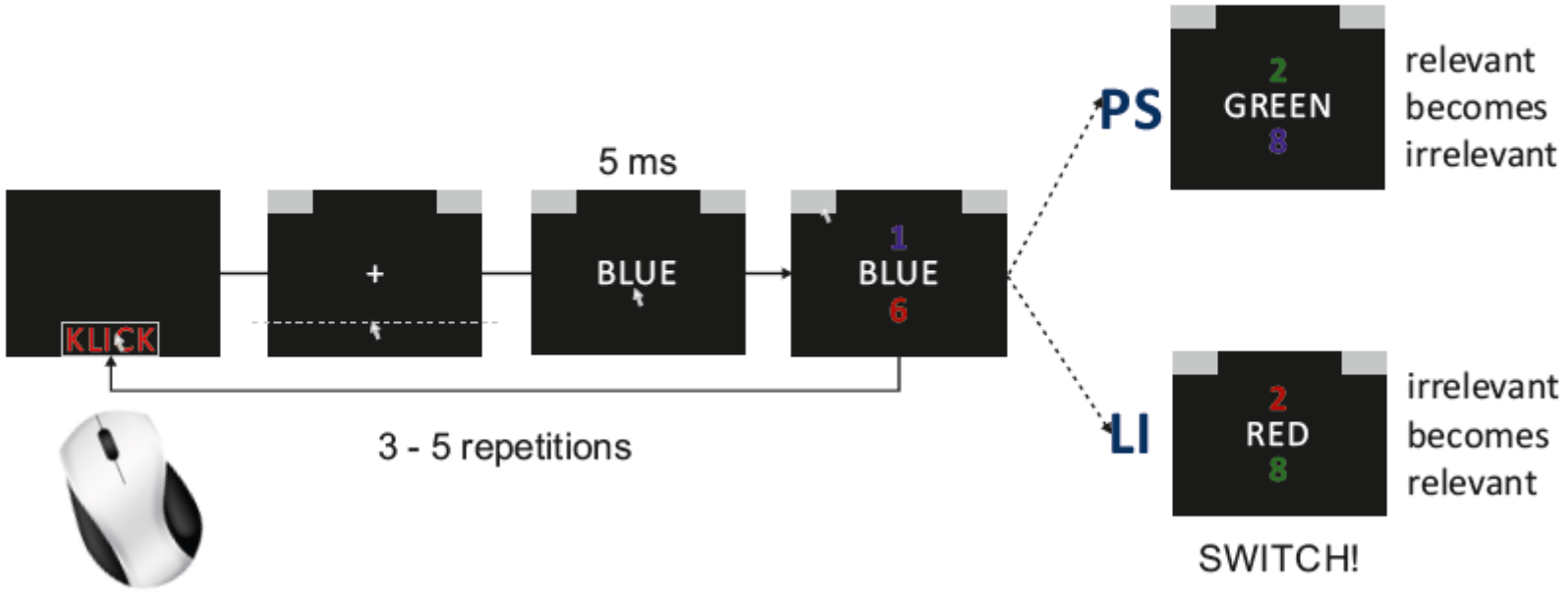
Areas of application
Set-Shifting





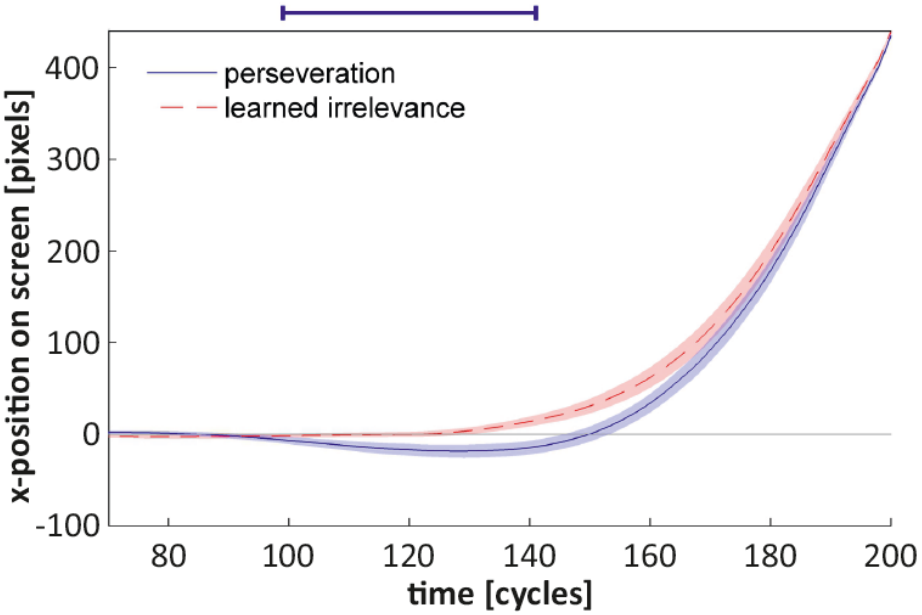
(Dreisbach & Goschke, 2004; Frisch, Dshemuchadse, Görner, Goschke, & Scherbaum, 2015)

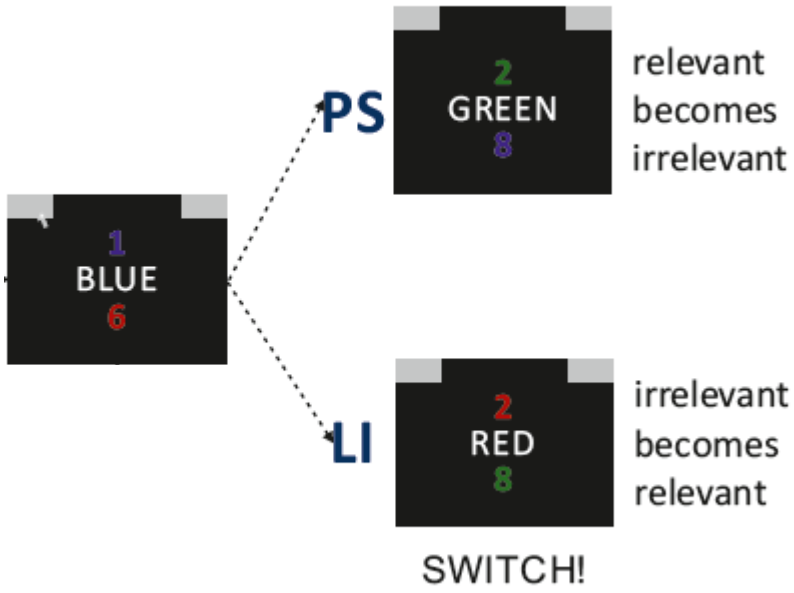
Areas of application
Set-Shifting



Frisch, Dshemuchadse, Görner, Goschke, & Scherbaum, 2015

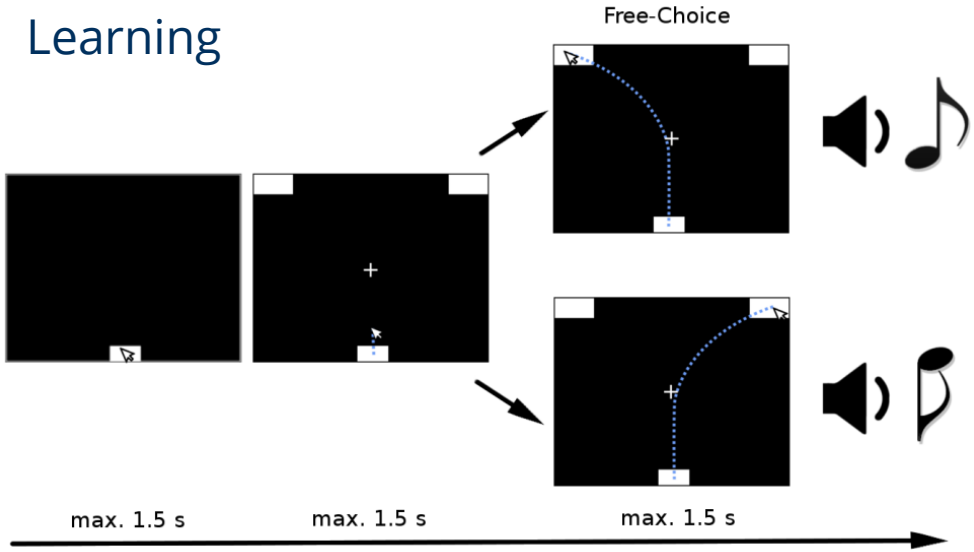
Areas of application
Set-Shifting

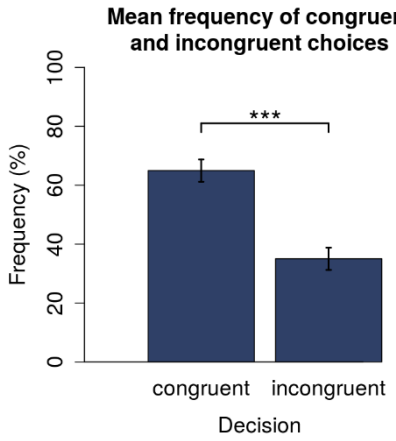




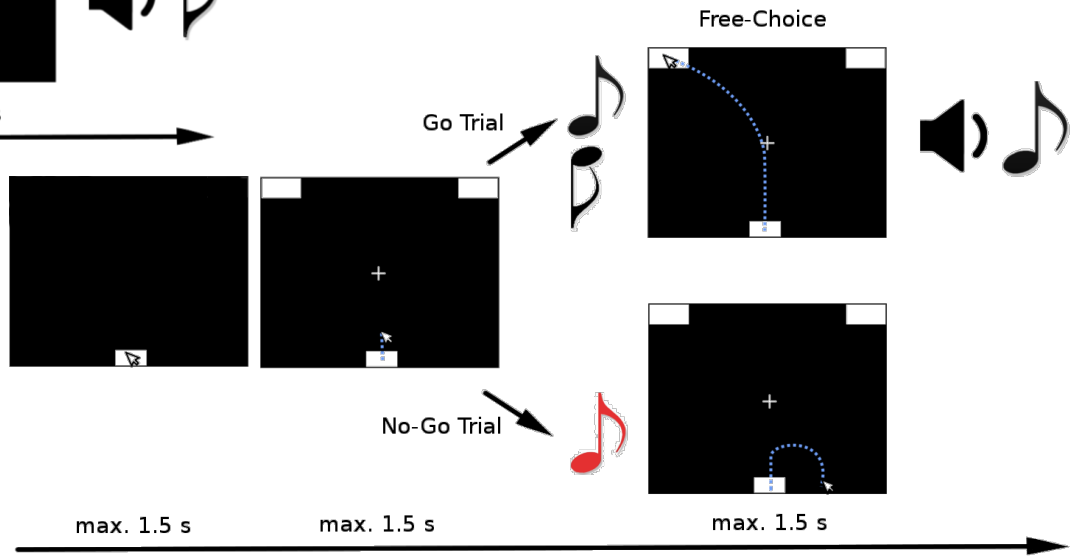
Frisch, Dshemuchadse, Görner, Goschke, & Scherbaum, 2015

Areas of application
Unwanted decision strategies in ideomotor learning





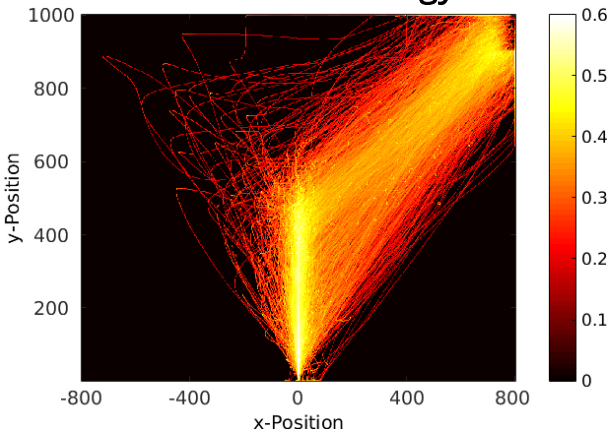
Testing: Will participants choose congruently?

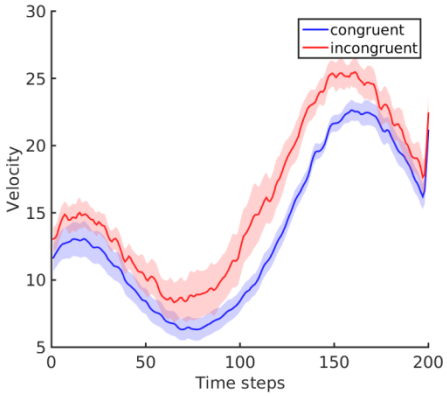


Vogel, Scherbaum, Janczyk, 2018

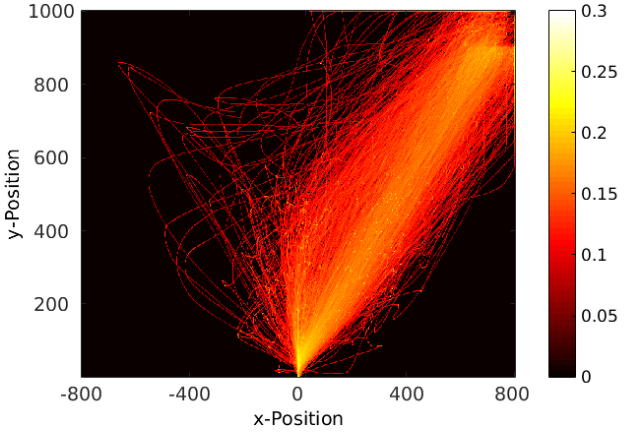
Areas of application
Unwanted decision strategies in ideomotor learning

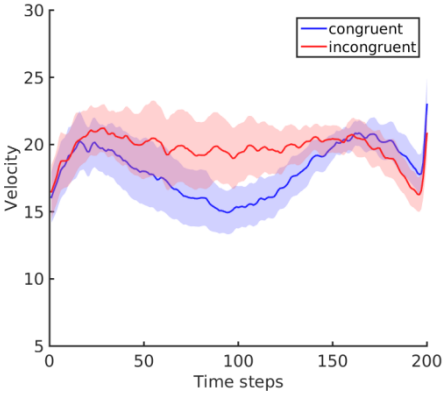
Late decision strategy

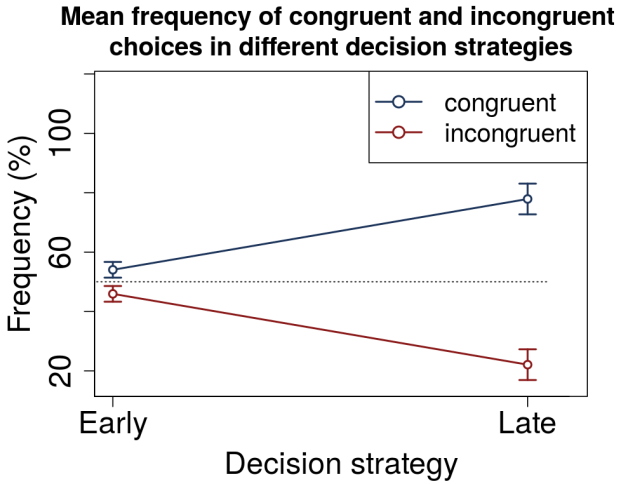




Early decision strategy







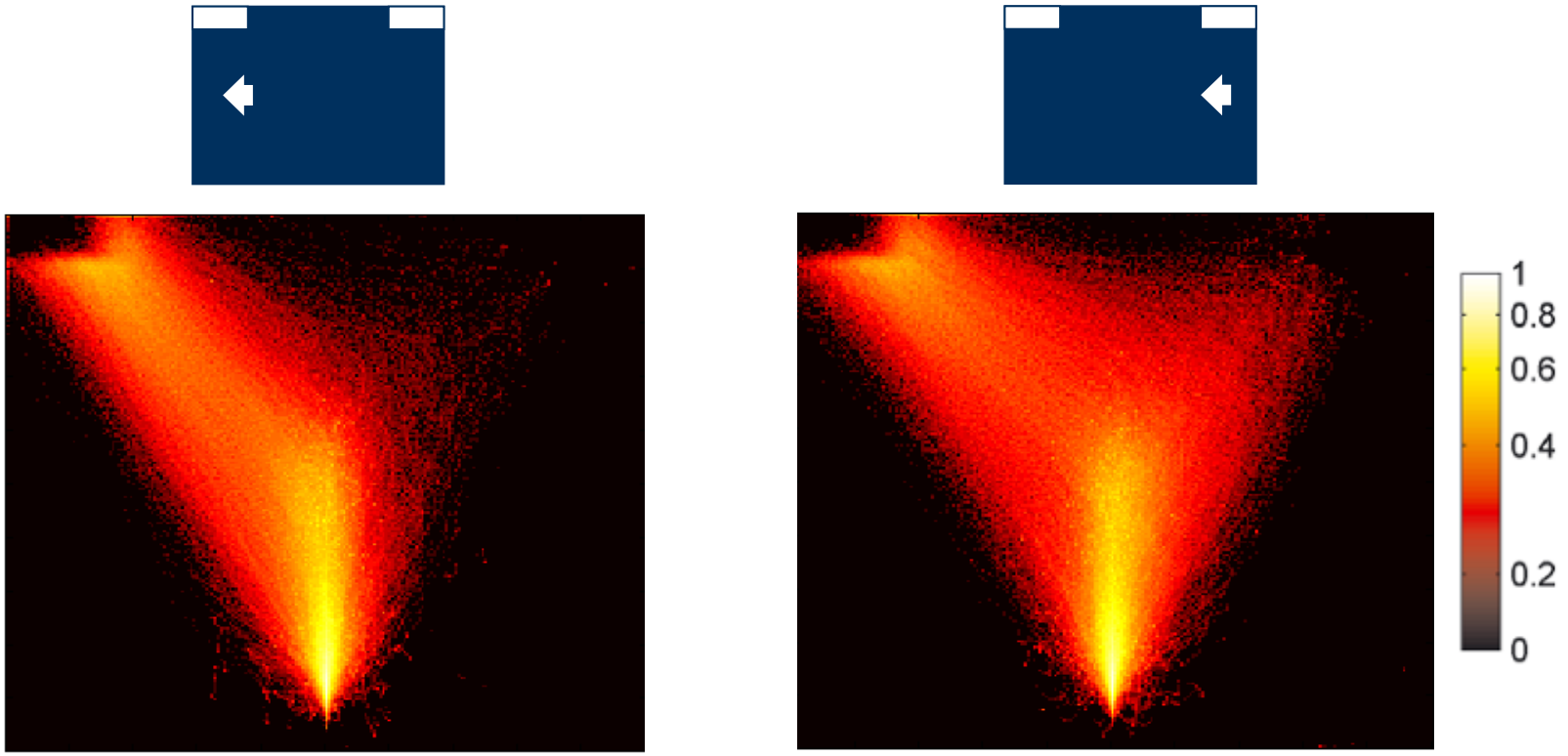
Vogel, Scherbaum, Janczyk, 2018

Areas of application
Cognitive Control: Simon task and cognitive conflict

Simon, 1969

Scherbaum, Dshemuchadse, Fischer, Goschke, 2010

Areas of application
Cognitive Control: Simon task and cognitive conflict



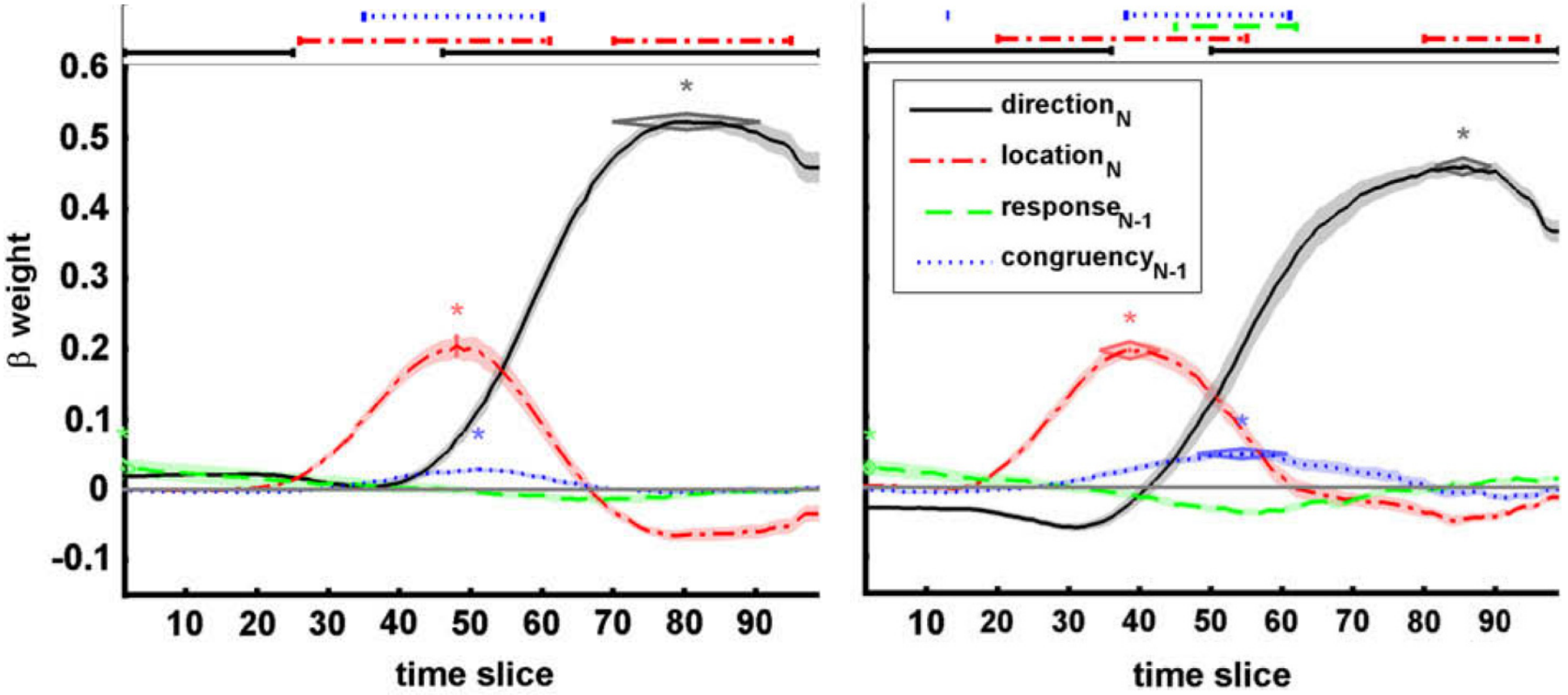
see also Ye & Damian, 2023

Areas of application
Cognitive Control: Simon Task and cognitive conflict

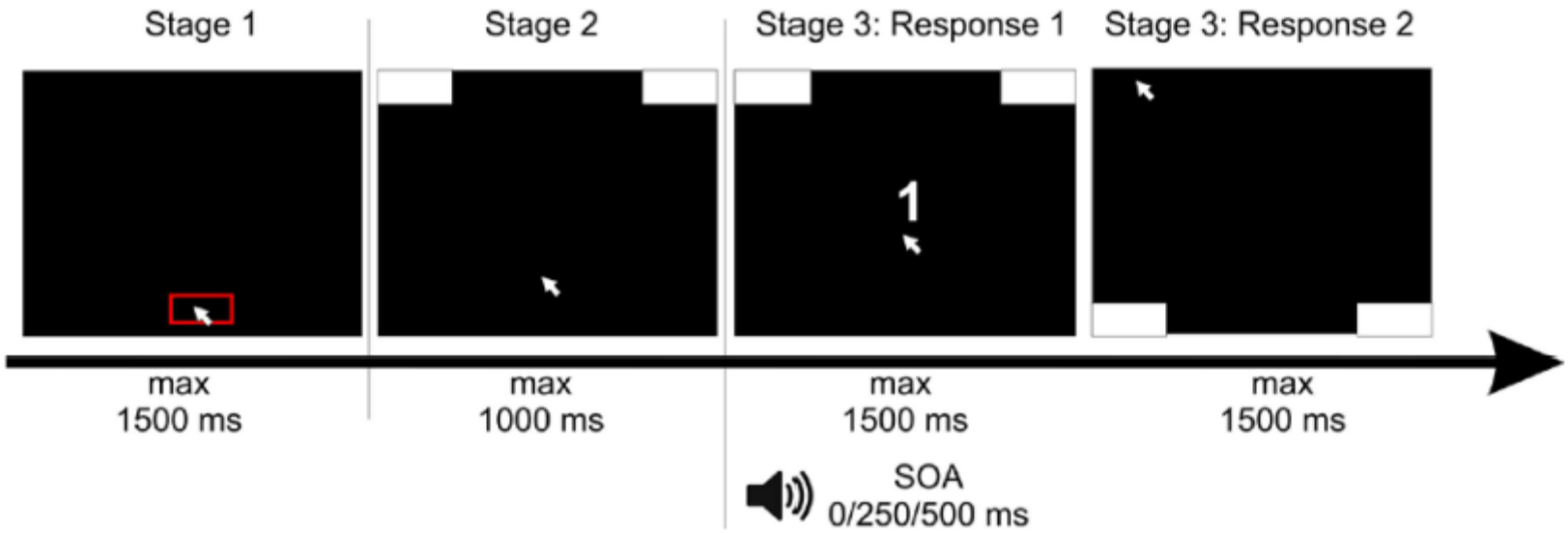
Time course of influences in TCMR

Fast trials

Slow trials



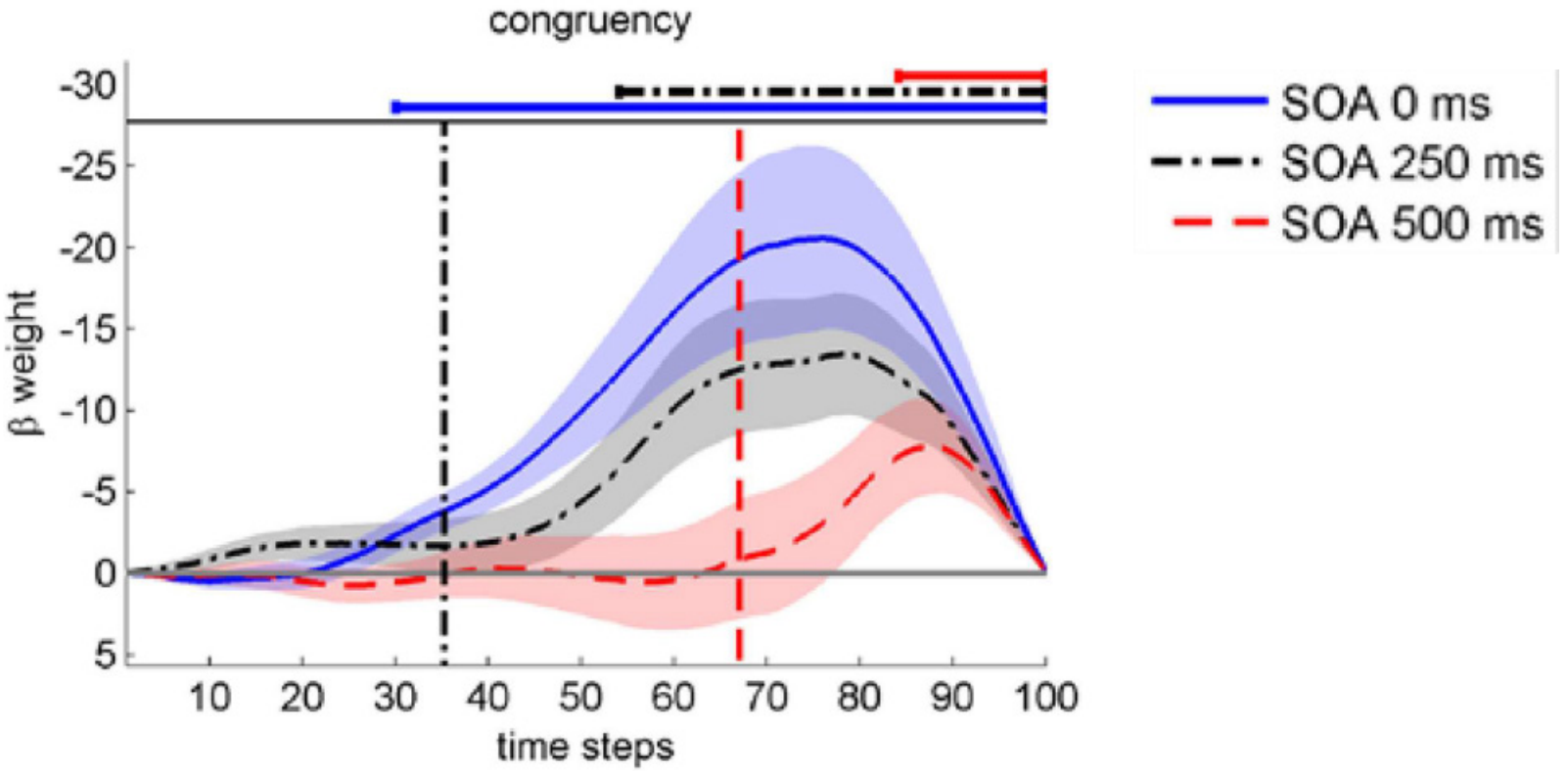
Areas of application
Multitasking



Scherbaum, Gottschalk, Dshemuchadse, Fischer, 2015

Areas of application
Multitasking

Time course of influences in TCMR



ıalk, Dshemuchadse, Fischer, 2015

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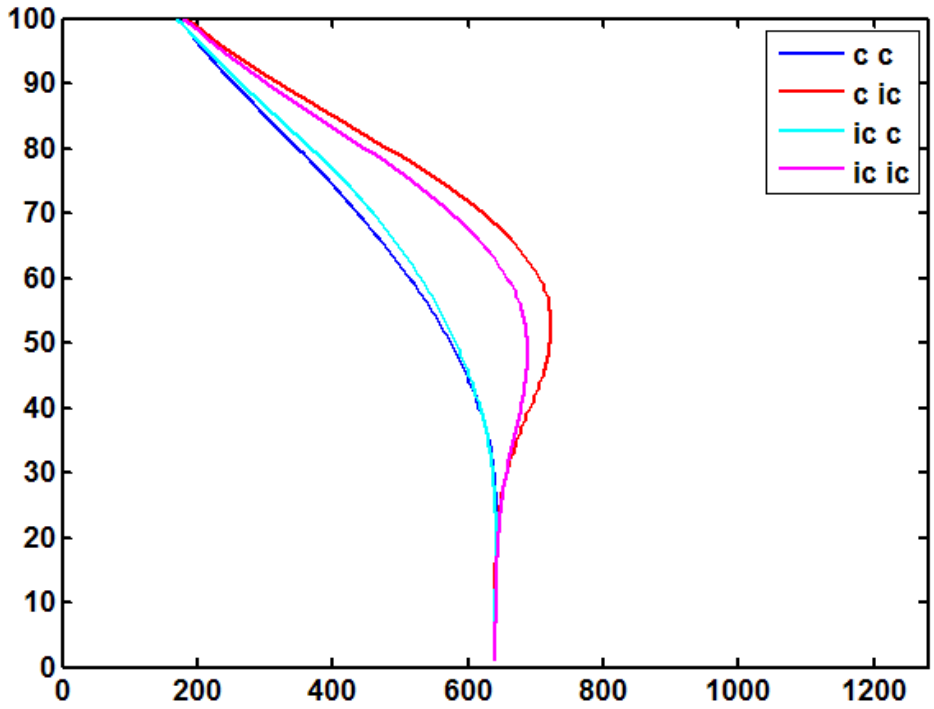
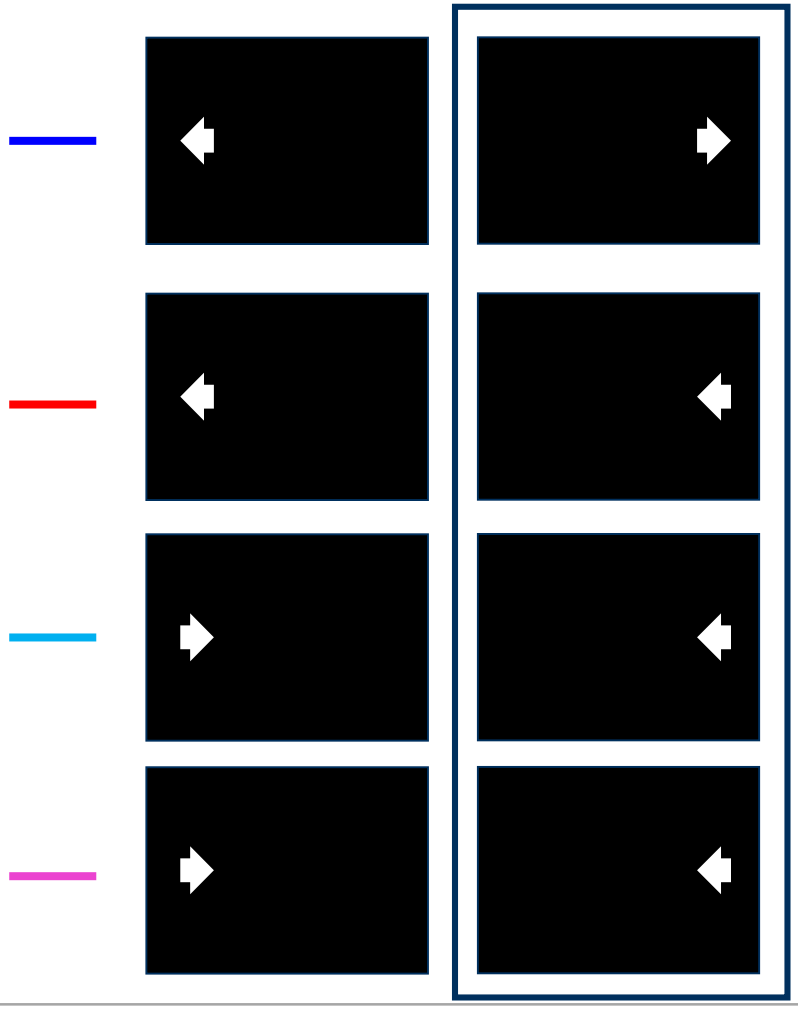
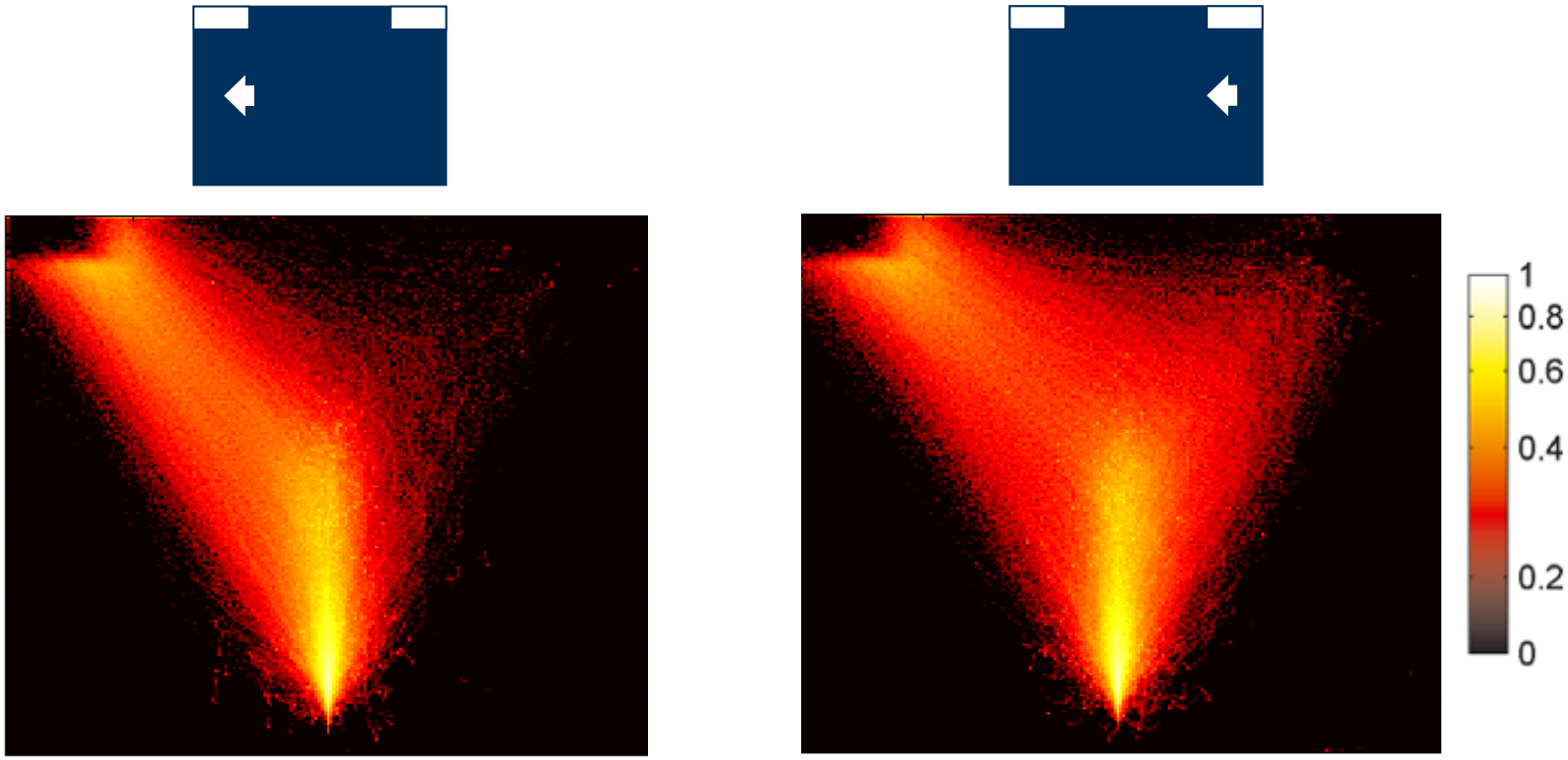
Methods of Analysis
2D Coordinates





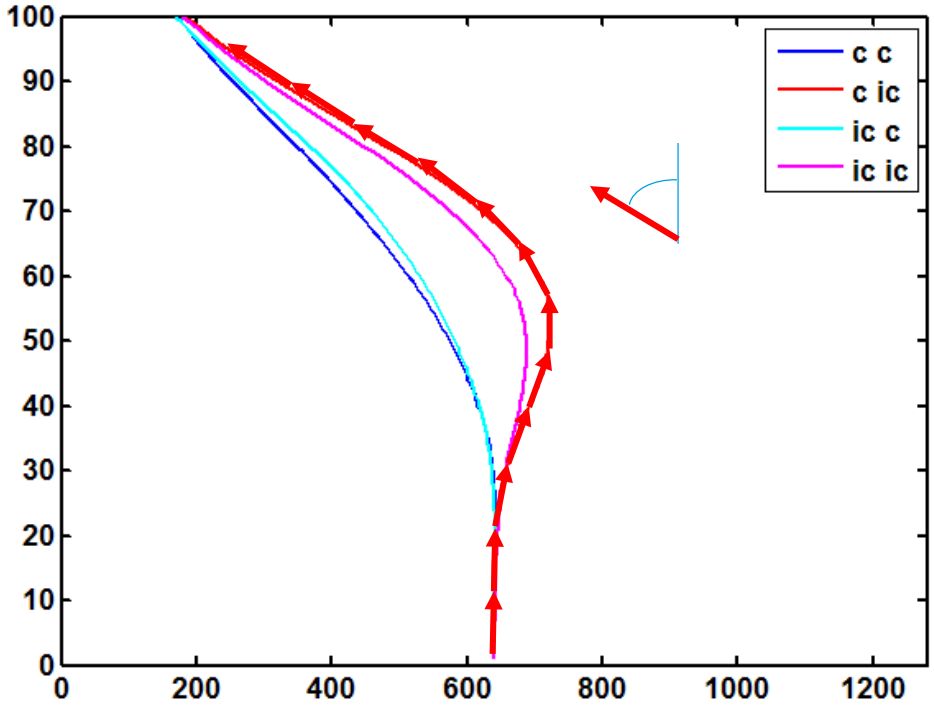
Interpretation:
Whatever you want to read into it qualitatively

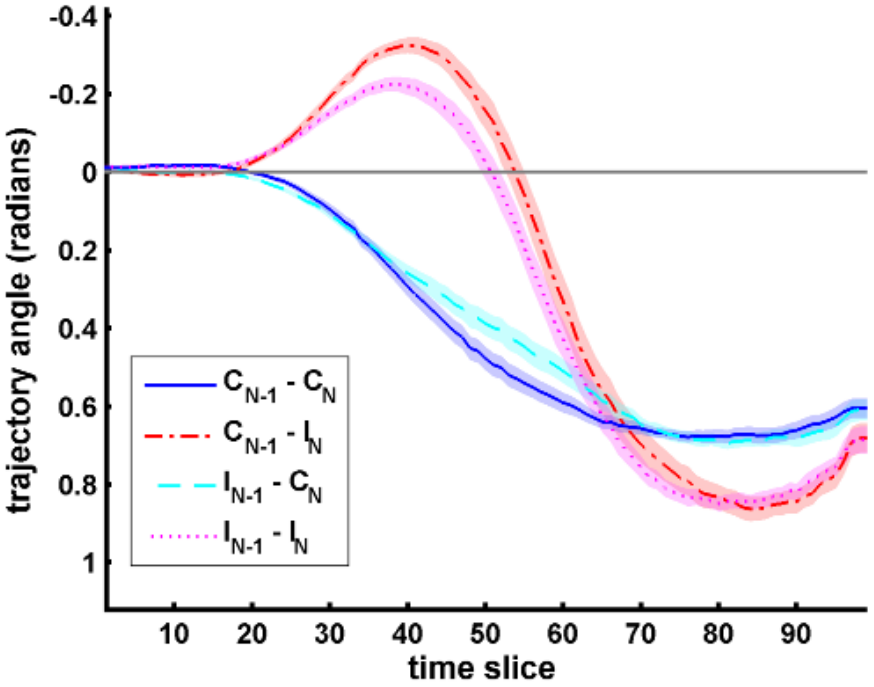
Methods of Analysis
Heat Maps



Interpretation:
Consistency of movements and biases on movements

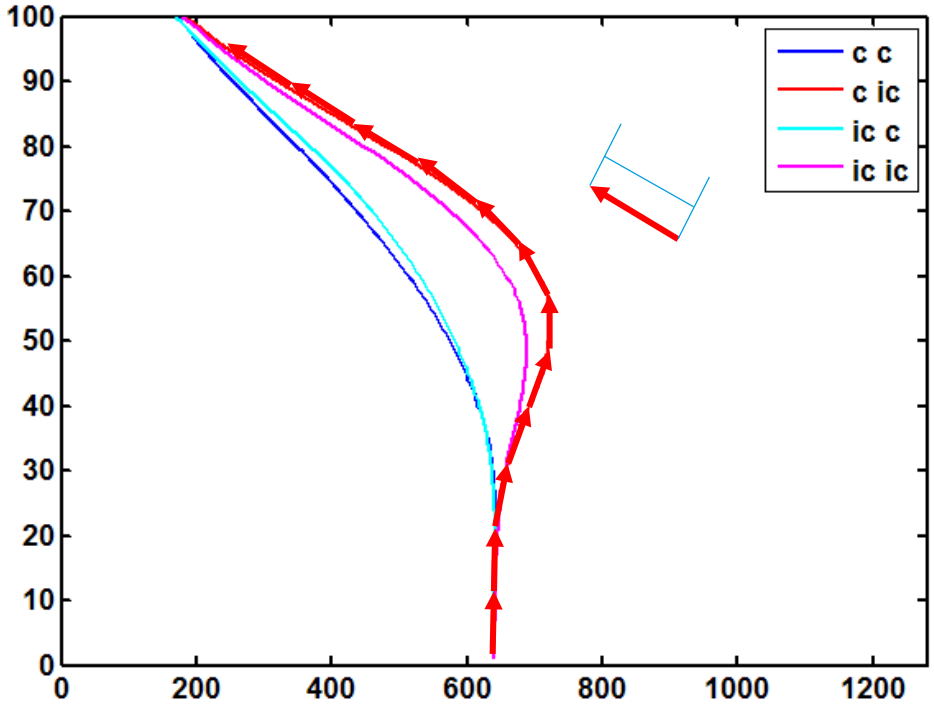
Methods of Analysis
Trajectory Angle

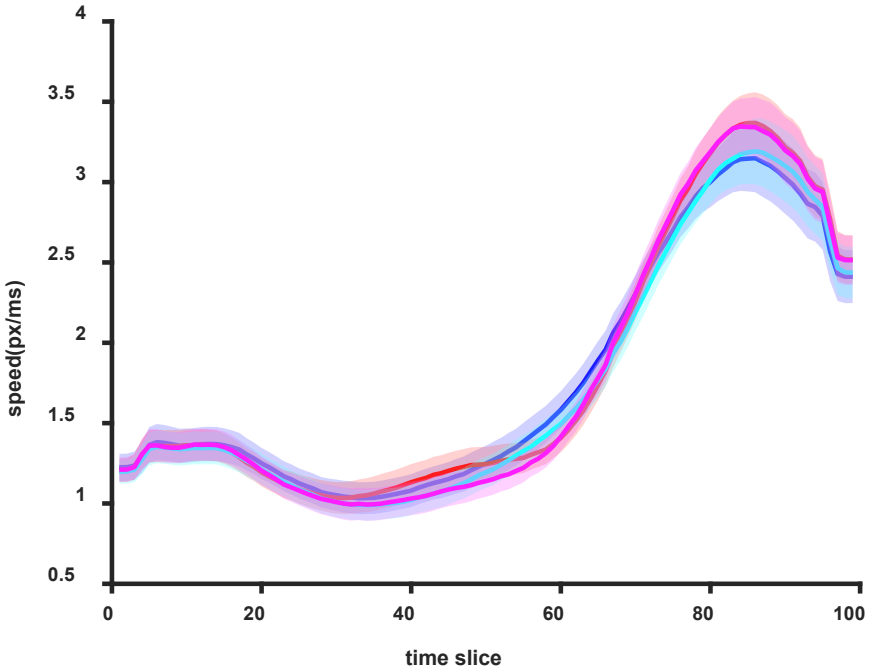




Interpretation:
Direct influences on movement direction

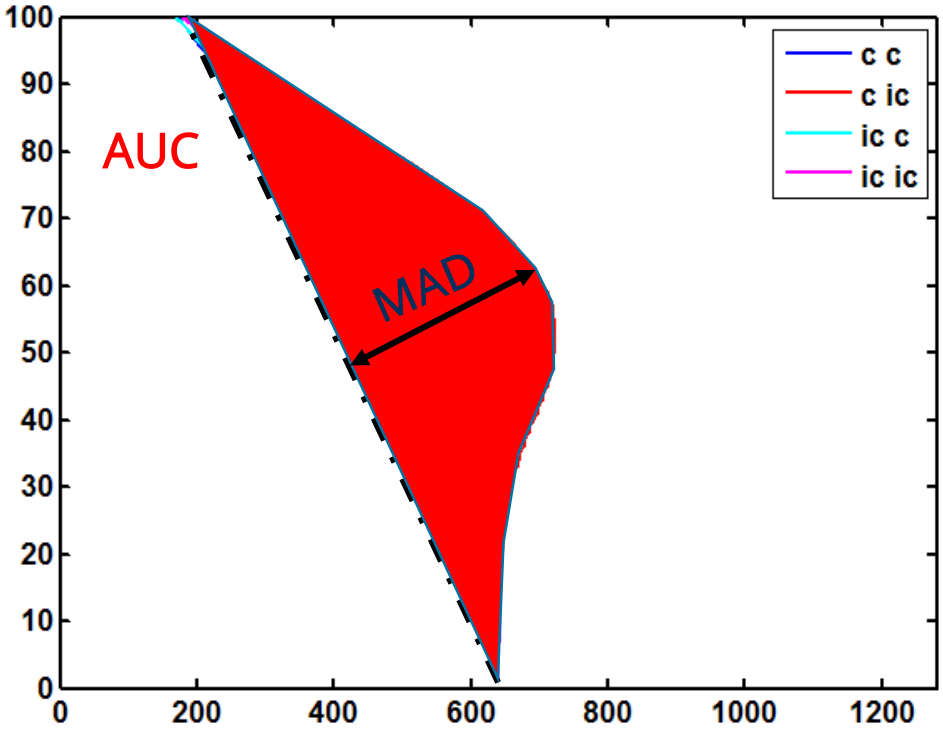
Methods of Analysis
Velocity

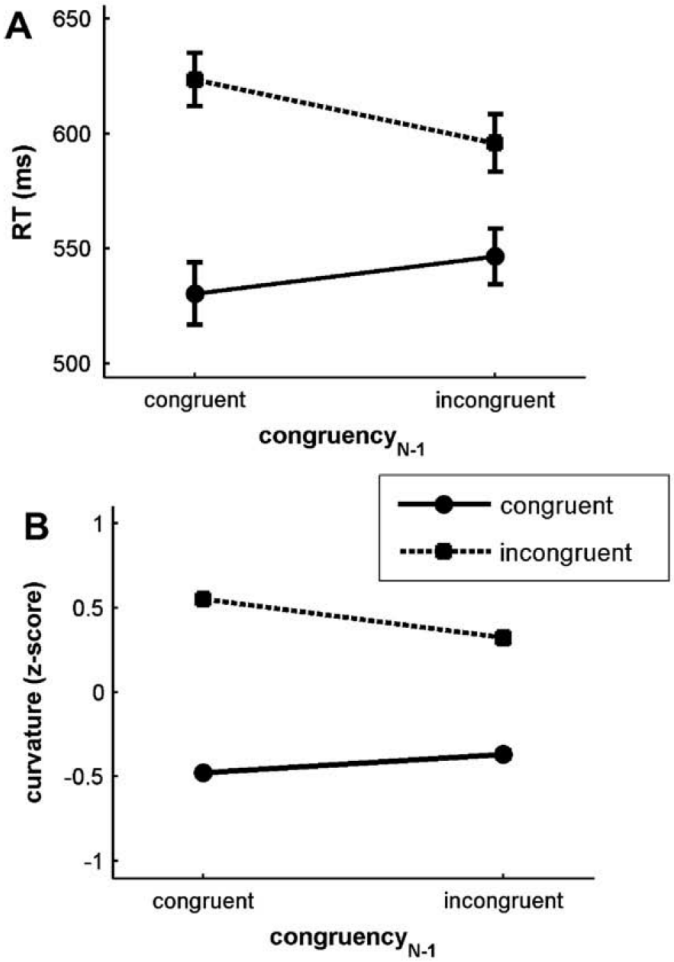




Interpretation:
Speed of processing, cognitive effort

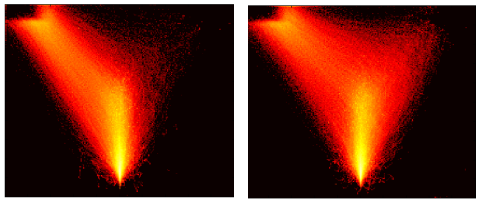
Methods of Analysis
Static measures: Area under curve, Maximum Deviation

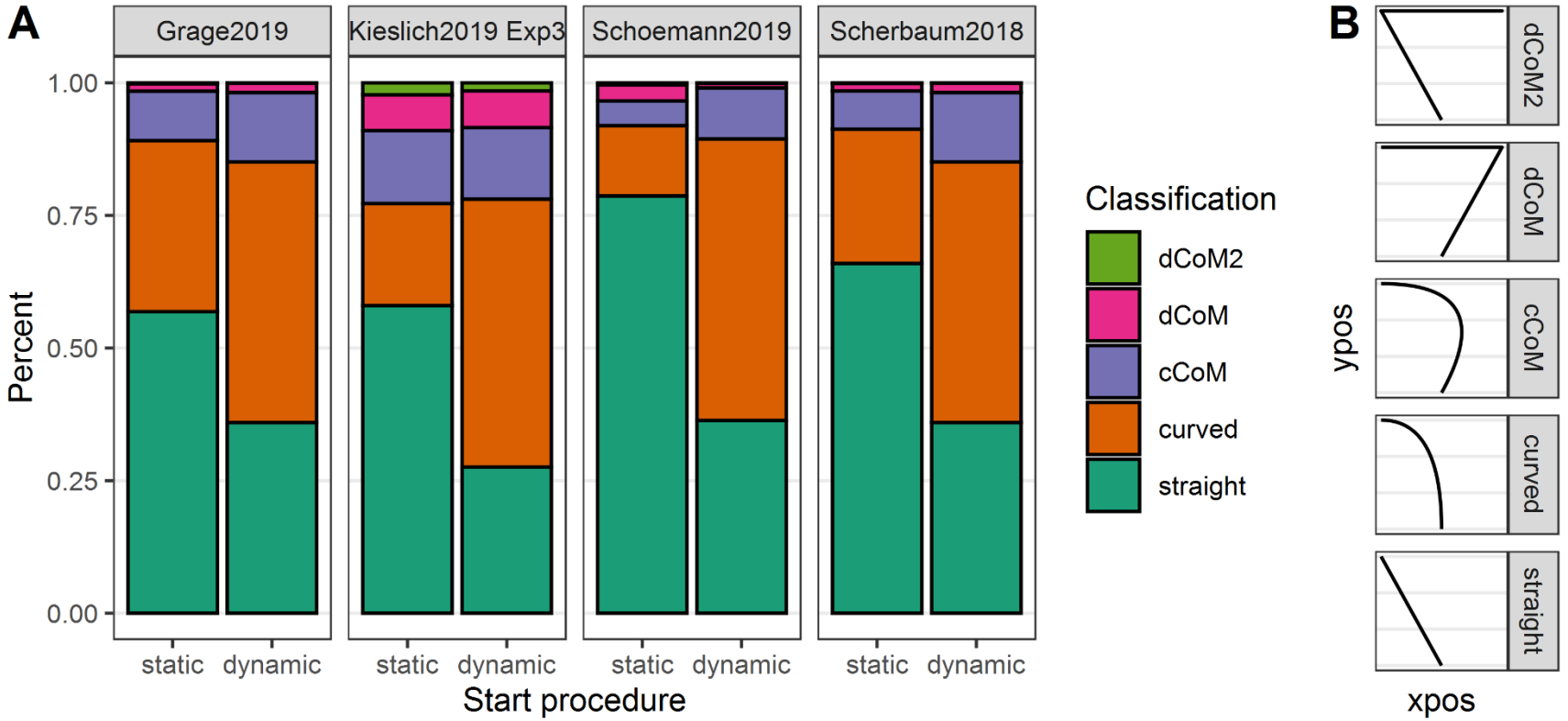




Interpretation:
Strength of conflict or bias

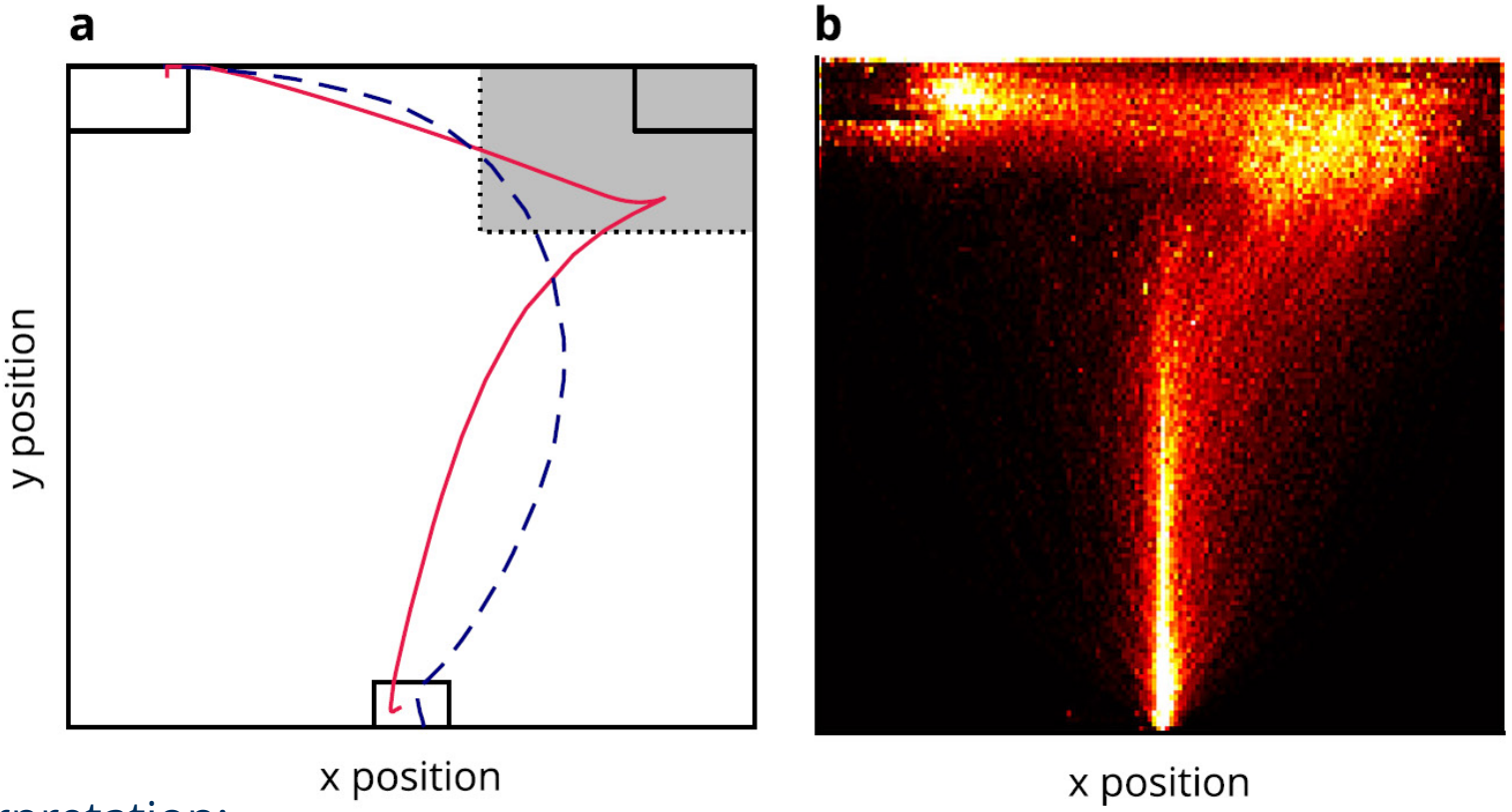
Methods of Analysis
Movement Prototypes





Interpretation:
Quality of conflict or bias / consistency of movements (/ dual systems)

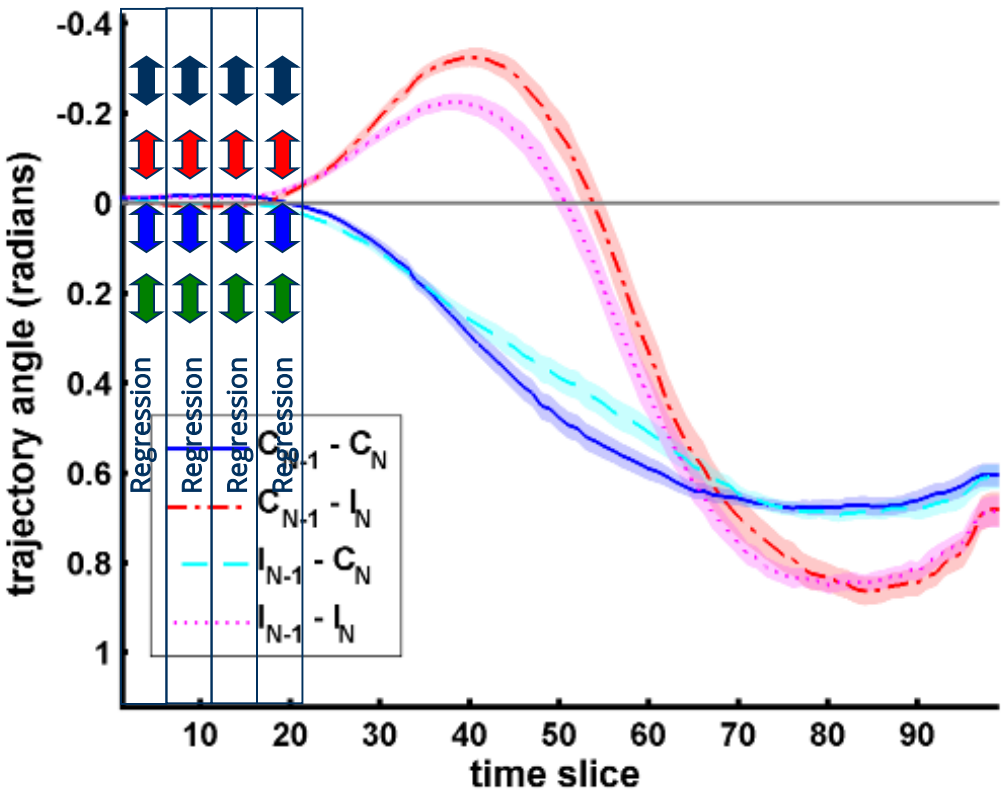
Methods of Analysis
Discrete changes of mind (dCoM) classification



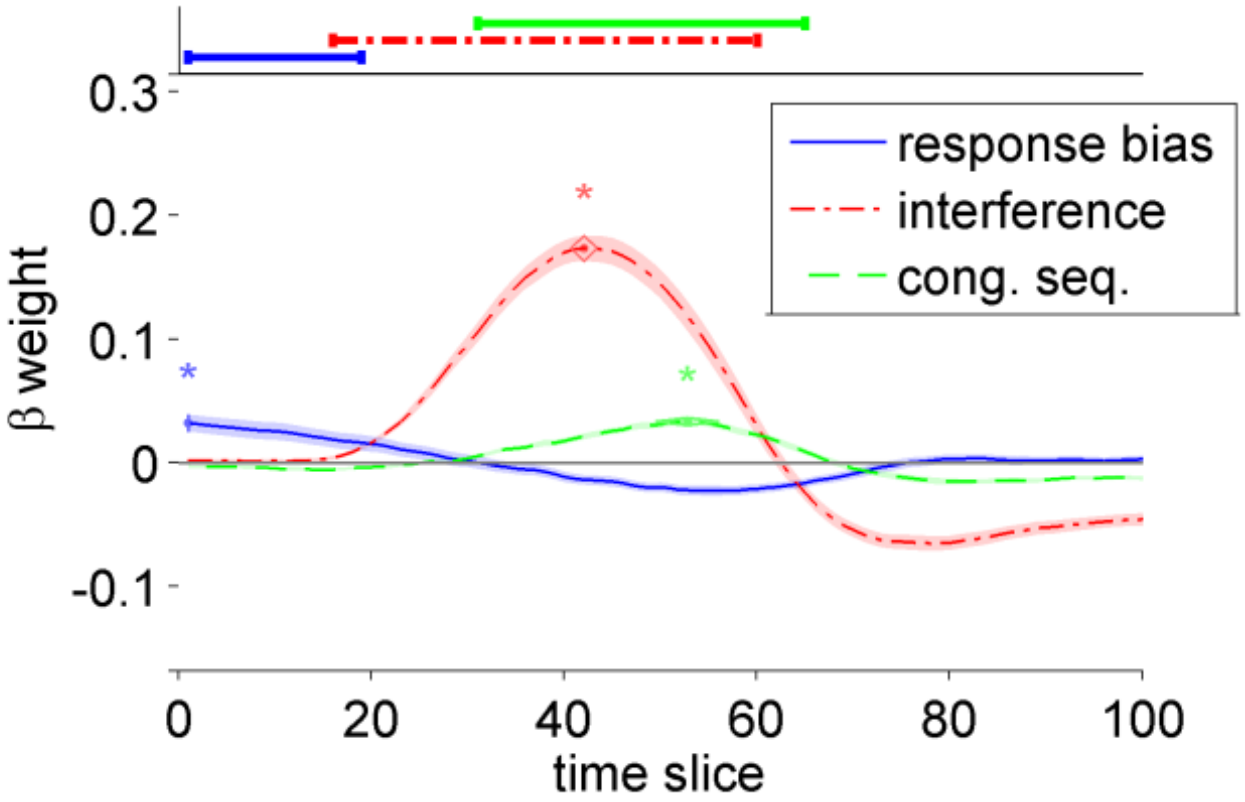
Interpretation:
Quality of conflict or bias / consistency of movements (/ dual systems)

Methods of Analysis
Dissection of influences: Time-continuous regression

- Direction
- Location
- prev. conflict
- prev. response



Methods of Analysis
Dissection of influences: Time-continuous regression

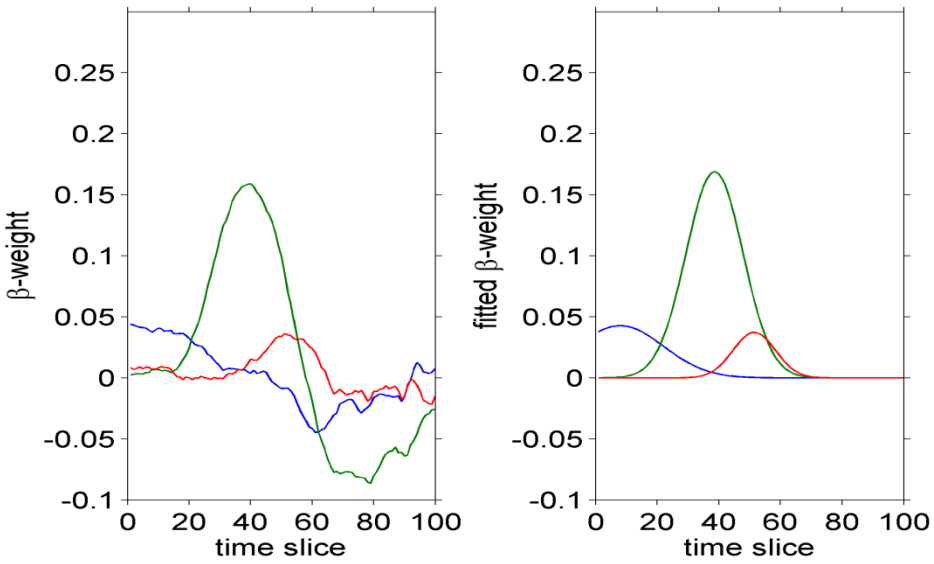


Interpretation:
Strength of different influences at different points in time

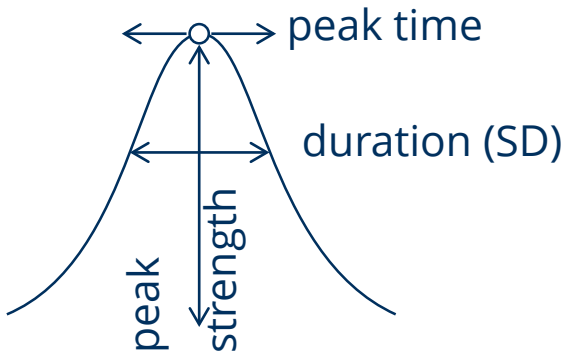
Methods of Analysis
Dissection of influences: Time-continuous regression & extraction of individual measures

Gauss fitting

Extracted β-weights from time-series data



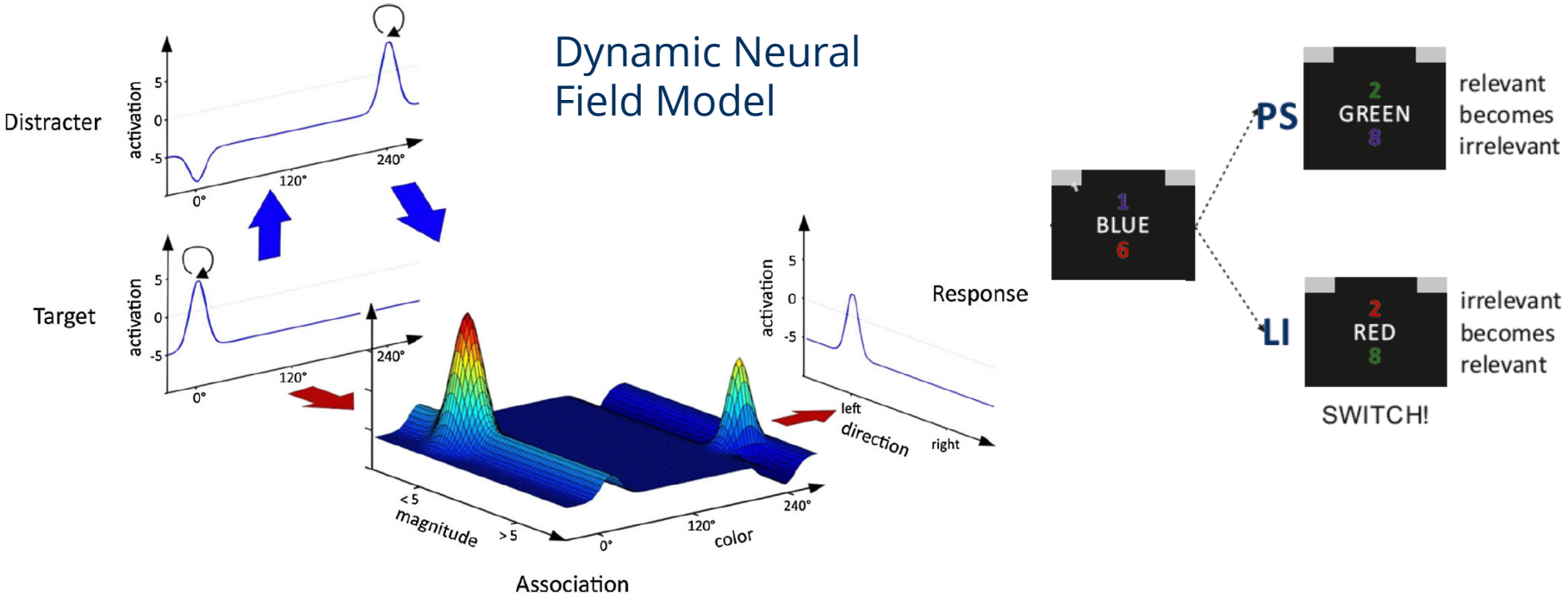
Fitted β-weights



Scherbaum & Dshemuchadse, 2020

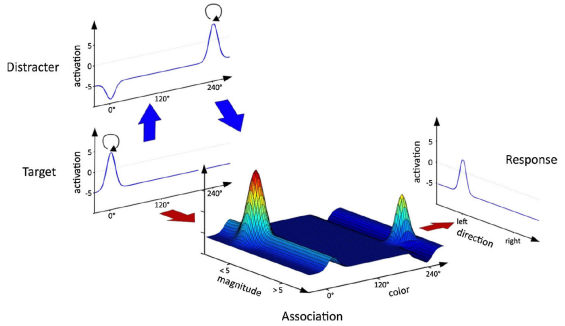
Interpretation:
Strength, duration and timing of different influences

Methods of Analysis and Synthesis: Modelling trajectories

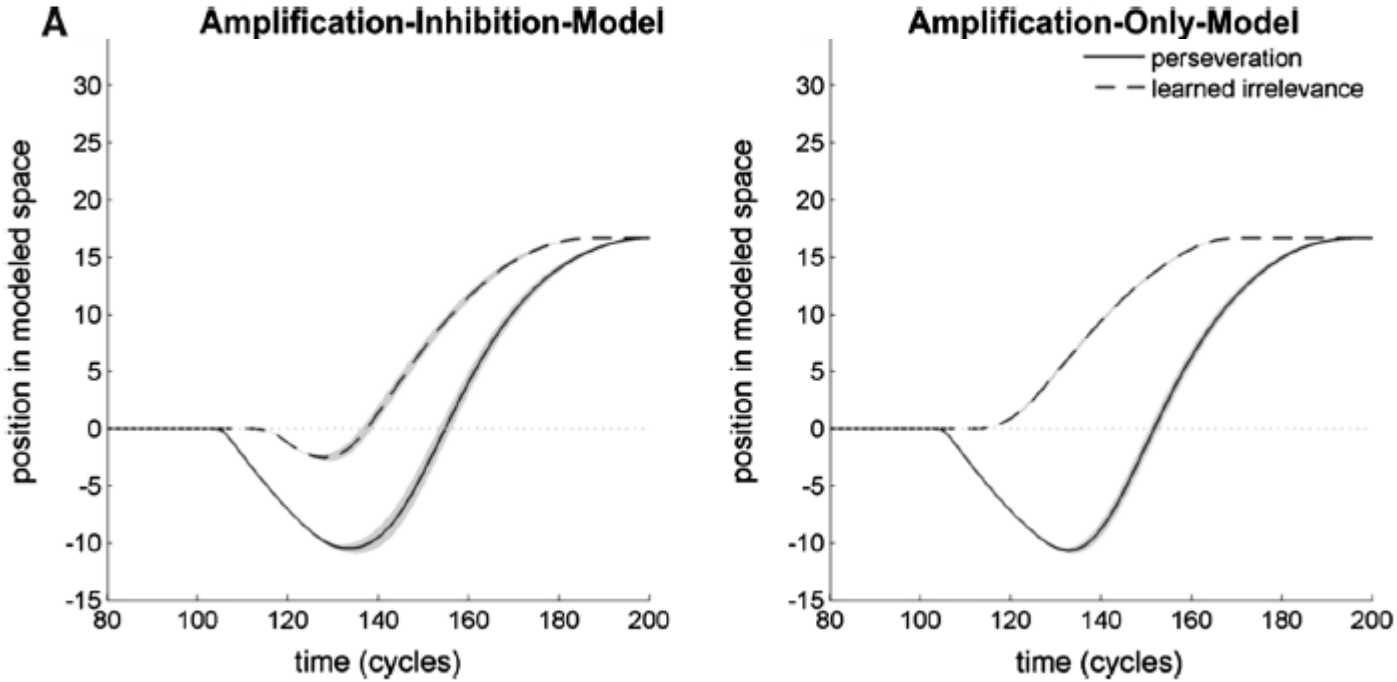


Frisch, Dshemuchadse, Görner, Goschke, & Scherbaum, 2015

Methods of Analysis and Synthesis: Modelling trajectories

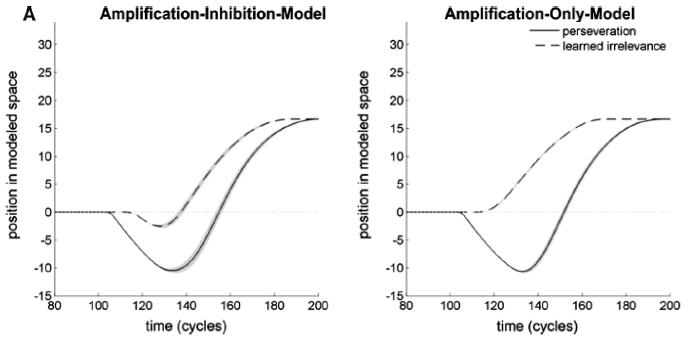


Predicted Movements

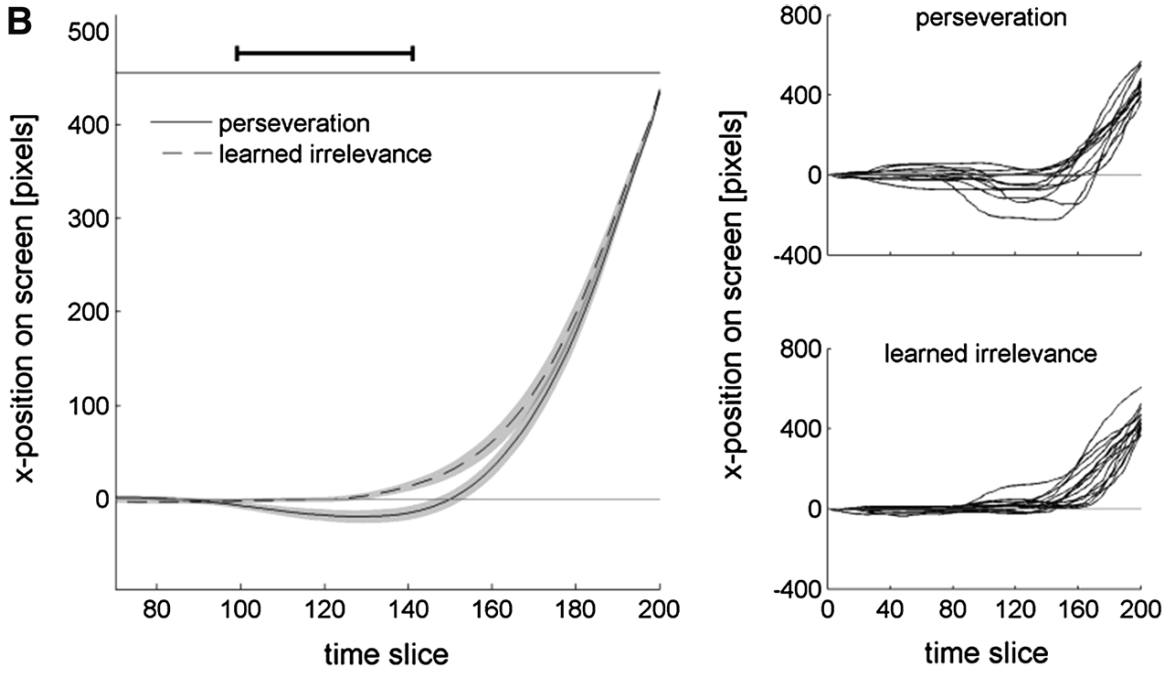


Frisch, Dshemuchadse, Görner, Goschke, & Scherbaum, 2015

Methods of Analysis and Synthesis: Modelling



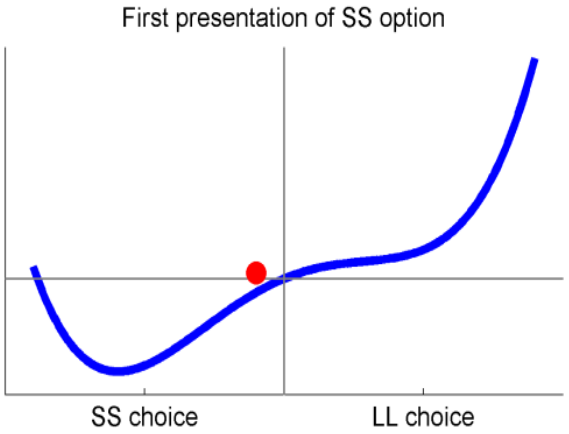
Measured Movements

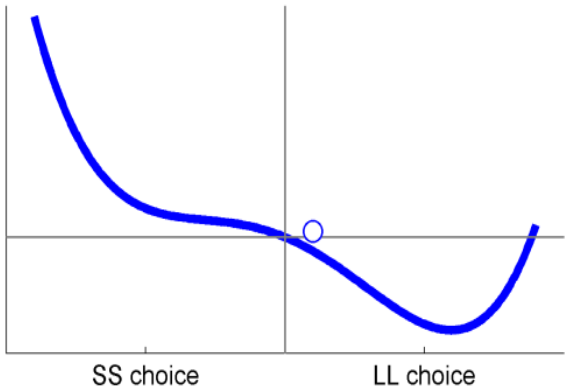


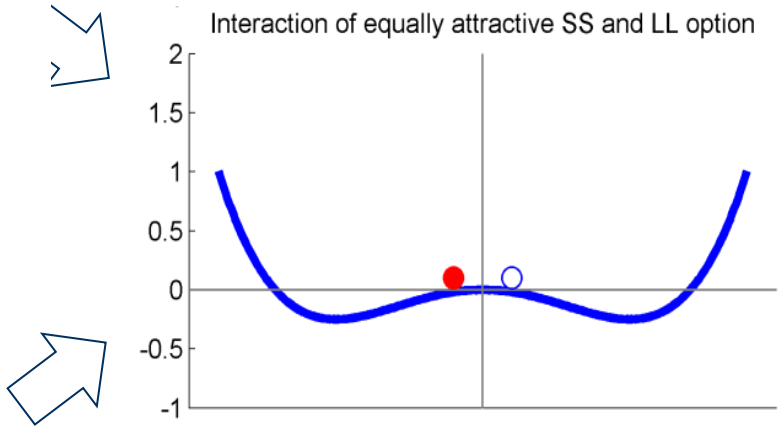
Frisch, Dshemuchadse, Görner, Goschke, & Scherbaum, 2015

Methods of Analysis and Synthesis: Modelling trajectories

SS = soon & small
LL = late & large



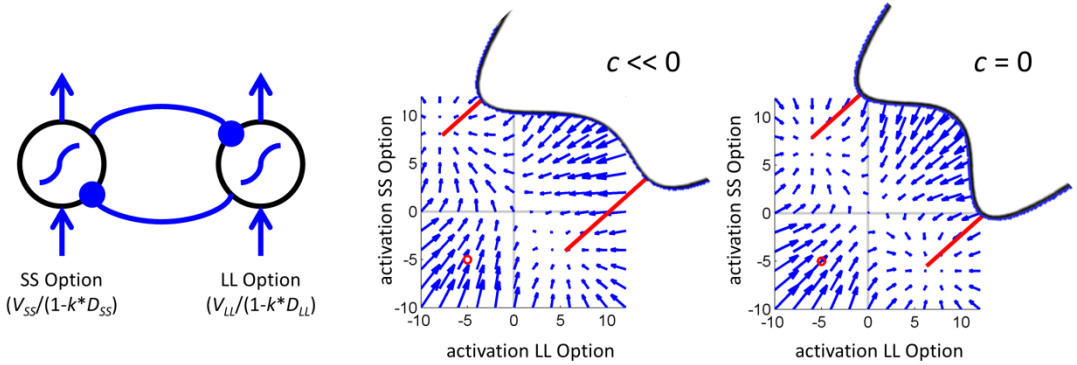




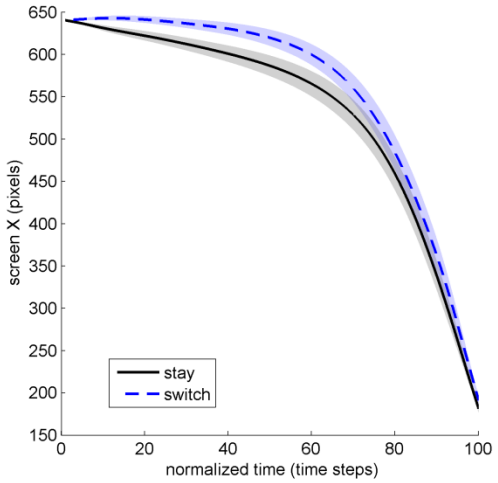
→ *Stay* easier than *switch*

Methods of Analysis and Synthesis: Modelling trajectories

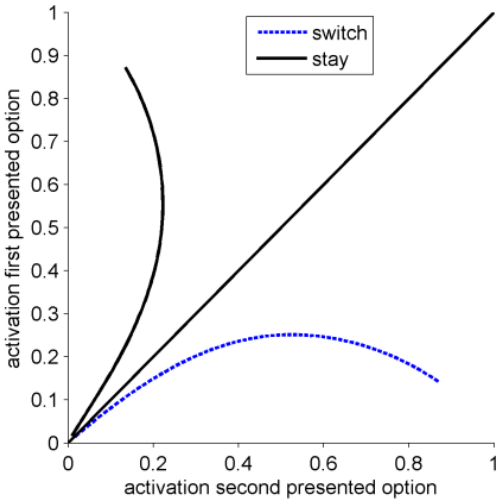
Neural attractor model

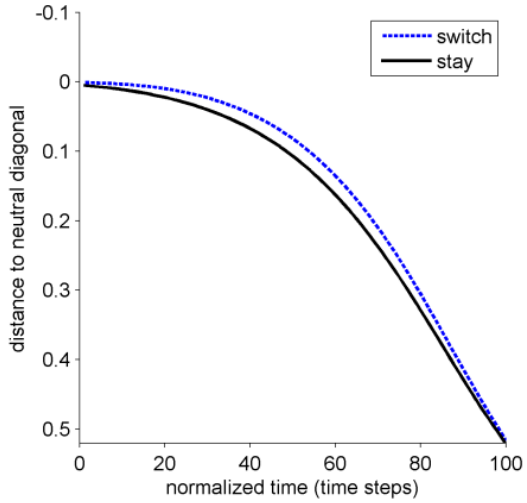


Measured movements

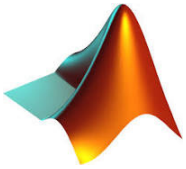


Modelled state-space trajectories





Toolboxes for these analyses



Matlab: TCMR Toolbox

https://osf.io/5e3vn/

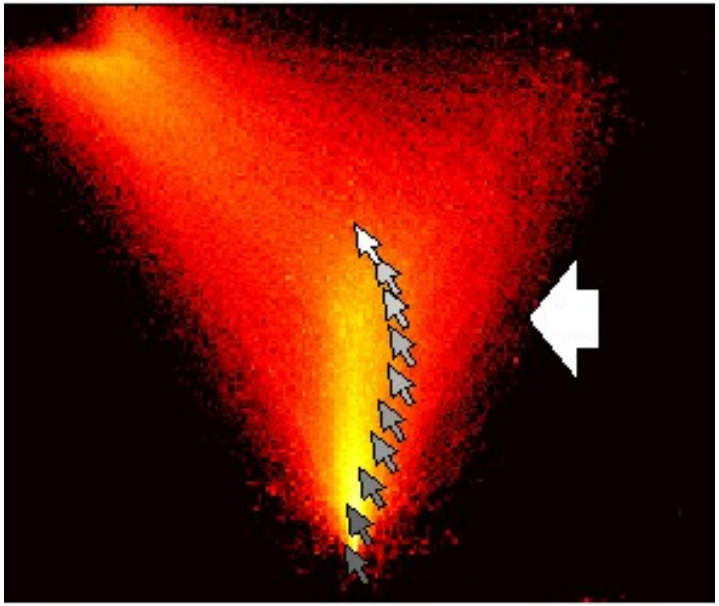
R: Mousetrap

https://cran.r-project.org/web/packages/mousetrap/

What we will look at today

- What will we do in the course?
- Where has it been applied?
- What can we look at?
- What do we need to keep in mind?
  → The black art of mouse tracking

The black art of mouse tracking
Issues of experimental design



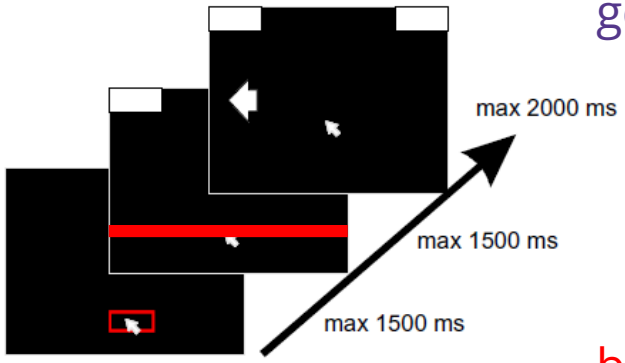
Issues of experimental design
Issue 1: What triggers stimuli

Participants need to move while thinking

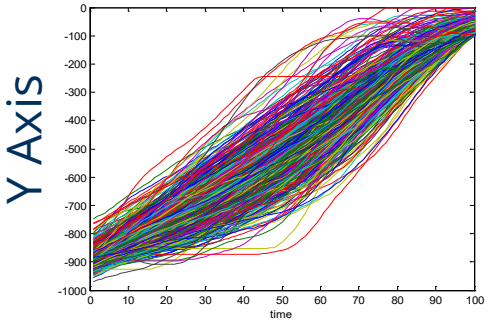
→Force them to move & present stimuli only after movement started

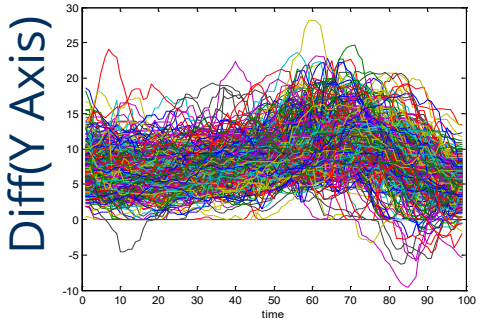
→Instruct them to move continuously

→Check for continuous movements and exclude stopping participants

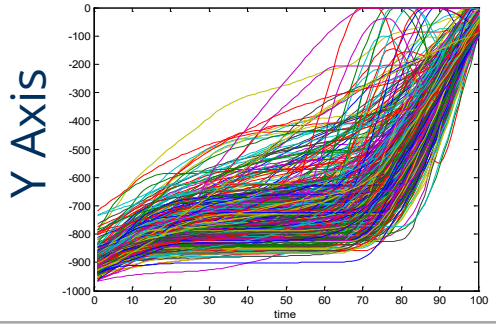


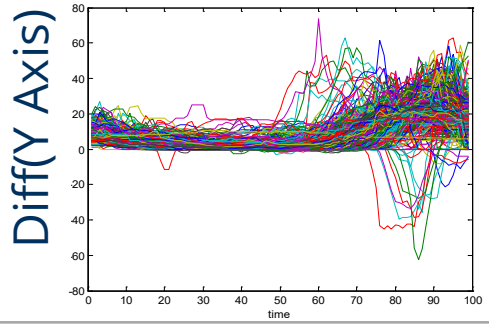
good





bad



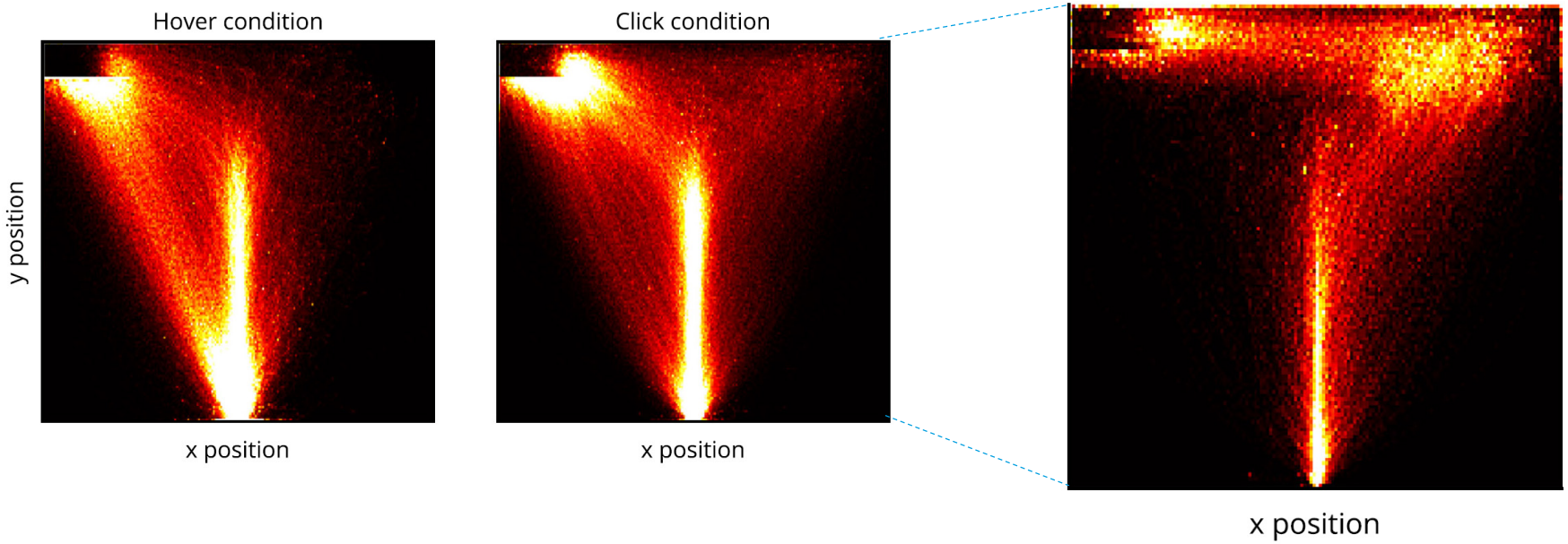


Issues of experimental design
Issue 2: Touching/hover or clicking

Use the power of ballistic movements

→Make choice movement as intuitive as possible

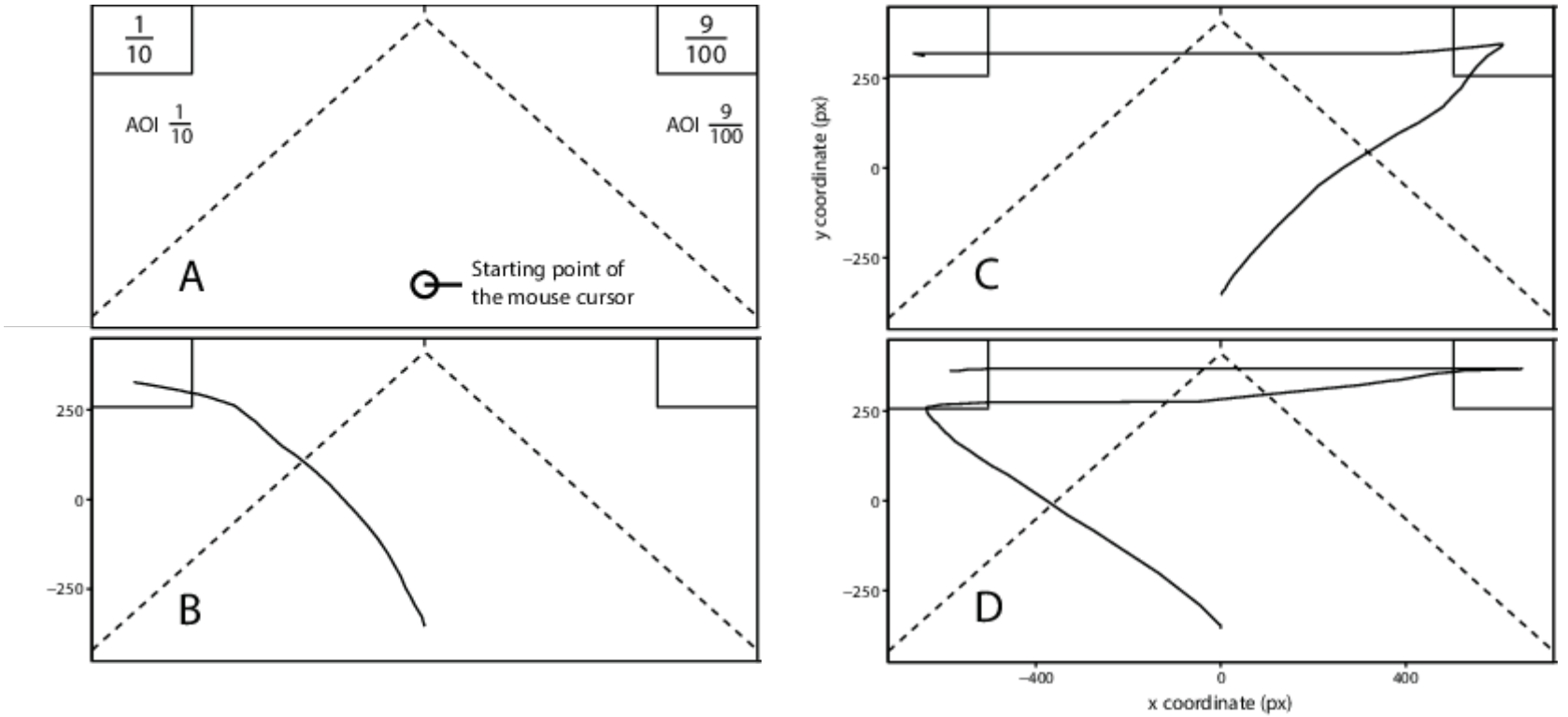
→Avoid irritation by clicking into target boxes or too small boxes



Grage, Schoemann, Kieslich, Scherbaum, 2019

Issues of experimental design
Issue 2: Touching/hover or clicking

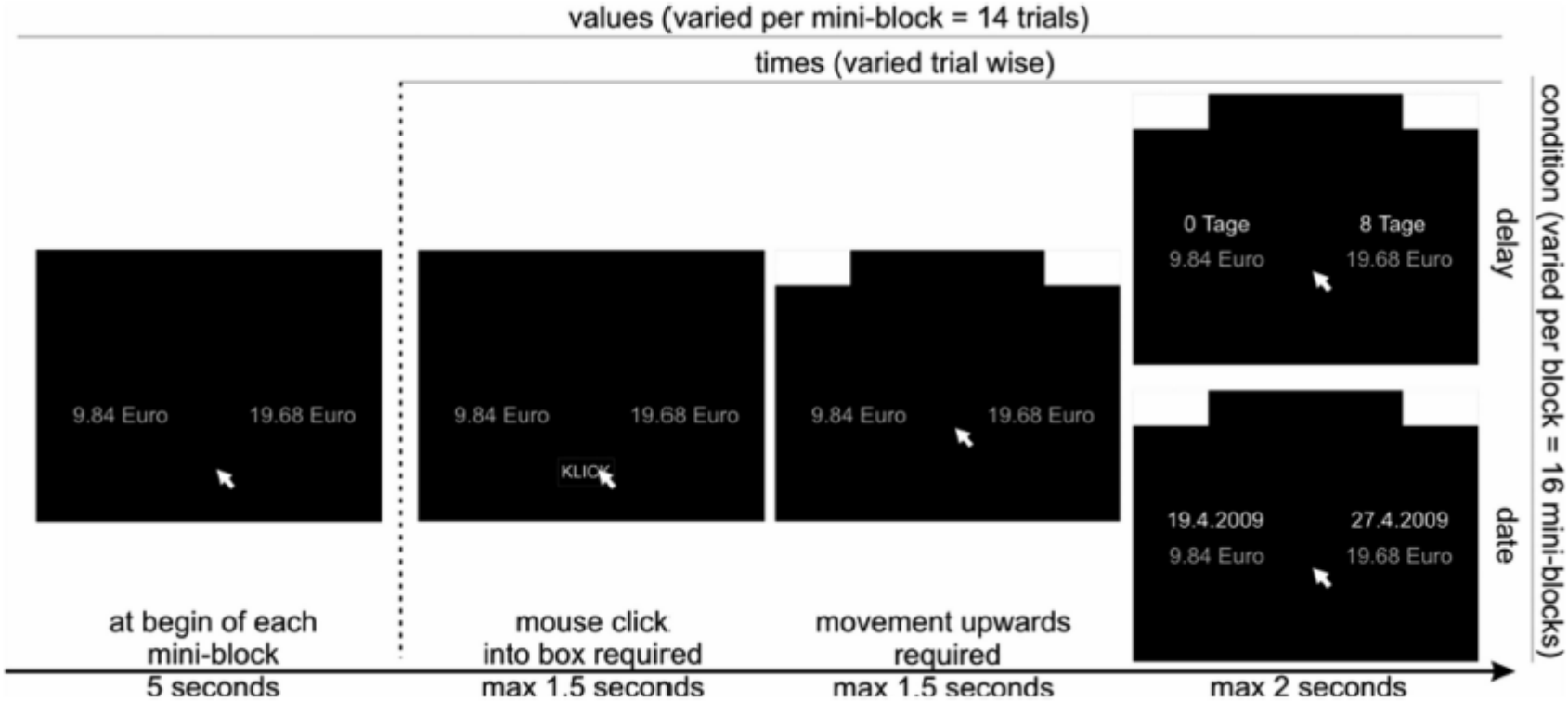
Or maybe you want re-decisions? Then clicking is good



Szaszi, Palfi, Szollosi, Kieslich, Aczel, 2018

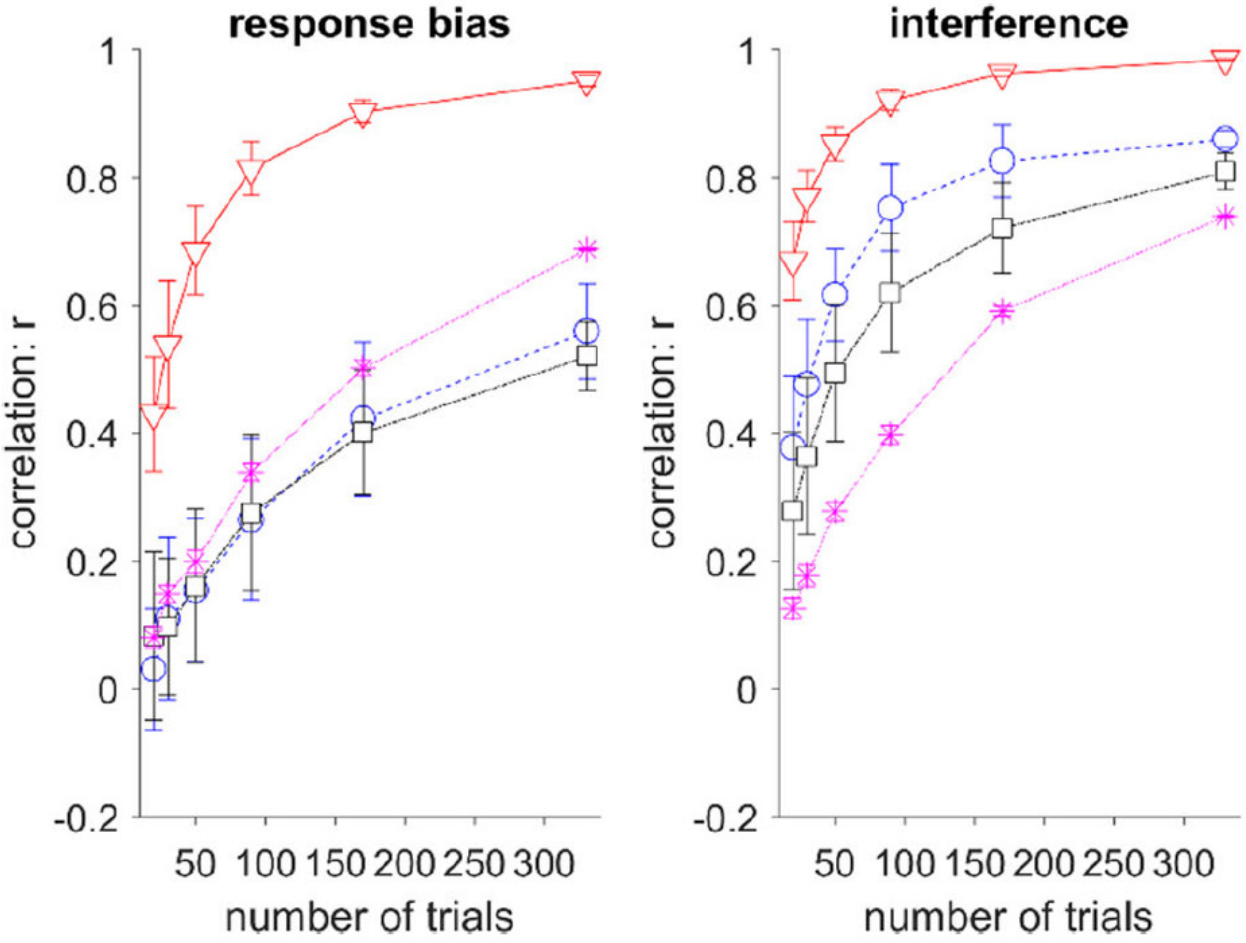
Issues of experimental design
Issue 3: Complexity of task

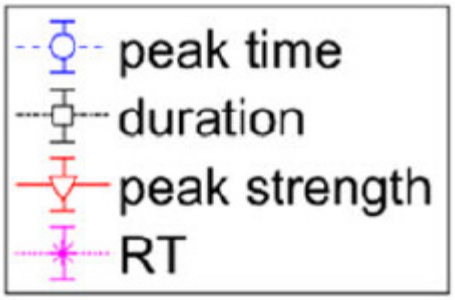
Participants will stop moving or move backwards when decision is too complex → study simple decision or simplify the decision

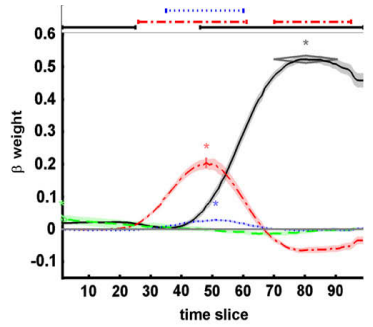


Dshemuchadse, Scherbaum, Goschke, 2012

Issues of experimental design
Issue 4: Have enough trials

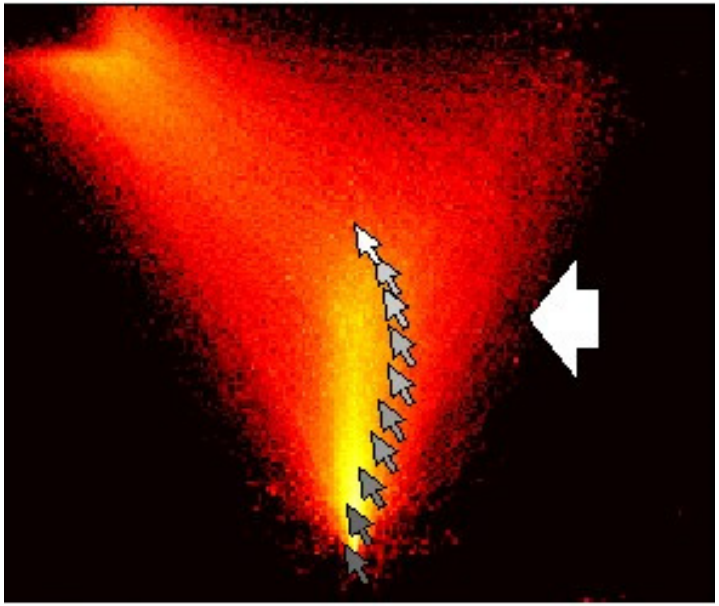






Scherbaum, Dshemuchadse, 2020

The black art of mouse tracking
Issues of data analysis



Issues of data analysis
Issue 5: Choose your trajectory measure

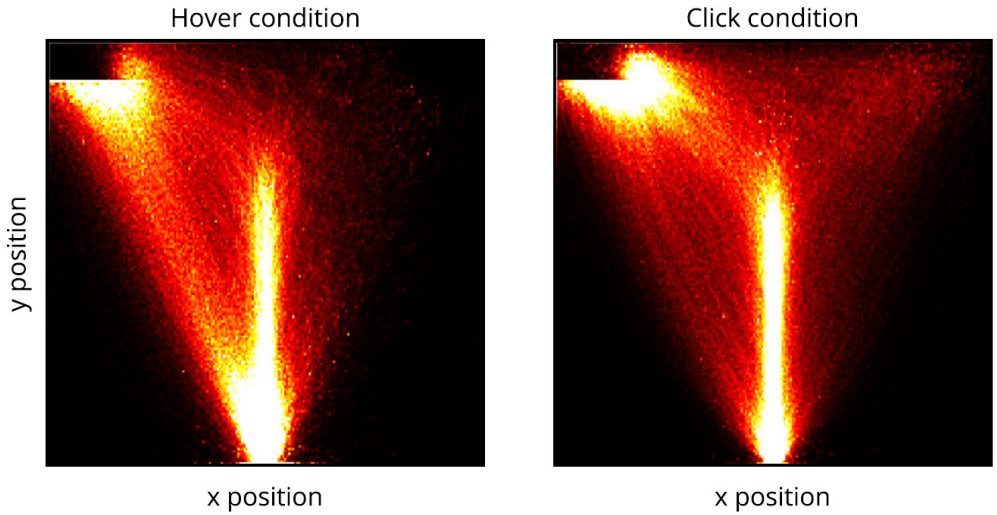
Continuous movements can be analyzed in different ways

- X-Y Movements
- Movement on X-Axis
- Angle to Y-Axis
- Speed
- Deviation
- Euclidian distance

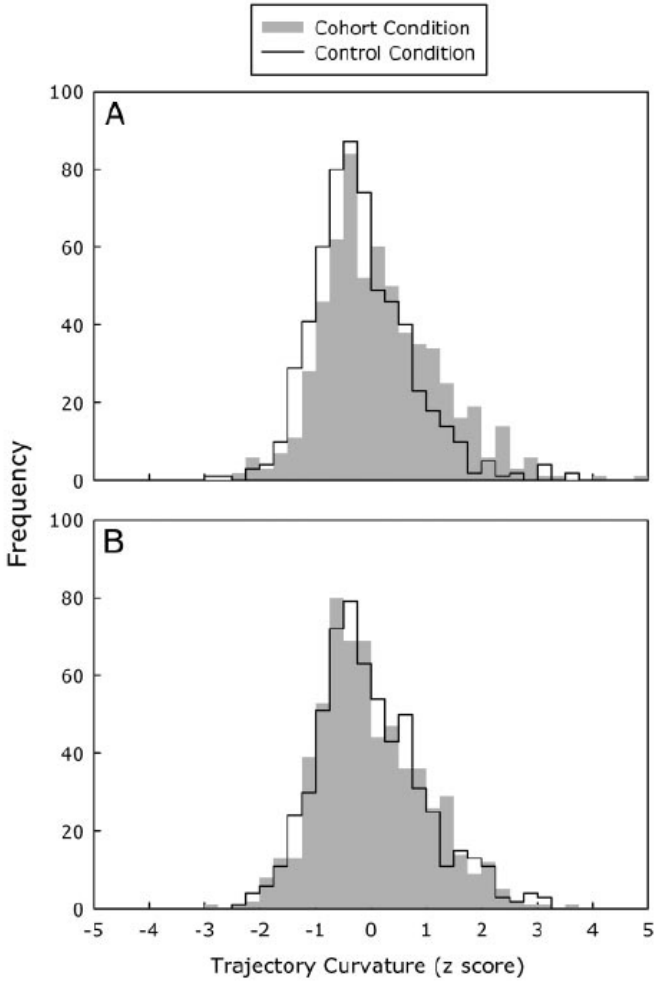
Issues of data analysis
Issue 6: Bimodality

Countermeasure

- Histograms of MAD or AUC
- Bimodality index on max/mean deviation
- Sexy & functional: Heat maps



Grage, Schoemann, Kieslich, Scherbaum, 2019

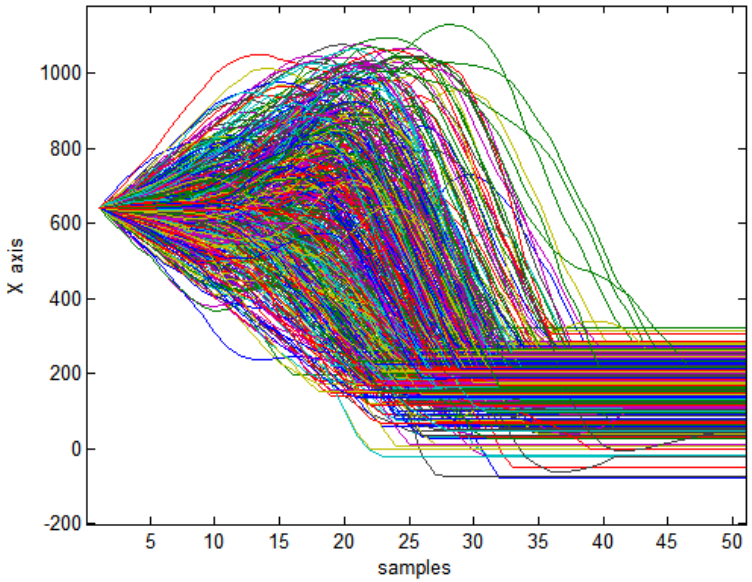


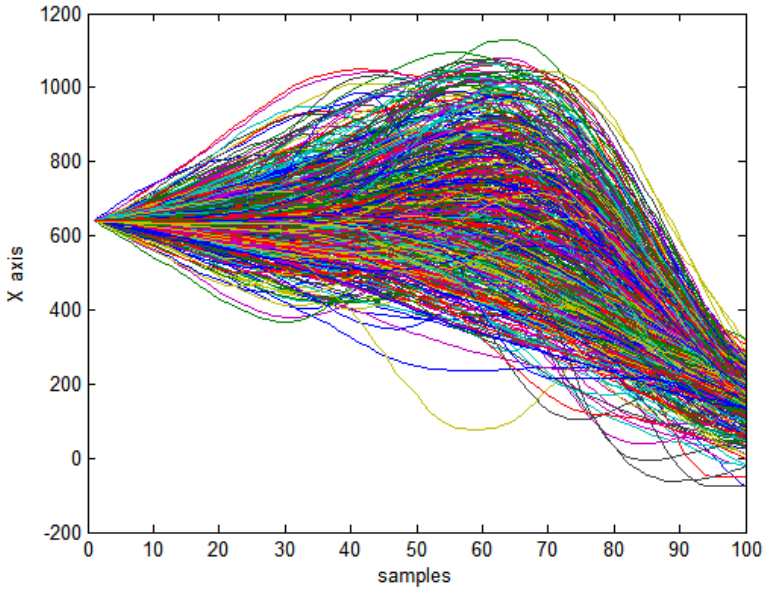
Spivey et al., 2005

Issues of data analysis
Issue 7: Time normalization?

What is the process of interest?

- **Stimulus locked**
- Response locked
- Center locked
- **Time normalized**

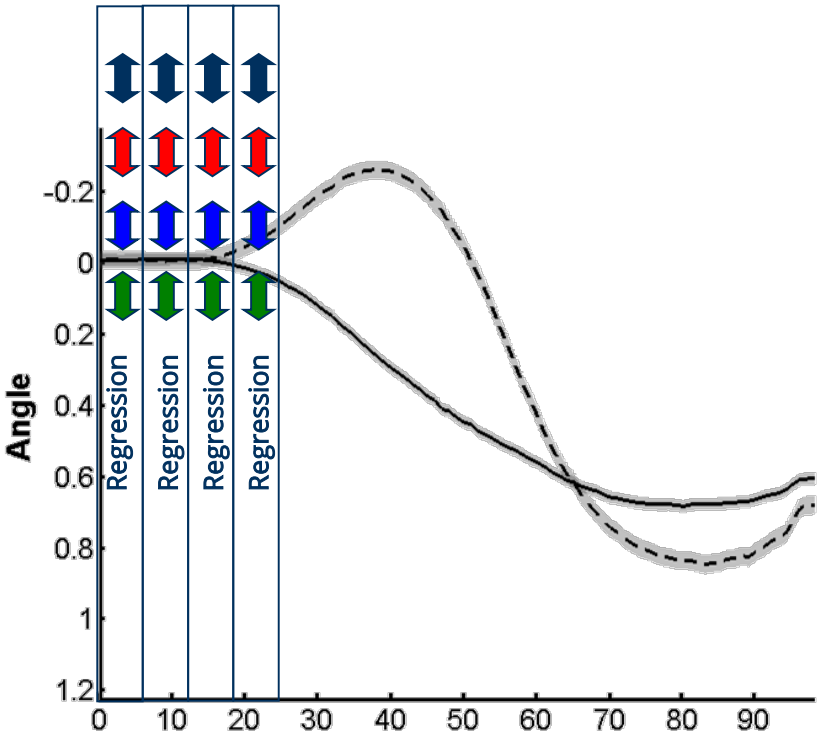




Issues of data analysis
Issue 8: Regression - Multicolinearity

When trial properties are dependent
due to Bad design or Post-hoc factors

- Direction
- Location
- Previous conflict
- Previous response



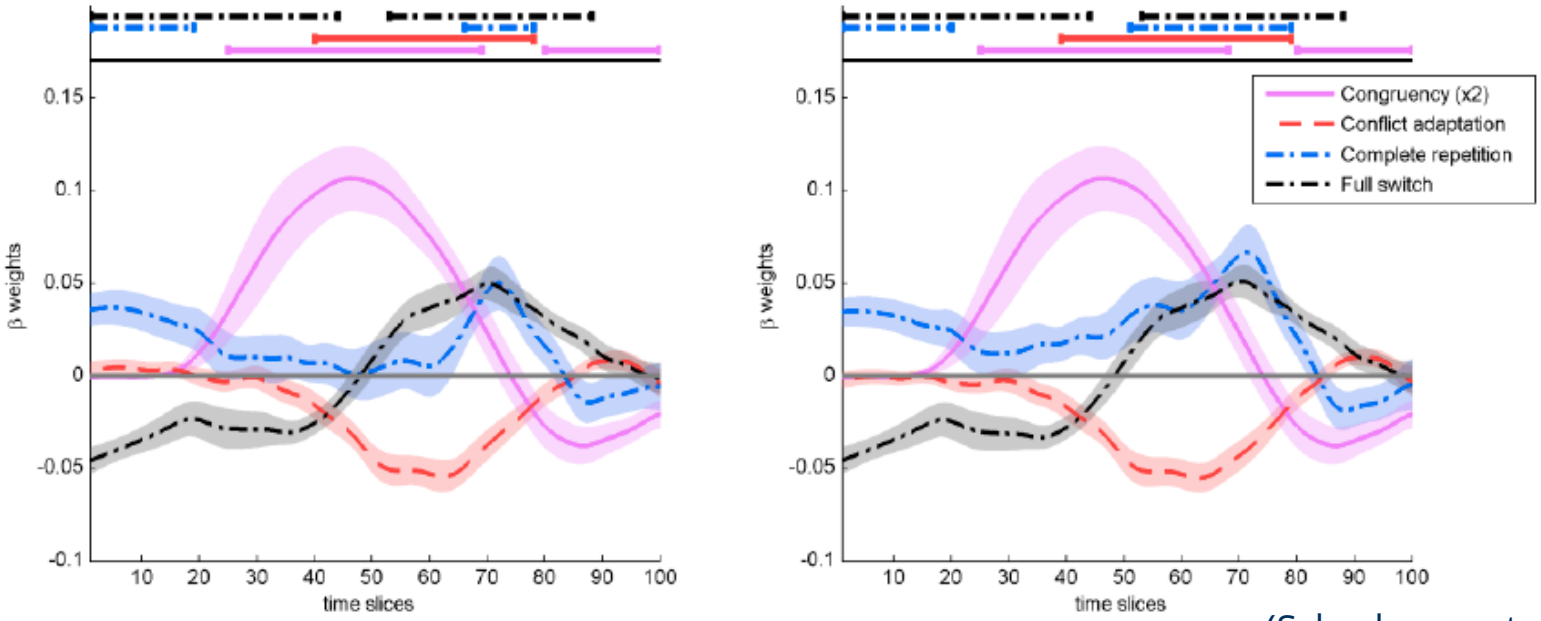
Issues of data analysis
Issue 8: Regression - Multicolinearity

Counter measures:

Covariance/correlation of trial properties

Variance inflation factor (https://en.wikipedia.org/wiki/Variance_inflation_factor)

Stepwise regression



(Scherbaum et al., 2016)

The black art of mouse tracking
A bunch of (hidden) choices

Aim to understand your method and the assumptions!

Experimental Design

- Stimuli triggers, Touching or clicking, Task complexity, Number of trials

Data Analysis

- Trajectory measures, Statistical measures, Bimodality, Multicolinearity

Summary

- Mouse tracking is a cheap method that lets us get a lot out of behavioral data from 2 alternative forced choice tasks
- Methods of analysis can go from simple (qualitative or maximum deviation) to complex (TCMR)
- You need to consider several design factors when designing your experiment

Until tomorrow:

- Talk about potential experiments and interests in groups. Decide which package you want to choose.
  → Check to Google Slides
  → Install R, Matlab, Open Sesame