Perception and Action

Cordula Vesper
BSc in Cognitive Science
Fall 2022

Why perception and action?

Hommel, B., Brown, S.B.R.E, & Nattkemper, D. (2016). Chapter 1: Introduction and Overview. In: *Human Action Control: From Intentions to Movements.* Springer International Publishing.

Rosenbaum, D. A., & Feghhi, I. (2019). The time for action is at hand. *Attention, Perception, & Psychophysics, 81*(7), 2123–2138. https://doi.org/10.3758/s13414-018-01647-7

Today's topics

- Brief intro
- Course overview & organization
- Degrees-of-freedom problem
- Heuristics in action planning
- Some easily observable effects
- Fitts' law & applications

A central question in Cognitive Science …

Do Ents have brains?!

Cognition and perception for action?

We have a brain to generate purposeful and complex movement!

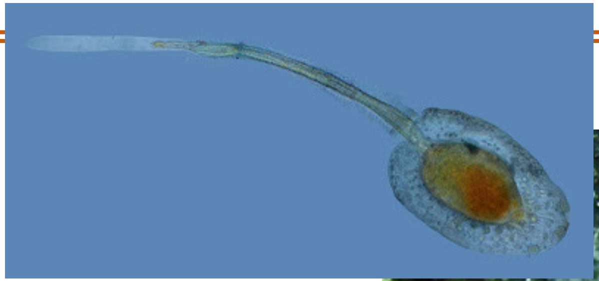
- **Embodied cognition** approaches emphasize the role of the body and its capabilities
- Interacting with the world (finding food, avoiding danger, mating, ...) and communicating (speech, gestures, writing)

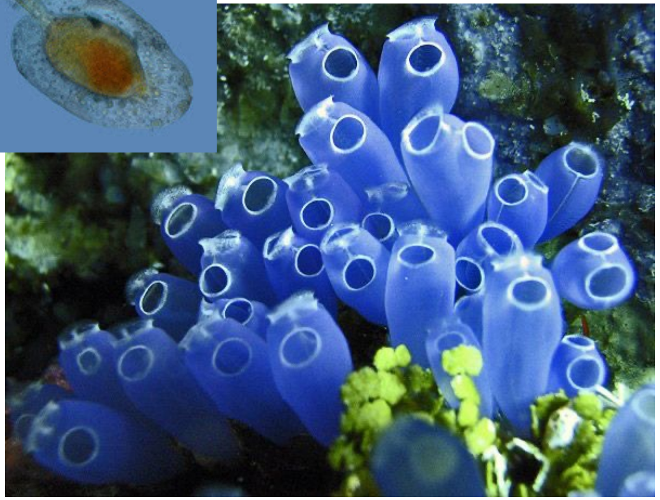
- For CogSci: Reveal aspects of perceptual processing and cognition otherwise hidden

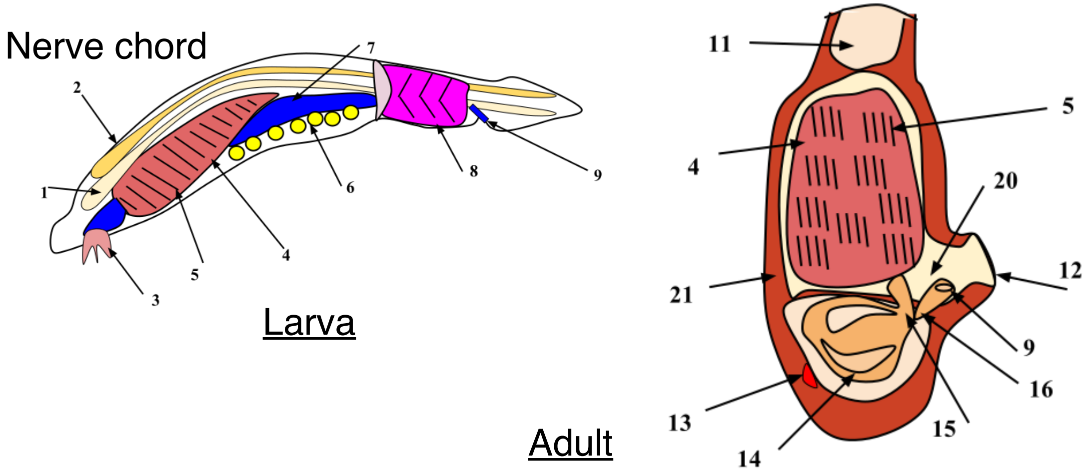
Other species: If they don‘t move they don‘t have brains

Cognition and perception for action?

Example: Metamorphosis of the sea squirt







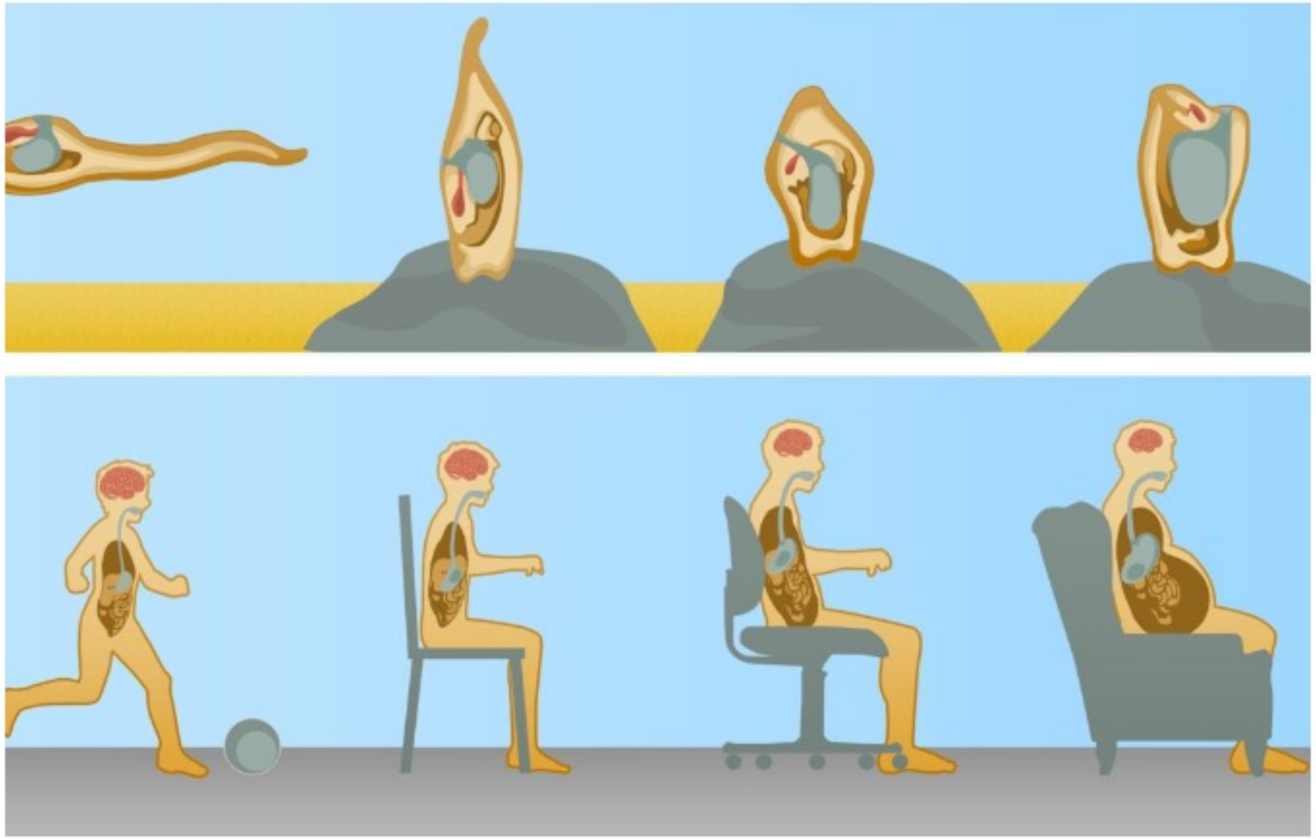
“Many physical changes occur to the tunicate's body during metamorphosis, one of the most significant being the reduction of the cerebral ganglion, which controls movement and is the equivalent of the vertebrate brain. From this comes the common saying that the sea squirt "eats its own brain“.” Wikipedia: Tunicate

Cognition and perception for action?

Same for humans?! ☺

When It Comes To Brain Health—Don't Be A Sea Squirt

by Dr. John Pepper | Mar 26, 2017 | Brain Health, Exercise | 0 comments

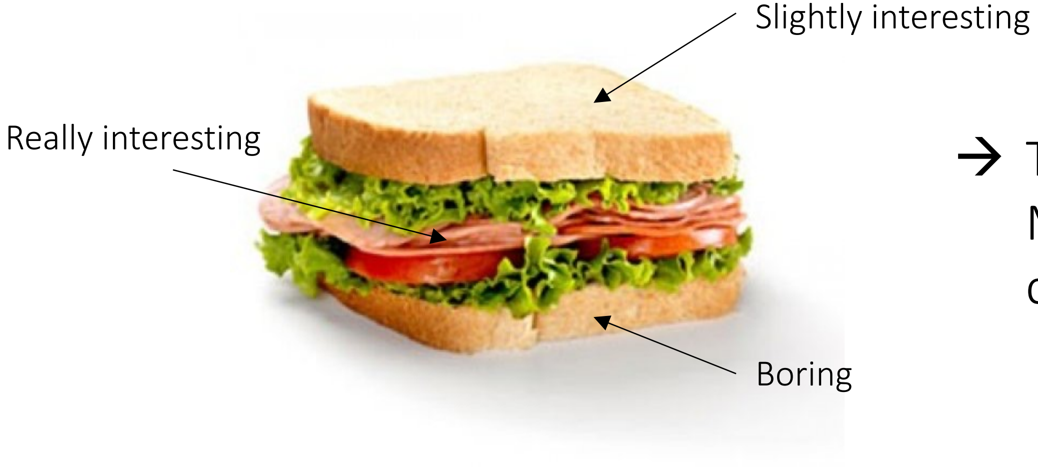


https://www.peppernaturalhealth.com/when-it-comes-to-brain-health-dont-be-a-sea-squirt/

No more sandwiches for us

Historically, focus on central cognitive processing:

- Perception as the relevant "input"
- Action has as the (uninteresting) output



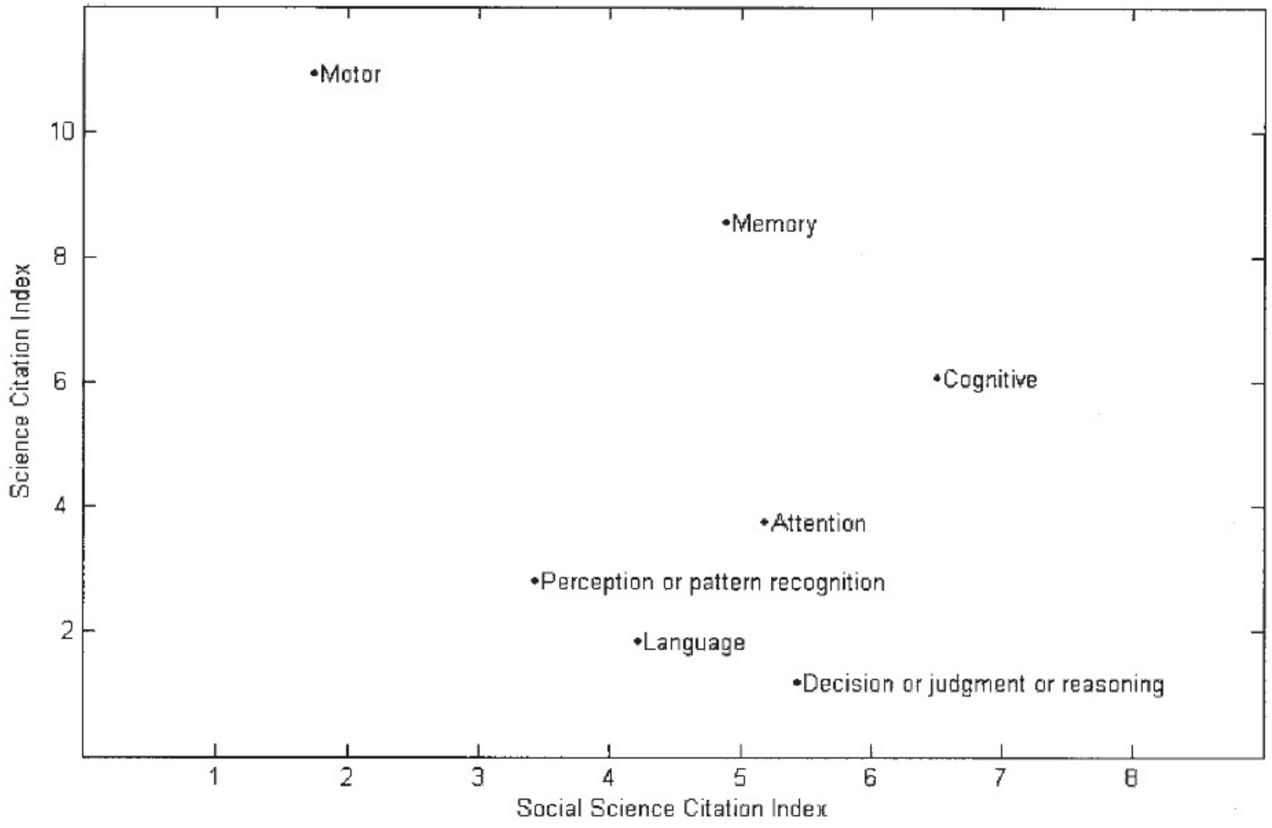
→ The "Sandwich Model" of perception, cognition and action

Our interest in cognition "cannot just be about how the brain *absorbs* information. It must also be concerned with how the brain *expresses* information" Rosenbaum & Feghhi, 2019

Action as the "Cinderella of Psychology" Rosenbaum, 2005

Research about action

Figure 1
Number of Articles in the Social Science Citation Index (Abscissa) and Science Citation Index (Ordinate) Pertaining to Each Topic Listed in the Graph



Note. Values on the abscissa are 1/10,000 the number of reported values. Values on the ordinate are 1/1,000 the number of reported values. For the Science Citation Index, the only journals included had the word *brain* or the letters *neur* in their titles.

Rosenbaum, 2005, p. 314

My background and interests

From Kiel ☺

BSc in Cognitive Science, University of Osnabrück

MSc in Neuro-cognitive Psychology, Ludwig-Maxilimians-University Munich

PhD in Social Sciences, Radboud University Nijmegen

Post-doc at Central European University, Budapest

Shorter research stays in Newark (New Jersey) and Cincinnati (Ohio)

At Aarhus University since 2017

Now Associate professor in Cognitive Science and Cognitive Semiotics

My background and interests

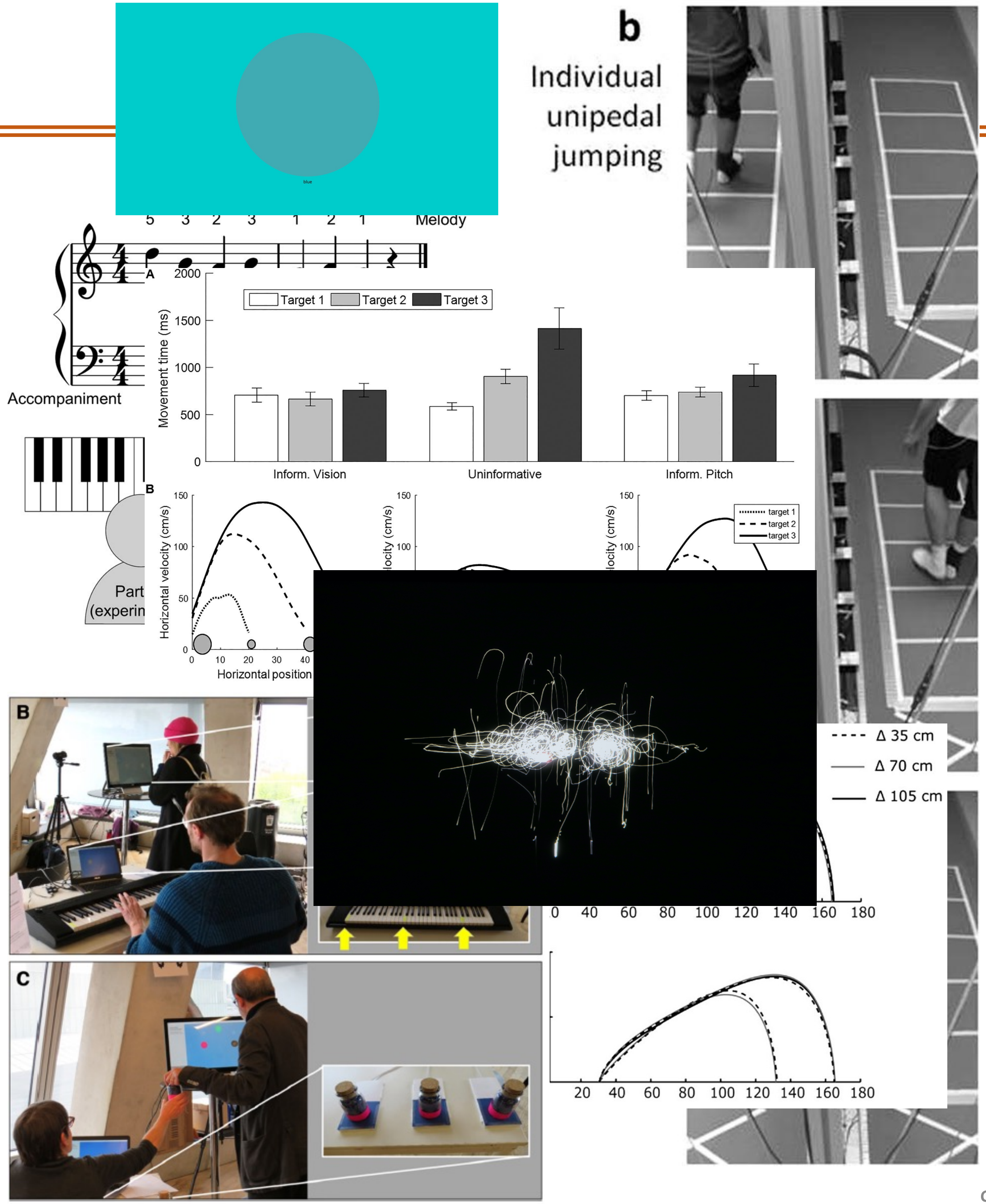
Joint Action & Cognition lab

Joint action, nonverbal communication, and general social cognition

Theoretically, quantitatively, and now also qualitatively

In the lab and "out there" in the world

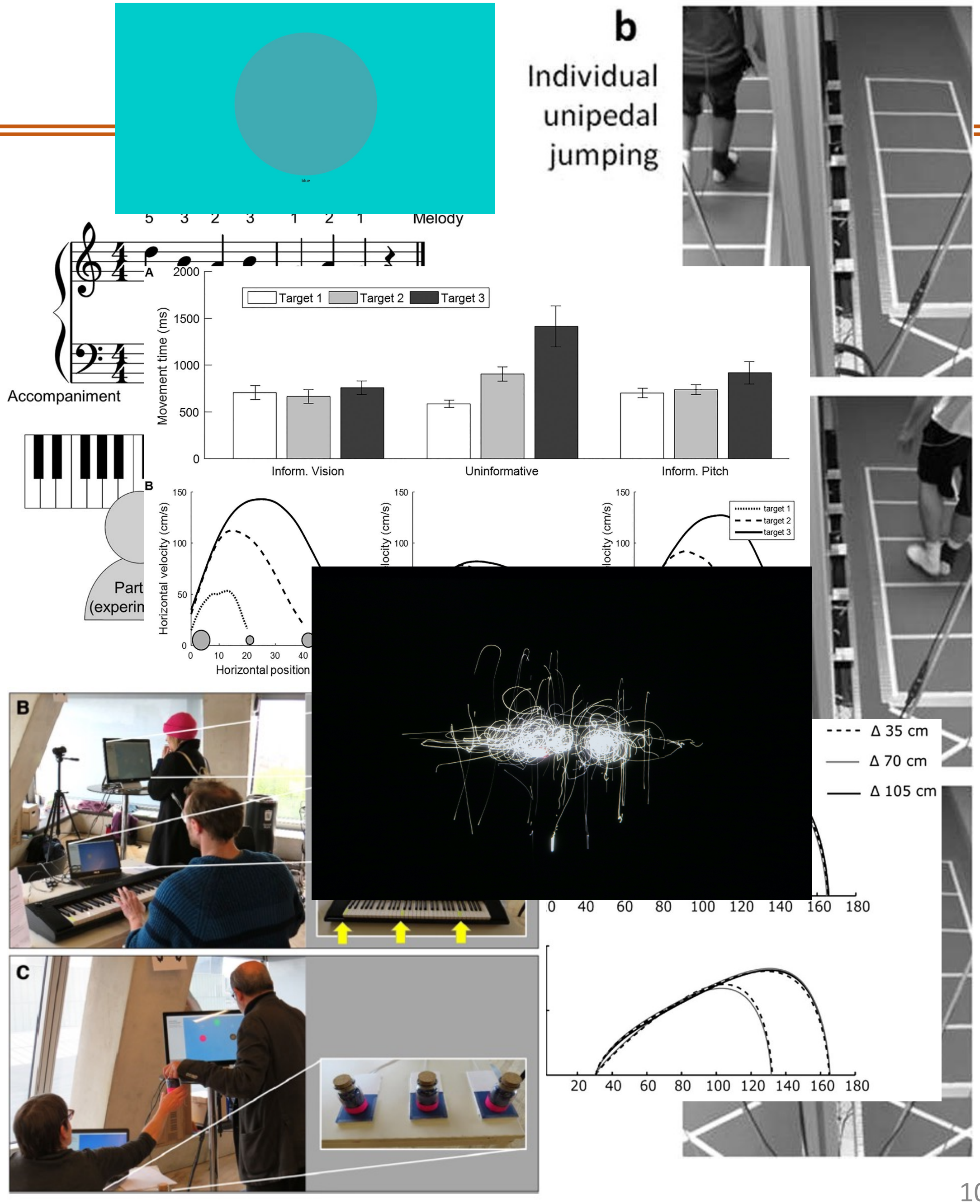
- How do we coordinate actions with other people?
- How do we form and act according to shared goals?
- What is the role of movement variability for joint action?
- To what degree is sharing perception important for action coordination?
- How can we use actions to spontaneously communicate with others?
- How does movement coordination affect people's wellbeing, social bonding, and emotions?
- Can people create art together through their movement?
- How does social context influence the way we perceive the world?



My background and interests

Thought exercise

Why is joint action interesting in relation to perception and action?



Purpose of this course

Our course will introduce topics on perception, action, and – importantly – the interaction of perception and action.

What this course offers:

\+ Introductions, overviews, topics, themes

\- Deep theoretical argumentations

Purpose (from the study regulations):

- the cognitive processes involved in perceiving and acting in the world
- methods designed specifically for studying perception and action
- sensory and motor systems
- the cognitive processes involved in transforming sensory information into perceptual experience
- the processes involved in transforming intentions into actions
- measurement and modelling techniques used to study perception and action, e.g. eye-tracking, motion tracking, and experimental psychophysics

Introduction to Cognitive Science Methods 1

Perception and Action

Cognitive Neuroscience

Course organization

All material in the Brightspace Lecture folder

Perception and action, Holdundervisning - Class 2 (E22.147201U014.A)
Ends January 31, 2023 at 11:59 PM

Perception and action, Holdundervisning - Class 1 (E22.147201U014.A)
Ends January 31, 2023 at 11:59 PM

Perception and action (E22.147201U014.A)
Ends January 31, 2023 at 11:59 PM

Course Home | Content | Course Tools | Classlist | Zoom | Help

Course material

- The Perception and Action Booklet (E22)
- Course schedule

Week 35: Why perception and action?

Week 36: Principles of multisensory integration

Week 37: Experimental psychophysics

Week 38: TBD

Week 39: Mouse-tracking

Week 40: Neurobiological foundations

Week 41: Common representational codes

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.	TBD
II	39	29.9.	Chapter 4: Mouse-tracking
		30.9.	Mouse-tracking with OpenSesame, matrix and group discussions
	40	6.10.	Chapter 5: Neurobiological foundations
		7.10.	MouseTrap analysis I
	41	13.10.	Chapter 6: Common representational codes
		14.10.	MouseTrap analysis II, poster preparation, mid-term evaluation
III	43	27.10.	Chapter 7: Decoding action intentions [+ studiepraktik]
		28.10.	Poster presentation, matrix and group discussions
	44	3. & 4.11.	Chapter 8: Kinematics Lab
IV	45	10.11.	Chapter 9: Joint action
		11.11.	Supervision: developing project idea, group discussions
	46	17.11.	Chapter 10: Embodied cognition
		18.11.	Supervision: fine-tuning project idea, group discussions, final course evaluation
	47	24.11.	TBD
		25.11.	Supervision: finalizing project plan, group discussions, exam paper writing exercises
V	48	29.11. – 1.12.	Chapter 11: Eye-tracking Workshop (with Fabio)
	49	6., 8. & 9.12.	

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		11.11.	Supervision: developing project idea, group discussions
	46	17.11.	Guest lecture: Lau Møller Andersen
		18.11.	Supervision: fine-tuning project idea, group discussions, final course evaluation
	47	24.11.	Chapter 10: Embodied cognition
		25.11.	Supervision: finalizing project plan, group discussions, exam paper writing exercises
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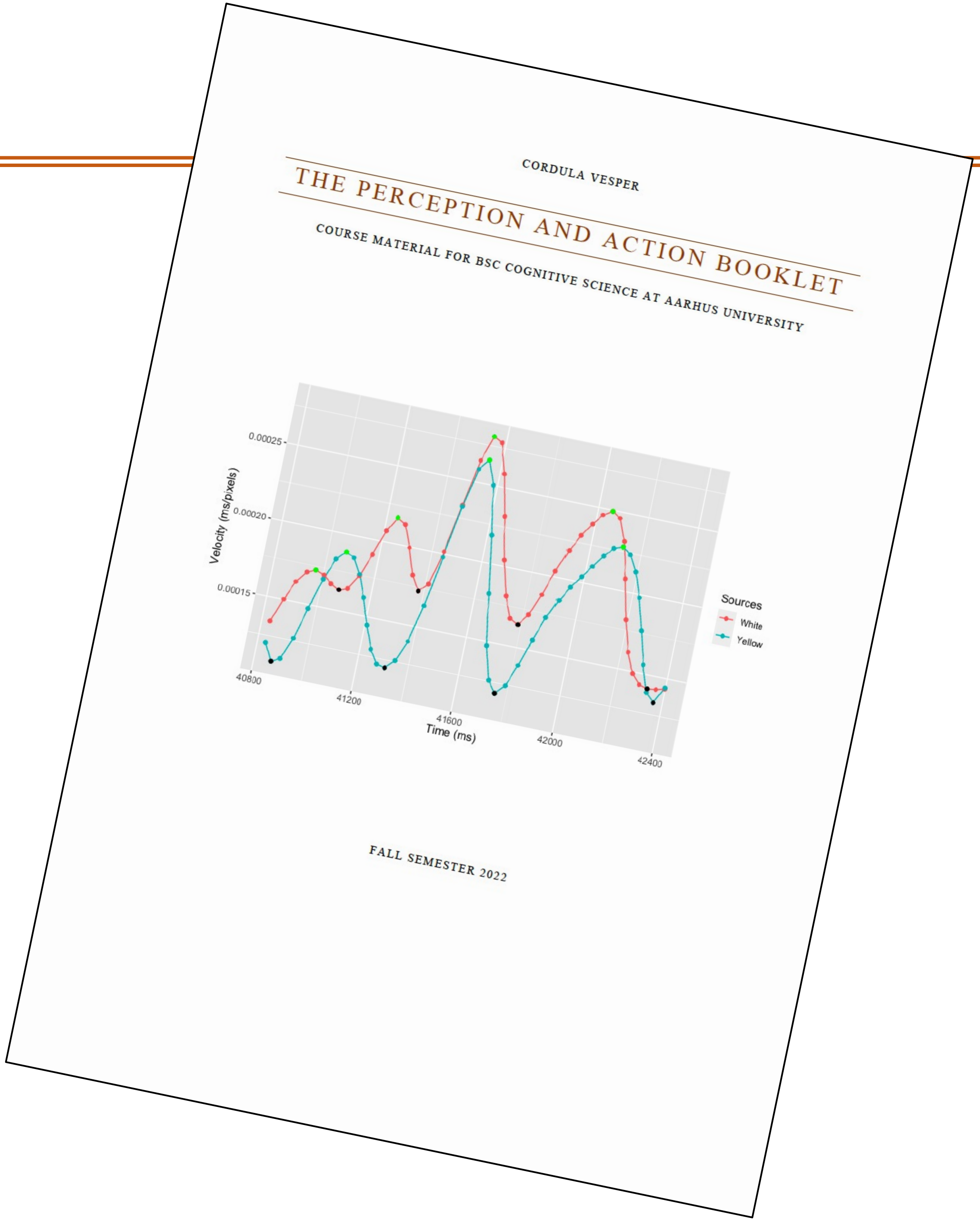
Course organization

Design principles:

- Booklet for preparation and “bigger picture”
- Self-study for acquiring new topics (with preparation questions)
- Lectures and classes to facilitate
- Small thought exercises
- Theoretical and practical exercises
  - Group discussions, data analysis, experiment building, matrix reading exercises, …
- Group work (study groups & mixed groups)
- Some kahoots etc.
- And Laura as your wonderful course instructor!



Learning outcomes and exam

Knowledge:

- explain the cognitive processes involved in sensation, perception, movement, and action
- explain the relationships between cognitive processes involved in perception and action

Skills:

- design studies to investigate cognitive processes involved in perception and action
- analyse data from specialised measurement devices
- employ statistical models designed to study perception and action

Competences:

- justify choice of experimental design, measurement devices, and statistical models, in one's own and in others' studies on perception and action

Learning outcomes and exam

Take-home assignment on a topic of the student's choice: relevant in relation to the content of the course and subject to the approval of the teacher

Length for one student: 10-12 standard pages

Length for two students: 17-22 standard pages

Length for three students: 24-32 standard pages

Any immediate questions?
(We'll talk more throughout the semester ☺)

1. Fitts' law	(Chapter 1)
2. Crossmodal correspondences	(Chapter 2)
3. Signal detection theory	(Chapter 3)
4. Mouse-tracking	(Chapter 4)
5. Motion tracking	(Chapter 8)
6. [Eye-tracking – only if you have prior experience	(Chapter 11)]

Biomechanical constraints

Our bodies are not made to perform movements of all kinds.

There are biomechanical constraints.

→ Both limitations on movement & reduction of complexity for planning and performing action

Thought exercise

What kind of constraints does a human body have? Think of some examples.

The degrees-of-freedom problem

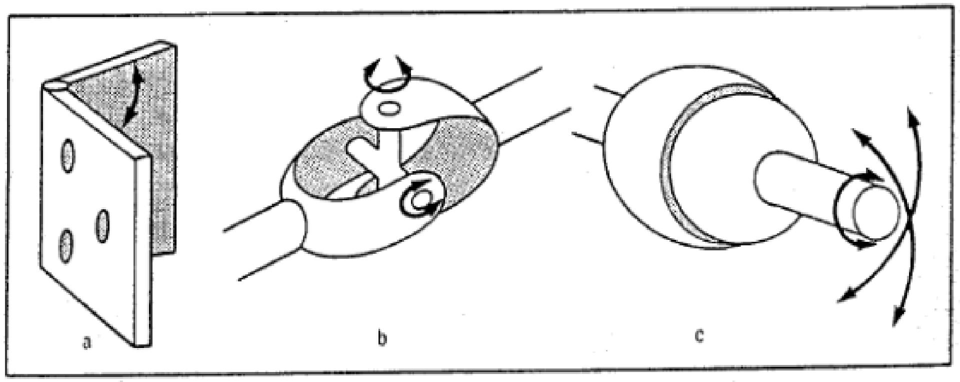
The curse of dimensionality

"This is vividly illustrated if we consider the 600 or so muscles in the human body as being, for extreme simplicity, either contracted or relaxed. This leads to 2^{600} possible motor activations, more than the number of atoms in the universe. This clearly prohibits a simple look-up table from motor activations to sensory feedback and vice versa."

Wolpert & Ghahramani, 2000

The degrees-of-freedom problem

<u>Examples</u>
Hinge joint: 1 dof
Ellipsoidal joint: 2 dof
Ball-and-socket joint: 3 dof



Thought exercise
Can you think of examples?

Degrees of freedom in a movement system add up, e.g. in an arm

Advantage: Extremely high flexibility in performing movements (e.g., needed for obstacle avoidance)

Degrees-of-freedom problem: How to select one combination of intrinsic coordinates from so many possibilities (underdetermined problem)?

The degrees-of-freedom problem

Why are certain movements performed and others not? How do you choose?

→ How is the degrees-of-freedom problem solved?

▪ Compute the optimal movement	*But what is optimal?*
▪ Rely on automatic movements	*But these do not give flexibility!*
▪ Plan movement sequences step by step	*But that can lead to detours and dead ends*

Actions are generated in a way that, at least by default, enhance smoothness within one action and minimize changes between successive actions.

But **soft constraints** only

The degrees-of-freedom problem

Monty Python's Ministry of Silly Walks (1970) https://www.youtube.com/watch?v=iV2ViNJFZC8

Basic idea: Motor system uses **cost functions** to calculate what the best possible movement is.

Motor control becomes cost minimization.

Calculated against what sensorimotor system is trying to achieve

Thought exercise
What is the task and what needs to be minimized (or maximized) when jumping as high as you can?

Many 'simple' models for what costs are minimized: **"Minimum X" theories**, e.g. energy, smoothness, accuracy, time, …

> *"A core claim is that the nervous system uses an efficient method to plan and prepare forthcoming actions: Whenever possible, forthcoming actions are planned to differ as little as possible from just-completed actions. This strategy is mechanically and computationally efficient."* Rosenbaum & Feghhi, 2019

Mutual influences of actions performed close in time:

- ***retrospective effects***: effects of the past on the present
- ***prospective effects***: effects of the future on the present

<u>Three examples</u>

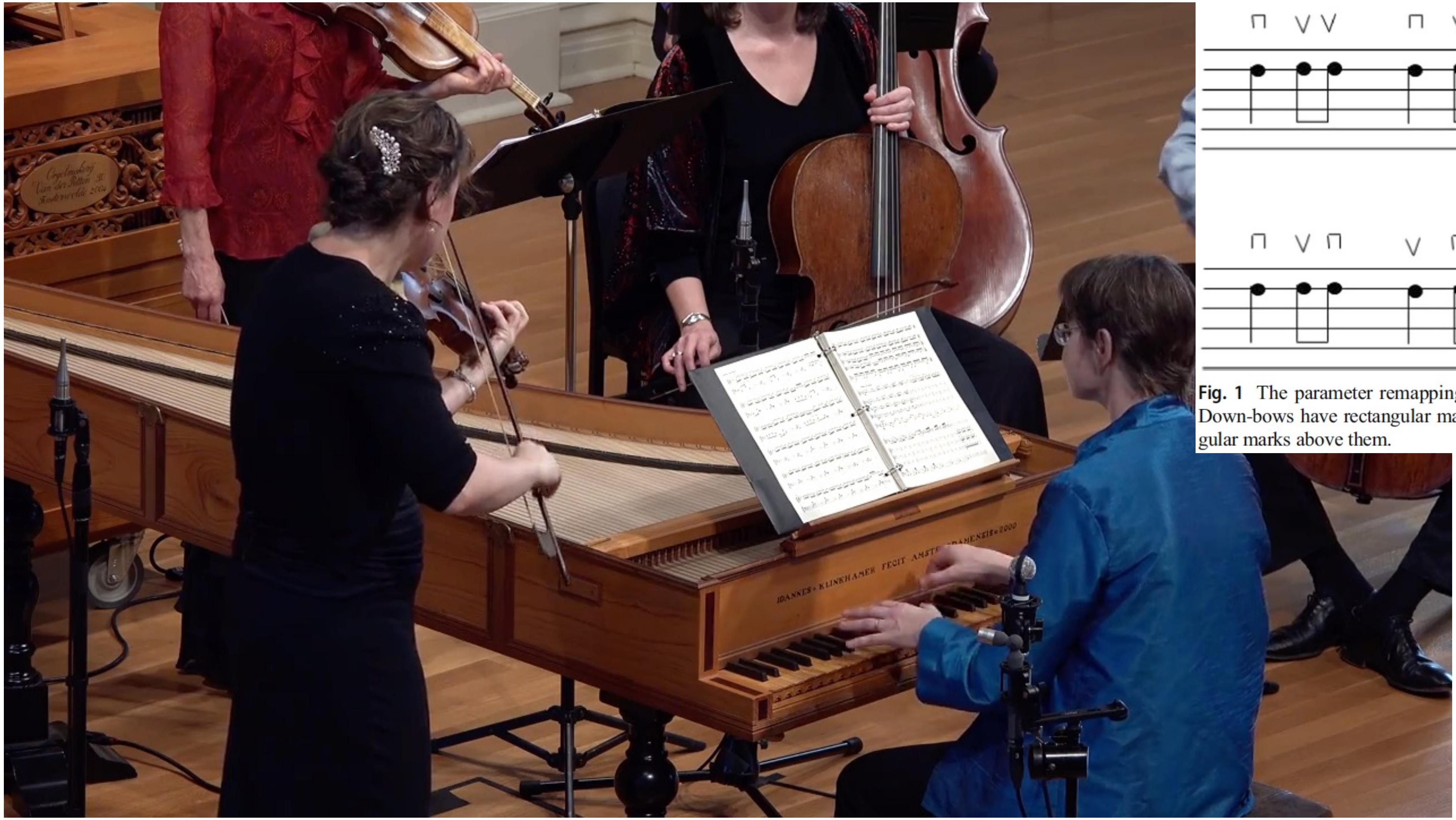
Parameter remapping effect

Grasp-height effect

End-state comfort effect

The parameter remapping effect

Rosenbaum & Feghhi, 2019. The time for action is at hand.



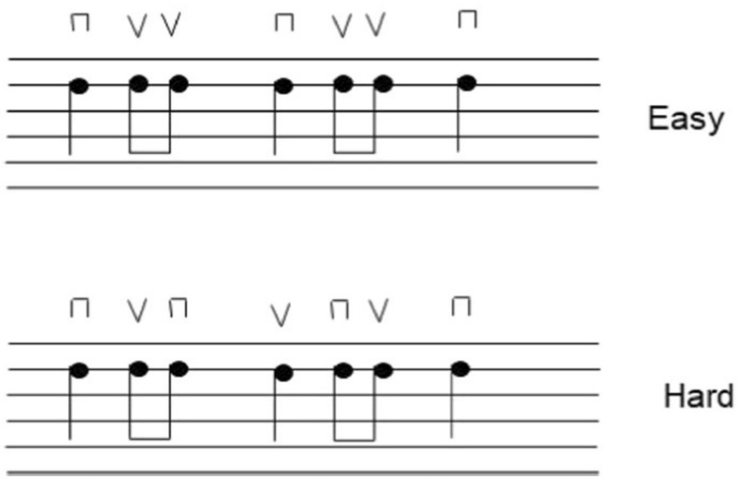


Fig. 1 The parameter remapping effect illustrated with bow bloopers. Down-bows have rectangular marks above them. Upstrokes have triangular marks above them.

https://www.youtube.com/watch?v=RvDt_KtOzbc

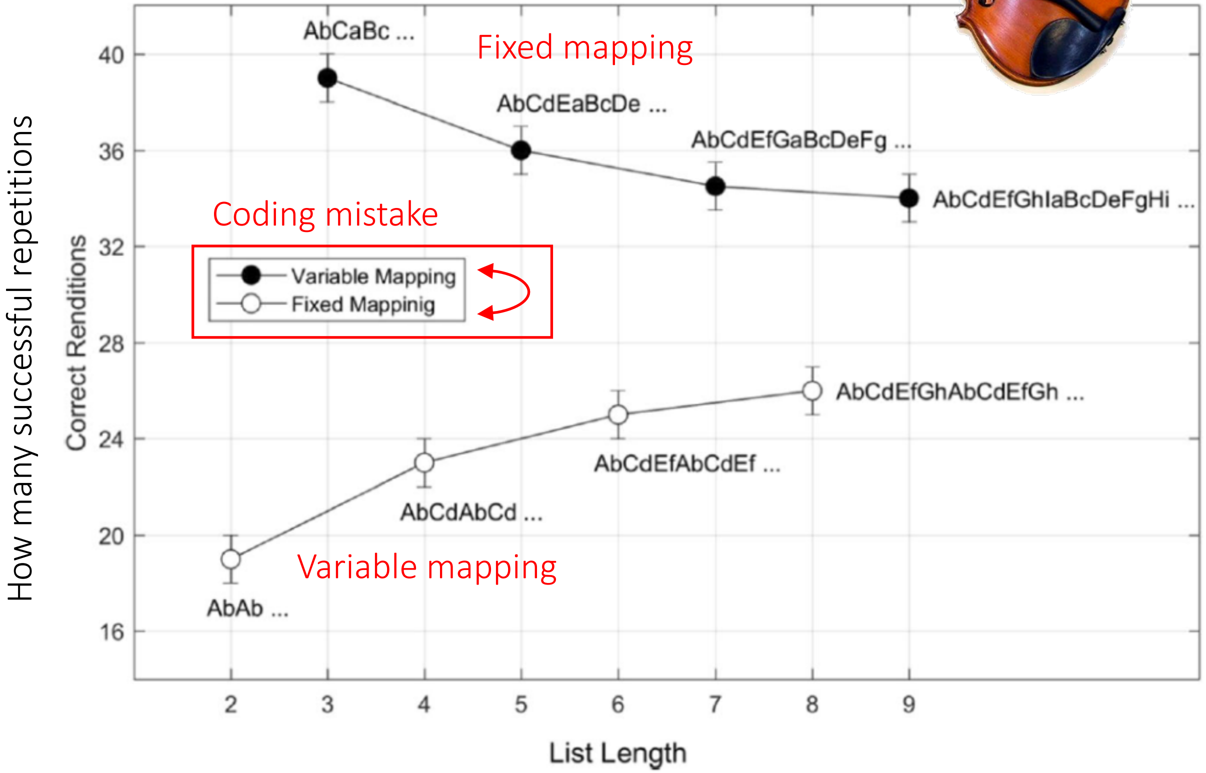
The parameter remapping effect

Rosenbaum & Feghhi, 2019. The time for action is at hand.

- Motor efficiency: performing similar actions similarly, i.e. keeping motor parameters unchanged
- Priming through memory trace of previously performed action (but fast decay of motor memory)
- Cognitive and motor costs when changing

Suggests that movements are planned with respect to making **minimal changes** to previous movements!

Reprogramming instead of programming



Rosenbaum & Feghhi, 2019. The time for action is at hand.

- Motor efficiency: performing similar actions similarly, i.e. keeping motor parameters unchanged
- Priming through memory trace of previously performed action (but fast decay of motor memory)
- Cognitive and motor costs when changing

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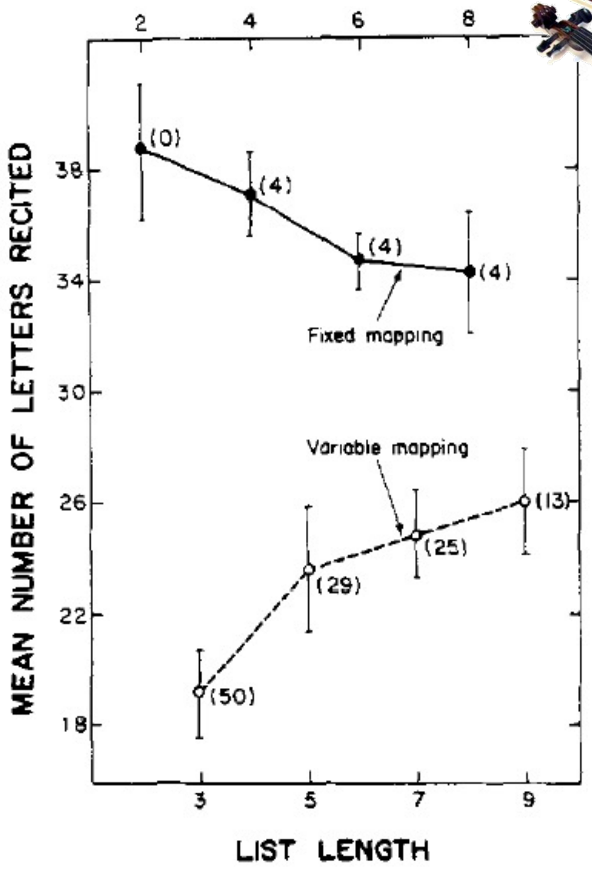
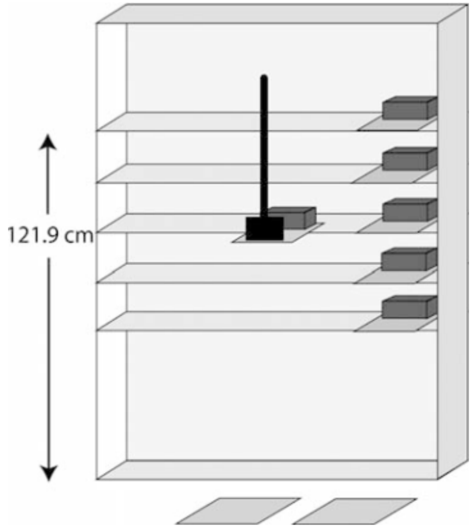
Reprogramming instead of programming

The same, but old and without a mistake ;-)



Rosenbaum et al., 1986. The parameter remapping effect in human performance

FIG. 1. Mean number of letters spoken during 10 s of repeated recitation of the first n letters of the alphabet, using strict stress alternation. Estimates of ± 1 SE based on between-subject differences. In parentheses, percentage of trials with errors. Data from Experiment 1.



Planning for future movement control

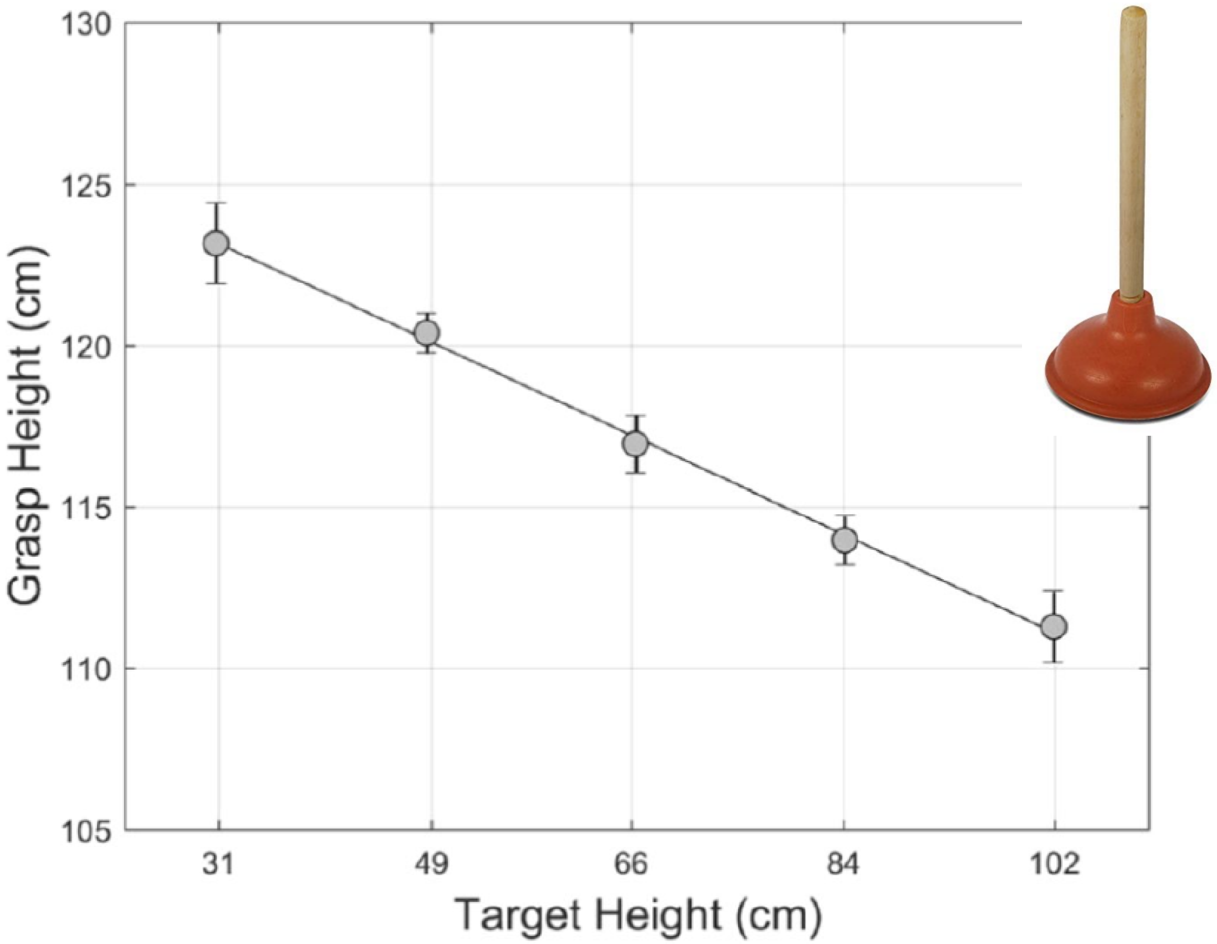
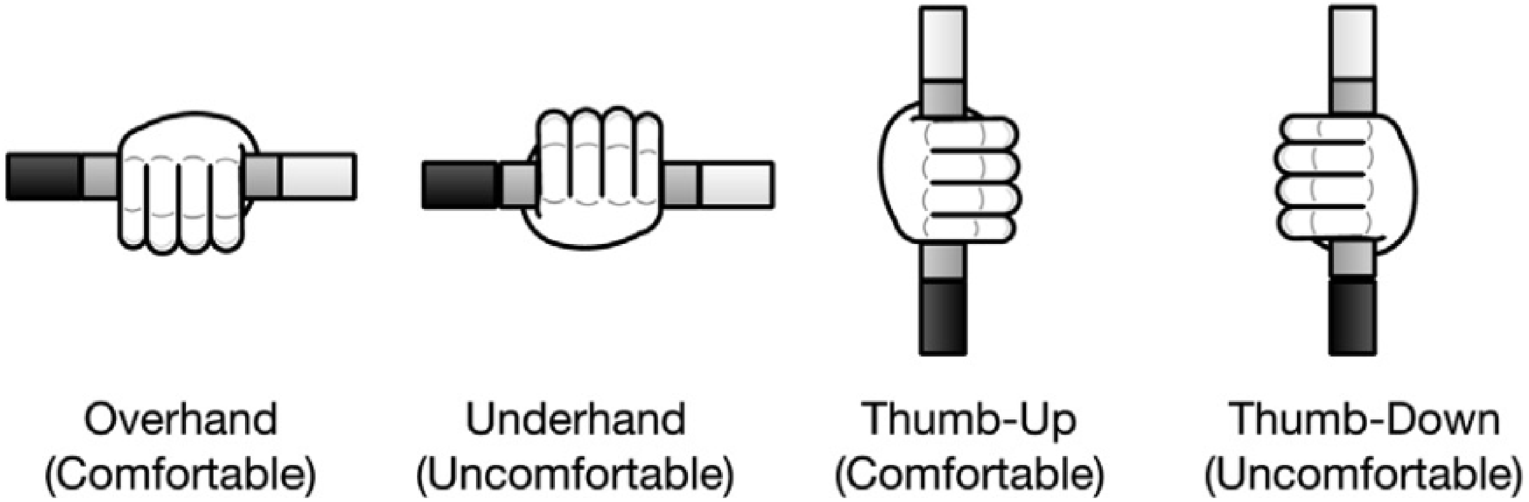


Fig. 5 The grasp height effect. Adapted from Cohen and Rosenbaum (2004)

The end-state comfort effect

Rosenbaum & Feghhi, 2019. The time for action is at hand.

- Certain hand (or body) positions biomechanically more *comfortable*
- Taking into account for action sequence planning: End position comfort maximized



You can try to observe this in real life!

End-state comfort effect: Choose the initial grasp in a way that avoids the least comfortable grasp at the end of the sequence.

Fitts' law: the equation

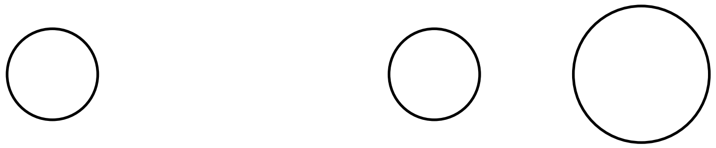
A movement law describing a tradeoff between speed and accuracy in speeded movements

$$\boxed{\mathrm{ID} = \log_2(2A/W)}$$

$$\boxed{\mathrm{MT} = a + b \times \mathrm{ID}}$$

Index of Difficulty is a log-relation of Amplitude (= Distance) and target Width

Movement time depends on ID plus some constants (baseline task difficulty and individual characteristics)



Thought exercise
What is so special and practical about ID?

First experiments

First study by Paul Fitts in 1954

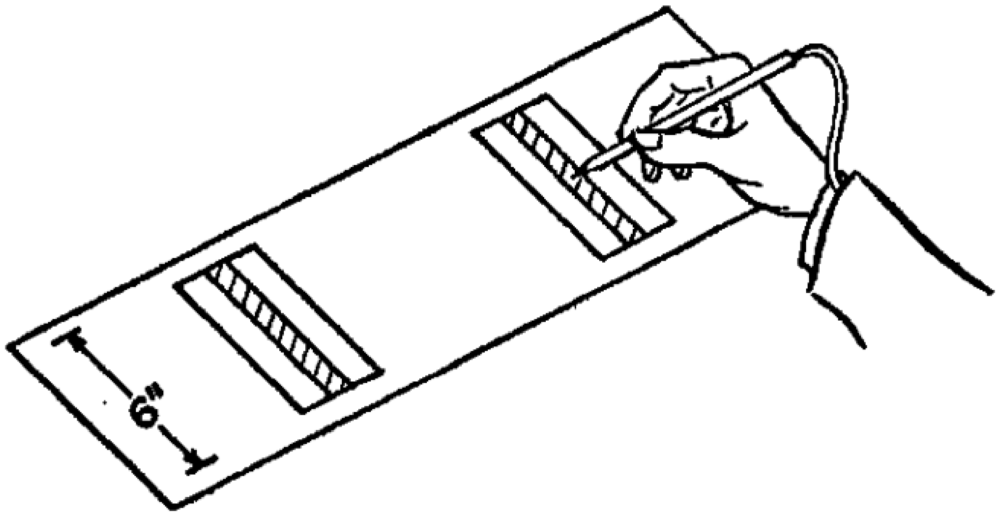
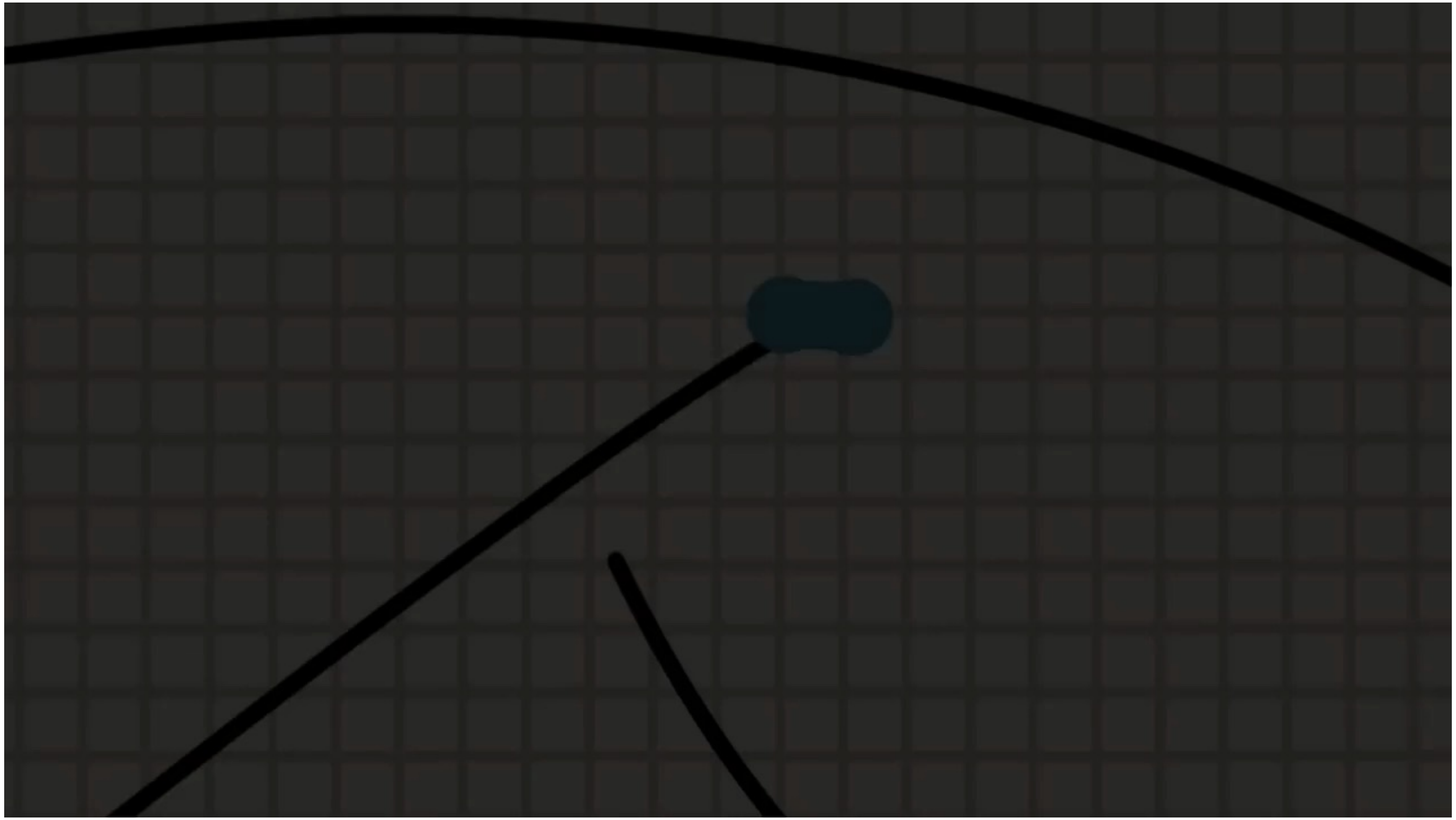


Fig. 1. Reciprocal tapping apparatus. The task was to hit the center plate in each group alternately without touching either side (error) plate.

W_s	A	I_d	t	Errors (%)
.25	2	4	.392	3.35
.25	4	5	.484	3.41
.25	8	6	.580	2.78
.25	16	7	.731	3.65
.50	2	3	.281	1.99
.50	4	4	.372	2.72
.50	8	5	.469	2.05
.50	16	6	.595	2.73
1.00	2	2	.212	0.44
1.00	4	3	.260	1.09
1.00	8	4	.357	2.38
1.00	16	5	.481	1.30
2.00	2	1	.180	0.00
2.00	4	2	.203	0.08
2.00	8	3	.279	0.87
2.00	16	4	.388	0.65

Fitts' Law in user design



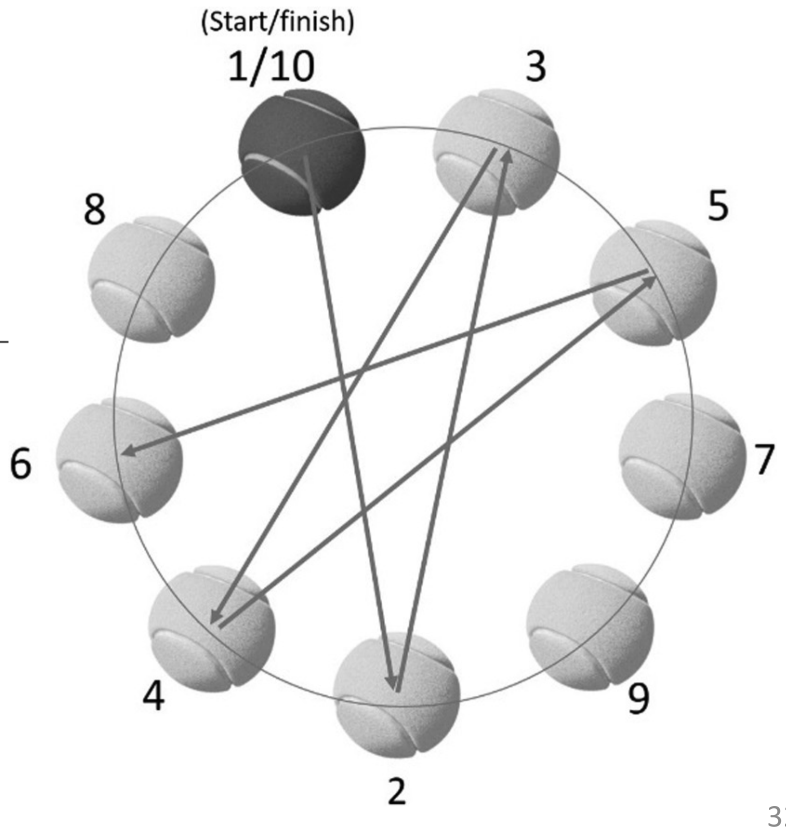
https://youtu.be/95RoKSFyQ_k

How can we use Fitts' law?

Lin & Ho, 2020, J Biomed Inform

Table 1
The indexes of difficulty (IDs) according to the combination of distance and width.

Index of Difficulty (bits)	Distance(pixels)	Width (pixels)
2.0	749	246
2.2	920	246
2.5	1177	246
2.7	770	139
3.0	610	86
3.2	1177	139
3.4	1359	139
3.7	1027	86
4.1	1359	86

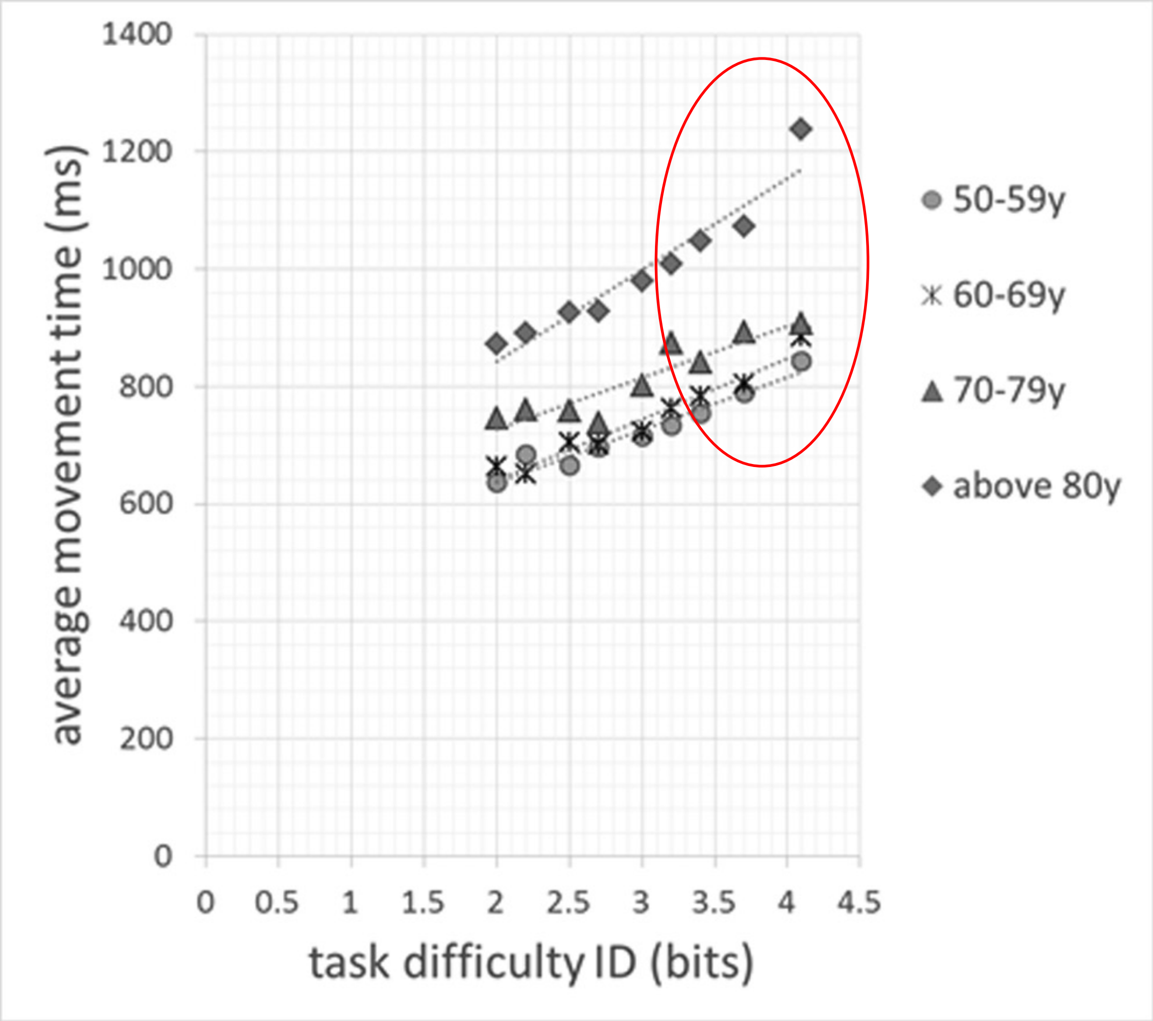


Multidimensional tapping task

Different age groups

How can we use Fitts' law?

Lin & Ho, 2020, J Biomed Inform



Age effect, though reliable only for the very old age range (above 80 years)

<u>Some points of evaluation on the study</u>

- Not controlled for more general cognitive impairments
- Potential age differences relating to task understanding
- Pretty complex task with 10 targets
- Then again, these might be what mobile phone users are confronted with
- Good: focus on the movement aspect in a controlled way

Take-home messages

- ✓ Action is an integral part of cognition, not mere output.
- ✓ The degree of freedom problem describes the problem of how to choose a particular movement trajectory among the infinitely many alternatives.
- ✓ Voluntary motor control is all about finding the *optimal* way of using muscles, joints, etc. towards achieving a particular goal. Different aspects of the movement could get optimized.
- ✓ Minimal Change Principle by Rosenbaum: When planning action sequences, a simple heuristic of the motor system seems to be to minimize change.
- ✓ Many interesting action effects can be observed in everyday life. Be observant!
- ✓ Fitts’ law is an example for a speed accuracy trade-off in motor control and one of the most used movement effects – not only in cognitive science research but also in user design and many other applied fields.

<u>Class tomorrow</u>

Getting to know each other
Group discussions

Practical exercise on Fitts’ law