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Sense of agency: theory, measures and applications

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Outline

- What is the sense of agency?
- How do we measure the sense of agency?
- Theories of sense of agency
- Applications of agency research:
  - Aberrant experiences of agency
  - Human-computer interaction

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WHAT IS THE 'SENSE OF AGENCY'?

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What is the 'sense of agency'?

- Agents intentionally make things happen

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What is the 'sense of agency'?

- Definition:
  - Sense of agency is the conscious experience we have of initiating and controlling our actions in order to influence the outside world

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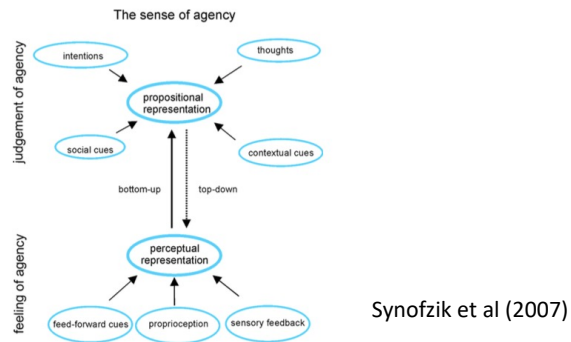# What is the 'sense of agency'?

- Characteristics of SoA:

Phenomenologically thin (Haggard, 2005)

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What is the 'sense of agency'?
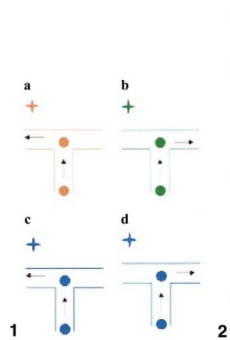
- Characteristics of SoA:

The sense of agency

Synofzik et al (2007)

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HOW DO WE MEASURE SENSE OF AGENCY?

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How do we measure sense of agency?

- Explicit measures - Just ask people!



Farrer and Frith (2002)

Farrer et al (2008)

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How do we measure sense of agency?

- Issues:
  - Need to think carefully about the question and the experimental set up
  - Issues around introspective access/accuracy
  - Demand effects

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How do we measure sense of agency?

- Implicit measures
  - Sensory attenuation paradigms
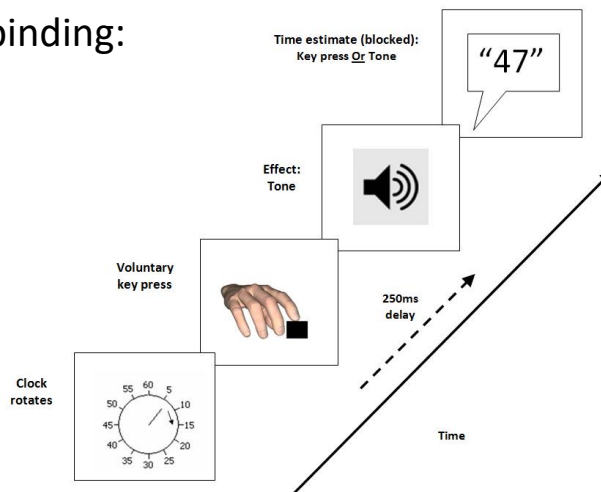   - E.g. central cancellation of self-produced tickle (Blakemore, Wolpert & Frith, 1998)
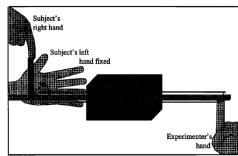
  - Intentional binding

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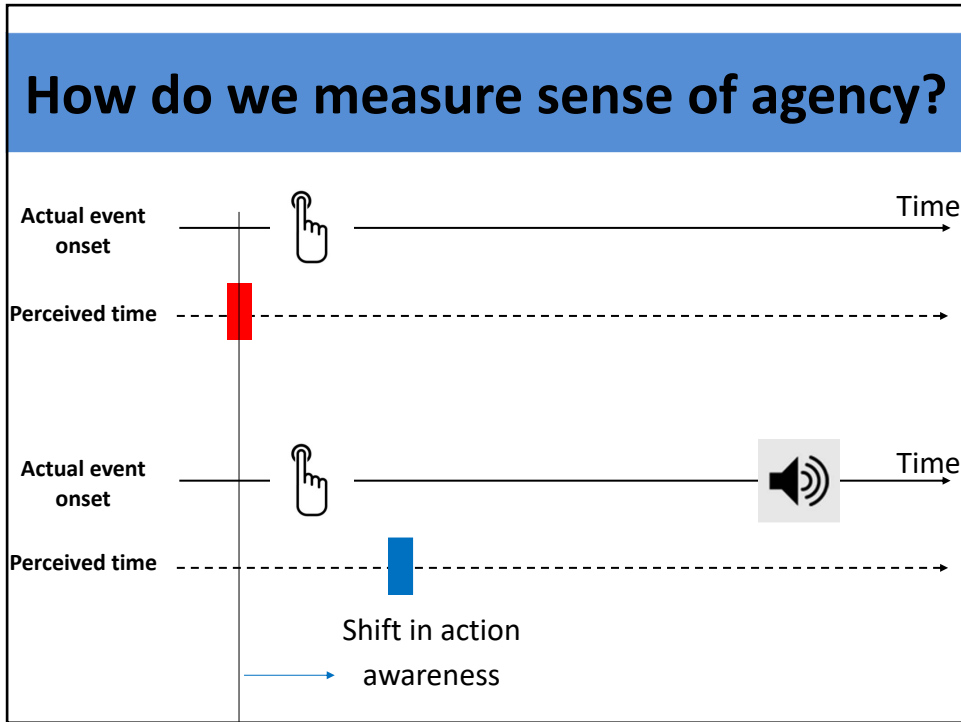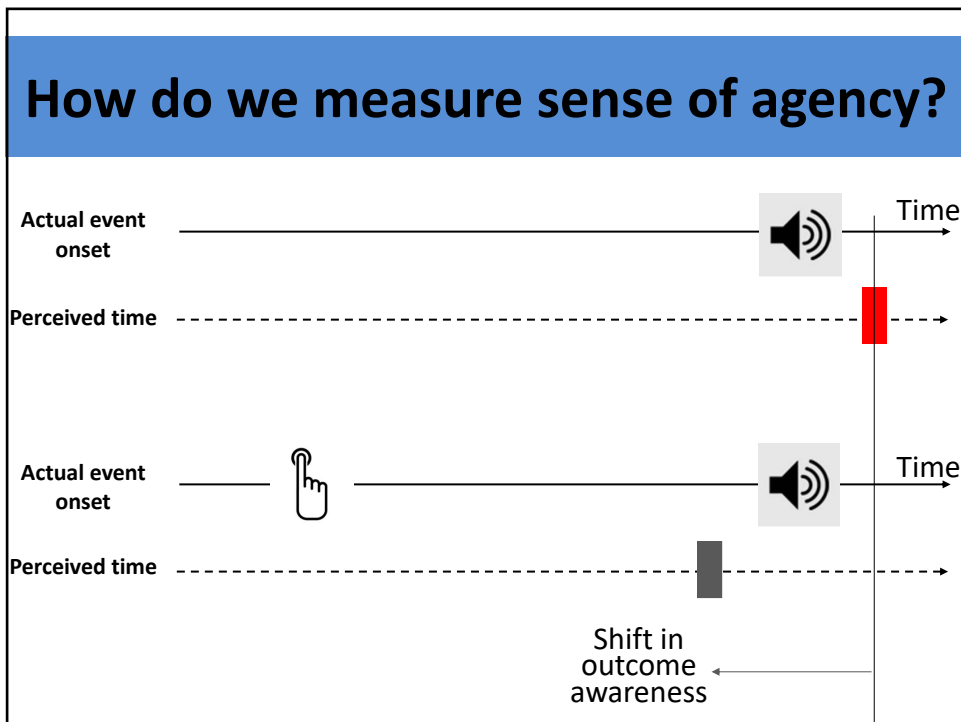# How do we measure sense of agency?

- Intentional binding:

Haggard, Clark & Kalogeras (2002) *Nat. Neurosc.*

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How do we measure sense of agency?

Actual event onset — Time

Baselines: Perceived time

Agency condition: Perceived time

Shift in action awareness

Shift in outcome awareness

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How do we measure sense of agency?

Magnetic field
TMS coil
Electric current
Skull

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How do we measure sense of agency?

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How do we measure sense of agency?

- Issues:
  - Indirect
  - Open to interpretation (causal vs. intentional binding)
  - Issues with measurement stimuli e.g. Libet clock?

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How do we measure sense of agency?

Ivanof et al. (2021)

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THEORIES OF SENSE OF AGENCY

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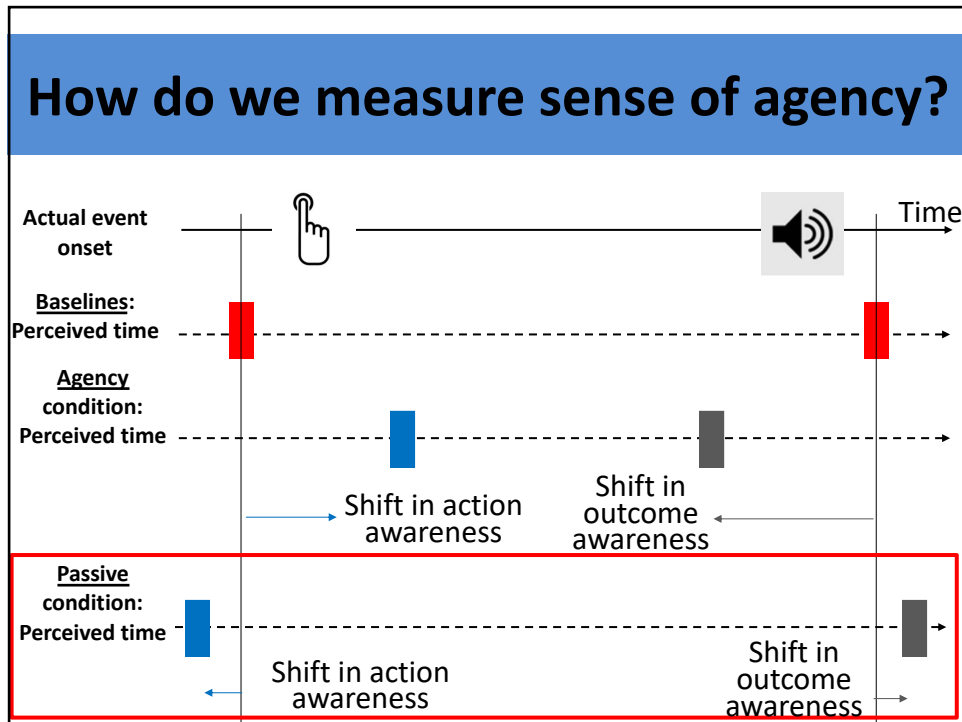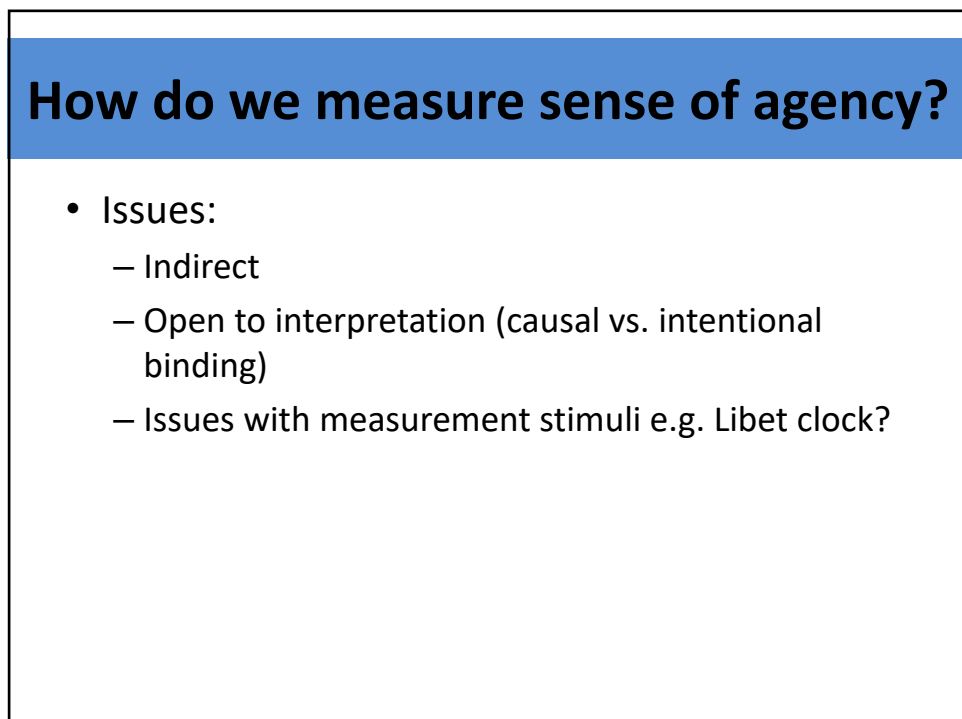
Theories of sense of agency

- This experience is malleable
  - Excessive agency: Illusions of control

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Theories of sense of agency

- Placebo buttons:

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Theories of sense of agency

– Diminished agency: Automata

Table turning/ tipping

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Theories of sense of agency

- Malleability suggests sense of agency is not a given

- We are constantly constructing this sense of agency

- What neurocognitive processes do this?

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Theories of sense of agency

- Sensorimotor prediction?

Predictive

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Theories of sense of agency

- The **'Comparator model'** of sense of agency
(Frith et al., 2000; Frith, 1992, 2004, 2005).

(From Synofzik et al., 2008)

Blakemore, Wolpert & Frith (2002). *TICS*:
- "**predictions** made by the forward model may be available to awareness"

- "the normal experience of the limb is often based on this **predicted state**, rather than the actual state"

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Theories of sense of agency

- Postdiction?

Postdictive

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Theories of sense of agency

- **Theory of apparent mental causation** (Wegner & Wheatley, 1999; Wegner, 2002)

Wegner (2002):
- "We are **not intrinsically informed** of our own authorship and must instead **build it up** virtually out of perceptions and thoughts and actions that we witness in consciousness"

- "It is as though reflecting on the reasons for our actions can prompt us to include stray, misleading, and non-optimal information in our **post-action assessments**"

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Theories of sense of agency

- Maybe sense of agency dependent on BOTH prediction and postdiction?

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Individual Judgements

Action Awareness

+13 ms	Postdiction	50 %
+5 ms		✖ 50 %

+13 ms	Prediction	75 %
+16 ms		✖ 25 %

Moore & Haggard (2008) *Consciousness & Cognition*
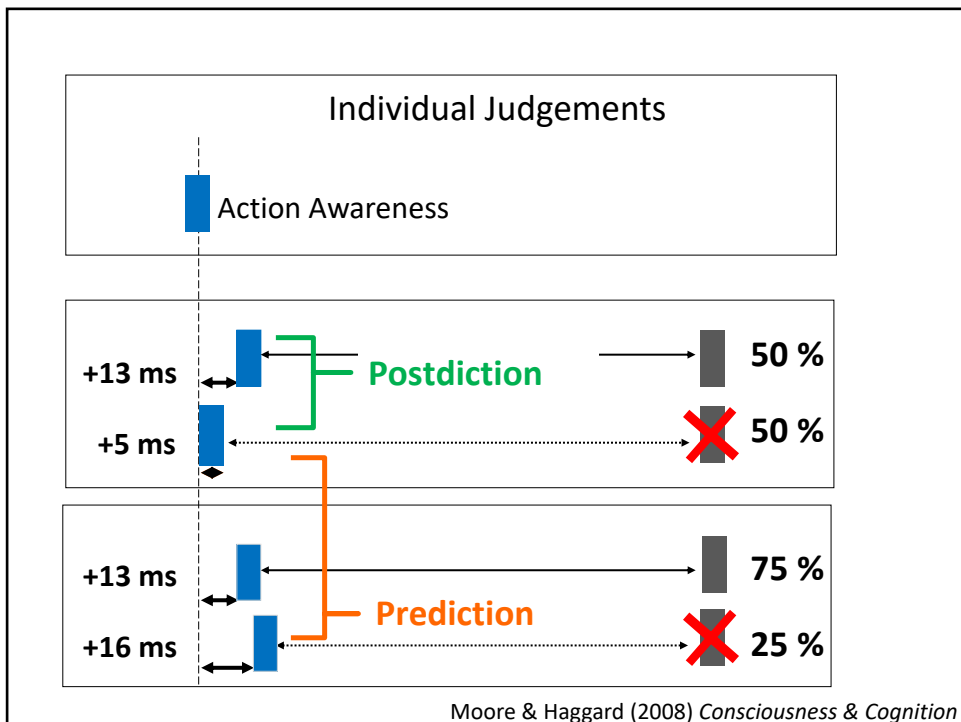
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Theories of sense of agency

- Predictive and postdictive processes use different **sources** of information
  - Predictive: internal information generated by motor system
  - Postdictive: external feedback about the movement

- Is sense of agency based on the **optimal integration** of theses different sources of information?
  (Moore, Wegner & Haggard, 2009; Moore & Fletcher, 2012)

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Theories of sense of agency

- Cue integration in human perception
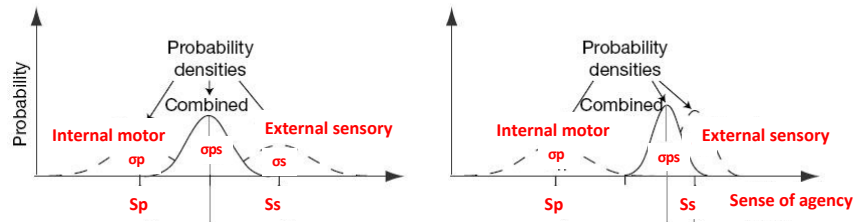 - Perceptual estimate: weighted sum of individual sensory estimates
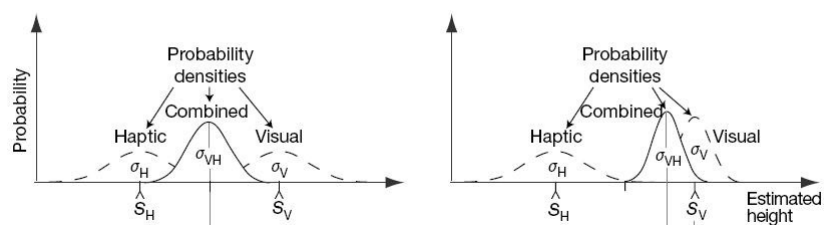
Ernst & Banks (2002)

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Theories of sense of agency

- Does the same apply to SoA?

(Moore, Wegner & Haggard, 2009; Moore & Fletcher, 2012)

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WHY DOES SENSE OF AGENCY MATTER? APPLICATIONS...

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ABERRANT EXPERIENCE OF AGENCY

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Aberrant experience of agency

- Schizophrenia:
 - Passivity symptoms (delusions of control):

'The force moved my lips. I began to speak. The words were made for me' (Frith, 1992)

'When I reach my hand for the comb it is my hand and arm which move, and my fingers pick up the pen, but I don't control them' (Mellor, 1970)

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Aberrant experience of agency

- Aberrant sense of agency in schizophrenia: a deficit in prediction? (Blakemore, Wolpert & Frith, 2002)
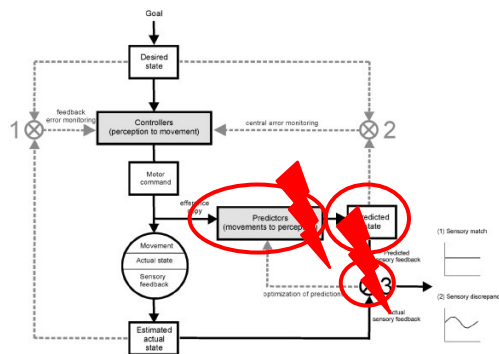
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Aberrant experience of agency

- Probabilistic relationship between key press and tone
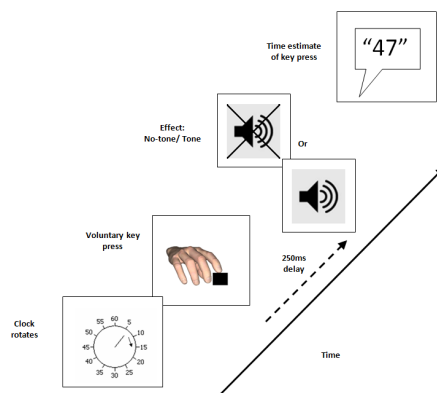
Voss et al (2010)

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Aberrant experience of agency

- Results

Voss et al (2010)

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Aberrant experience of agency

- Summary:
  - Absence of prediction in schizophrenia
  - Increased postdiction in schizophrenia
  - May help explain passivity symptoms

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Aberrant experience of agency
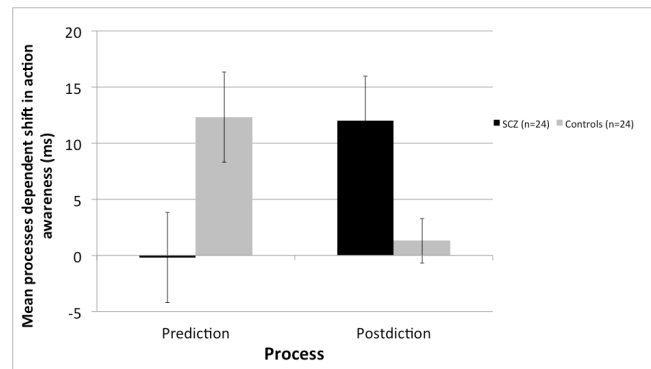
- Autism:
  - Evidence for difficulties in self-other distinction (Brass & Wiersema, 2021)
  - Mixed evidence for self-agency processing issues

  e.g. David et al (2008) – no evidence of impairment/ Sperduti et al. (2014) – evidence of impairment
  - Predictive processing framework: is prediction a core deficit in autism (Pellicano & Burr, 2012)?

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Aberrant experience of agency

- Intentional binding and force matching

Finnemann et al., (2021)

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Aberrant experiences of agency
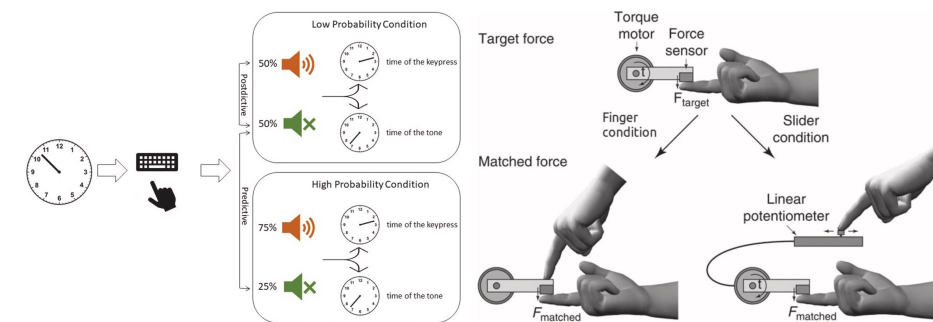
Finnemann et al., (2021)
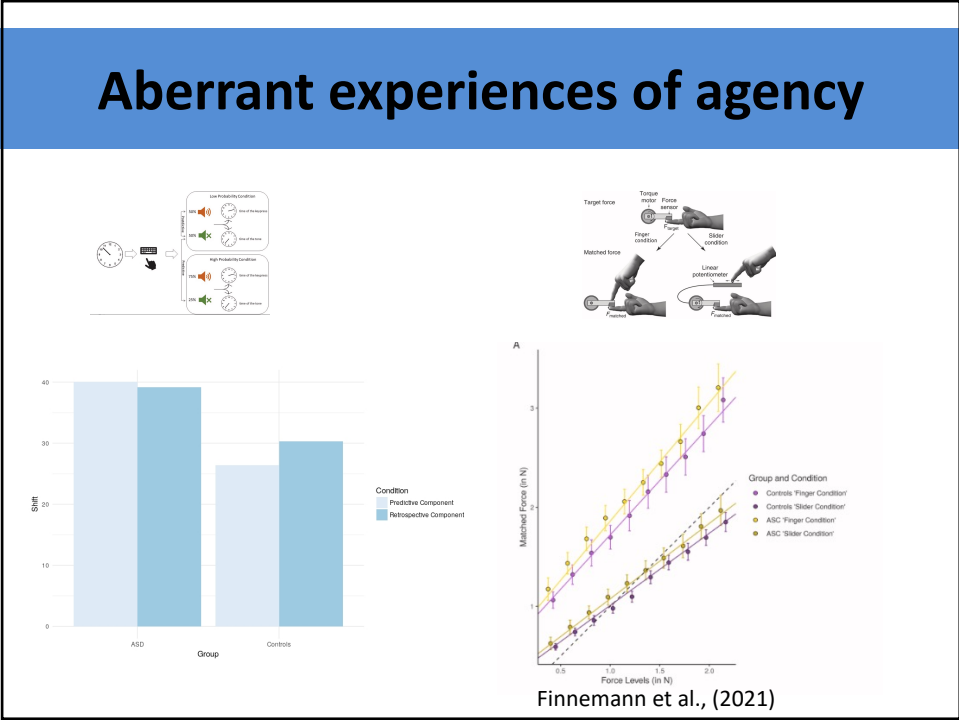
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Aberrant experience of agency

- Summary:
  - Predictive processes in sense of agency were unimpaired in those with autism diagnosis
  - What about in a social context?

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HUMAN-COMPUTER INTERACTION

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Human-computer interaction

- The feeling of control matters when we are interacting with computers

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Human-computer interaction

Support internal locus of control. *Experienced operators strongly desire the sense that they are in charge of the system and that the system responds to their actions.*
(Schneiderman, 1987)

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Human-computer interaction

What effect do novel input modalities have on sense of agency?

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Human-computer interaction

- Skinput:

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Human-computer interaction

- Our skinput device:

Coyle et al., (2012)

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Human-computer interaction
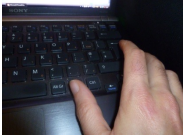
- We compared intentional binding with Skinput vs. Keyboard

Coyle et al., (2012)

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Human-computer interaction

- Results:

	Action binding	Outcome binding	Total binding
Button	6.81ms (45.6ms)	⁻36.11ms (45.46ms)	42.92ms (67.43ms)
Skin-based	29.66ms (42.84ms)	⁻79.82ms (91.23ms)	109.47ms (74.54ms)

*

Coyle et al., (2012).

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Human-computer interaction

- Result: SoA is **increased** for Skinput vs. Keyboard

- Why?
  - Don't know
  - Presence of additional sensory information from stationary (target) limb?
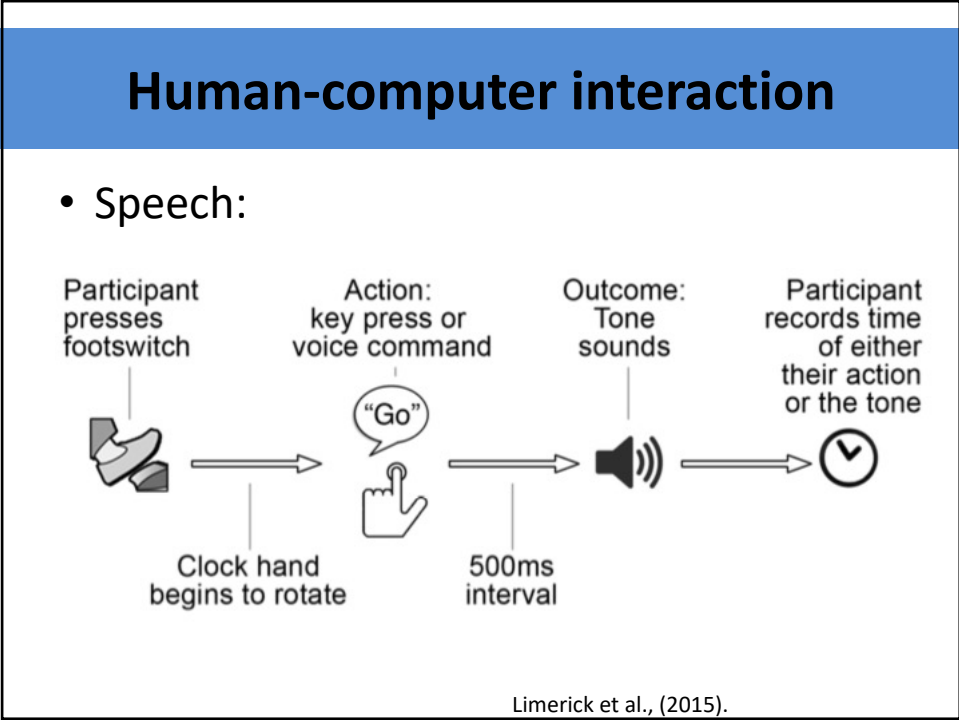 - Are self-targeted actions psychologically unique?

Coyle et al., (2012)

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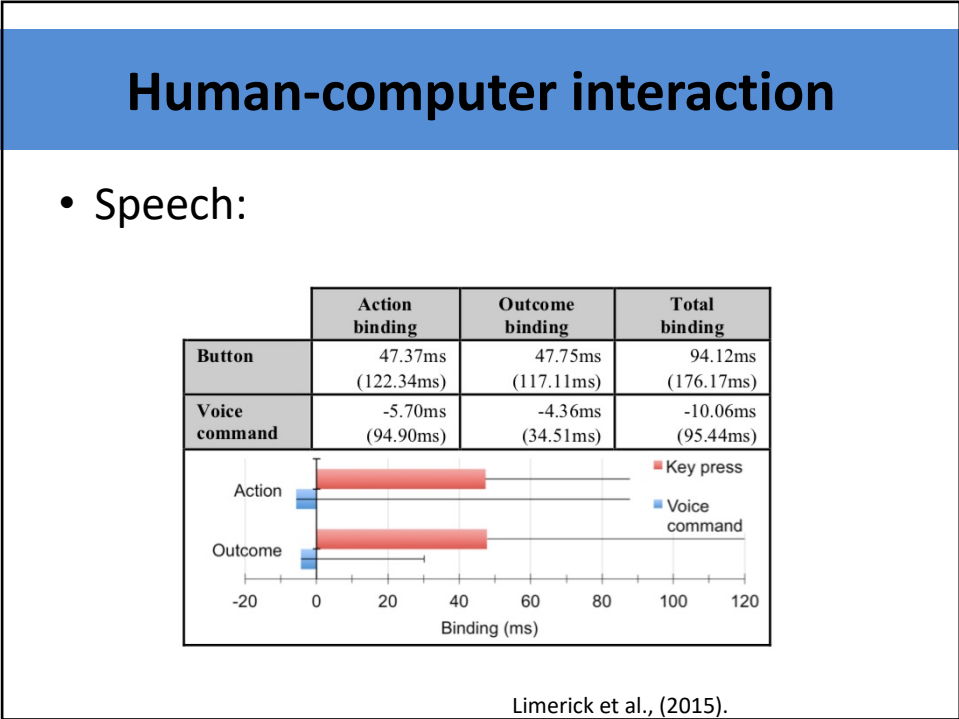## Human-computer interaction

- Speech:

Limerick et al., (2015).

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Human-computer interaction

- Speech:

Participant presses footswitch — Action: key press or voice command "Go" — Outcome: Tone sounds — Participant records time of either their action or the tone

Clock hand begins to rotate — 500ms interval

Limerick et al., (2015).

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Human-computer interaction

- Speech:

	Action binding	Outcome binding	Total binding
Button	47.37ms (122.34ms)	47.75ms (117.11ms)	94.12ms (176.17ms)
Voice command	-5.70ms (94.90ms)	-4.36ms (34.51ms)	-10.06ms (95.44ms)

Limerick et al., (2015).

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Human-computer interaction

- Sense of agency **reduced** for speech interface

- Surprising given popularity of speech interfaces?

- Does the interaction need to be "social"?
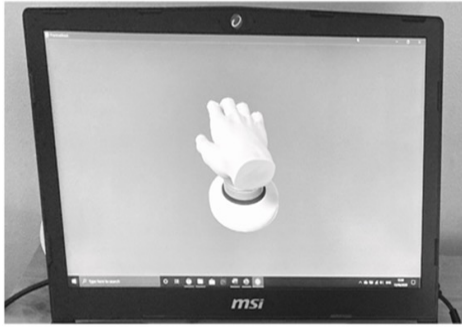
Limerick et al., (2015).

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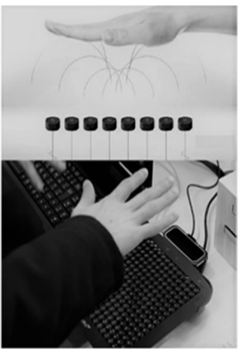## Human-computer-interaction

- Haptics and agency in VR

ultraleap
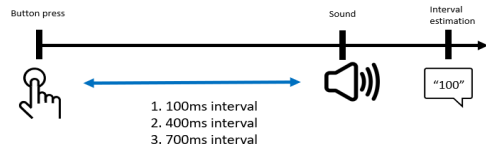
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Human-computer interaction

Evangelou et al (2021)

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Human-computer interaction

Trial sequence x36 per block

Button press   Sound   Interval estimation

1. 100ms interval
2. 400ms interval
3. 700ms interval

"100"

1. With haptic
2. without haptic

1. 0ms
2. 50ms latency
3. 100ms latency
4. 150ms latency

Two DVs

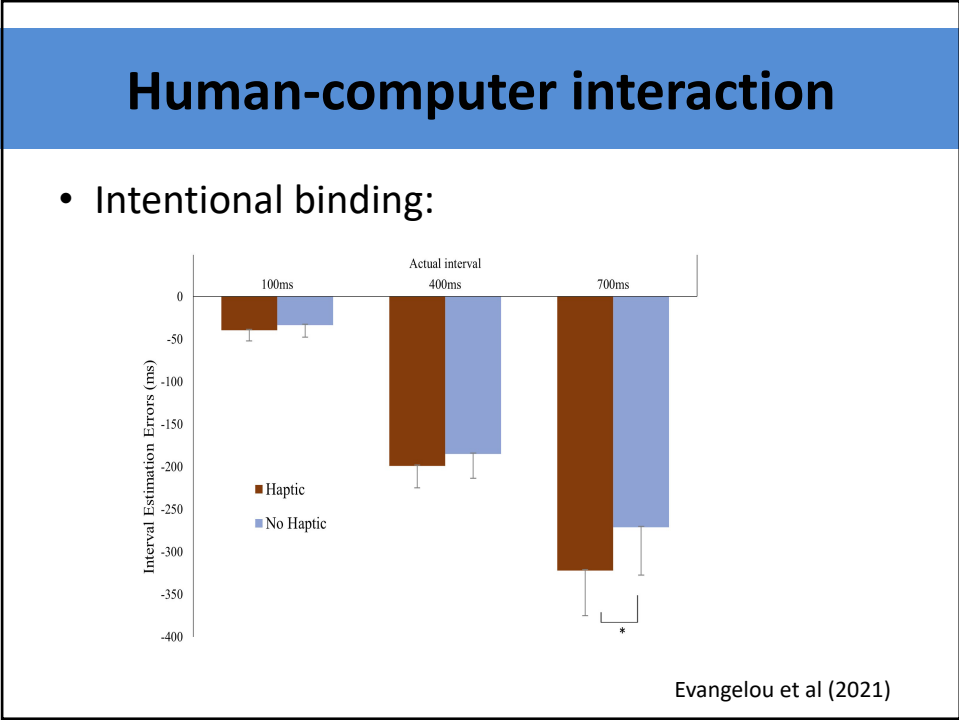1) **Intentional binding (implicit)**

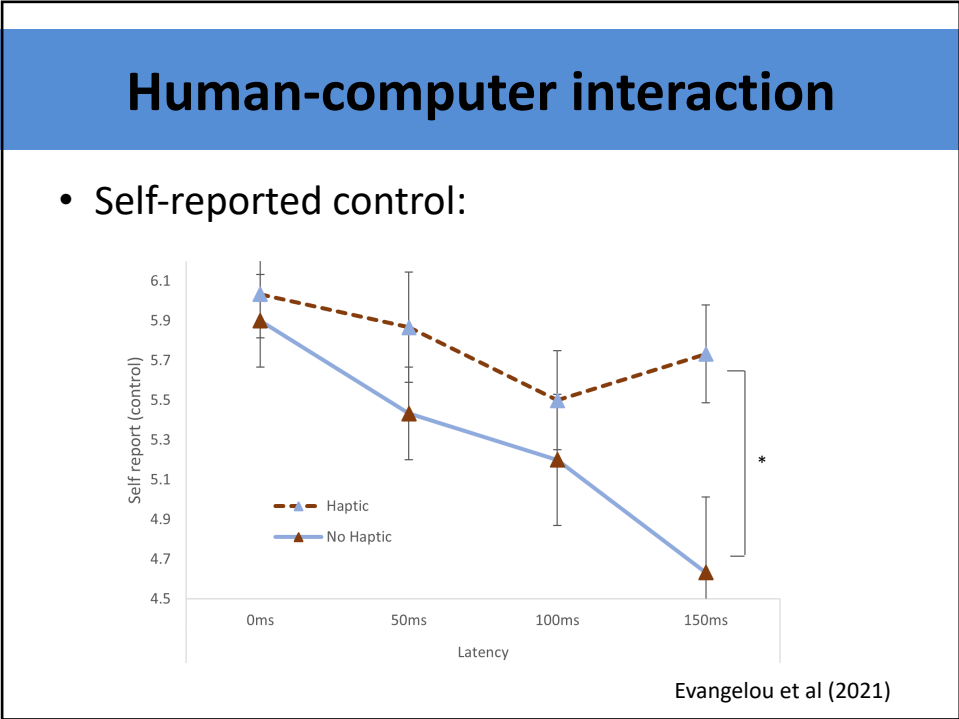1) **Self-report Likert scale (explicit)**

Every 12 trials asked:
- "I feel in control of the hand movement"
- "I feel I am causing the sound"

Evangelou et al (2021)

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Human-computer interaction

- Intentional binding:

Evangelou et al (2021)

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Human-computer interaction

- Self-reported control:

Evangelou et al (2021)

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Human-computer interaction

- Summary
  - Implicit – significant impact of haptics at longer action-outcome delays
    - Haptics useful with agentic uncertainty?

  - Explicit – haptics protects against negative effect of latency on self-reported agency

Evangelou et al (2021)
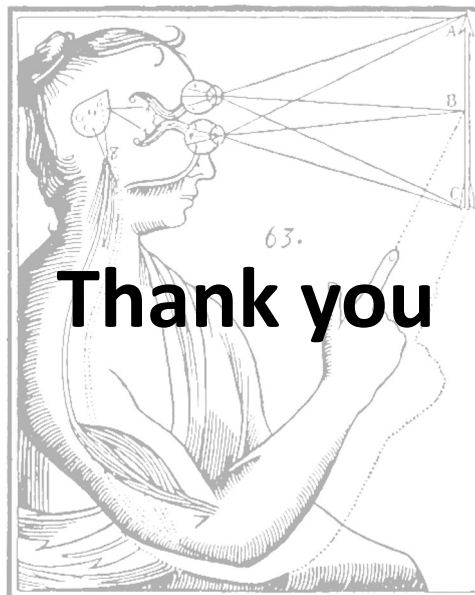
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OVERALL SUMMARY

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Overall summary

- Sense of agency
  - Definition
  - Phenomenologically thin
  - Distinction between feeling and judgement of agency
- Measures
  - Explicit vs. implicit measures
- Applications
  - Aberrant experiences of agency e.g. SCZ and autism
  - Human-computer interaction

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Thank you

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