ANIMAL COGNITION 3

IPAM Tutorials

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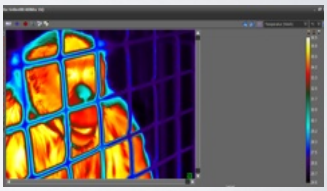
BEYOND BEHAVIOR: USING TECHNOLOGY TO MEASURE NATURAL BEHAVIOR

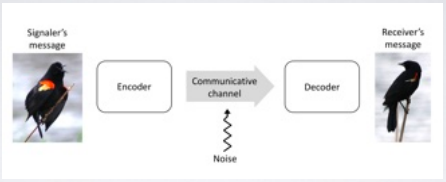
Examples of **externally-measurable** biometrics:

- Hormones
- Gaze (Eye-tracking)
- Pupil dilation (pupillometry)
- Skin temp (thermal imaging)
- Skin conduction
- Heartrate
- Respiration rate
- Oxygen consumption
- Bloodflow (hyperspectral imaging)
- Neuroimaging (fMRI, EEG)



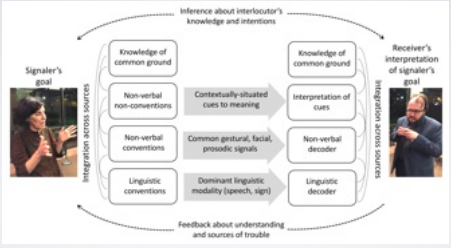
OUR (IMPLICIT) THEORETICAL MODELS CONSTRAIN THE QUESTIONS WE ASK

MODEL UNDERLYING (MOST) ANIMAL COMMUNICATION RESEARCH



Cartmill, E.A. (2023) Overcoming bias in the comparison of human language and animal communication. *PNAS*, 120 (47), e2218799120
Shannon, C. E. (1948). A mathematical theory of communication. *The Bell system technical journal*, 27(3), 379-423.
Reddy, M. (1979). The conduit metaphor. *Metaphor and thought*, 2, 285-324.

SIMPLIFIED MODEL OF HUMAN LANGUAGE



Cartmill, E.A. (2023) Overcoming bias in the comparison of human language and animal communication. *PNAS*, 120 (47), e2218799120

SOME POSSIBLE DREAM PROJECTS

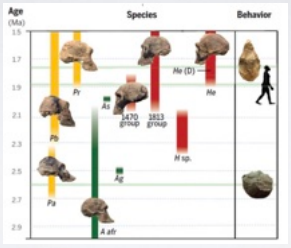
1. Expand Shannon information model to create model of animal communication that allows for (some) inference
2. Use animal cognition to build new methods for assessing *understanding* in AI

PHYSICAL VS. SOCIAL COGNITION

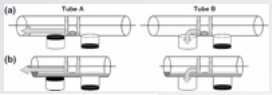
IS COGNITION DOMAIN SPECIFIC?

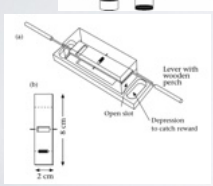
Teschke, I., Cartmill, E. A., Stankewitz, S., & Tebbich, S. (2011). Sometimes tool use is not the key: no evidence for cognitive adaptive specializations in tool-using woodpecker finches. *Animal Behaviour*, 82(5), 945-956.

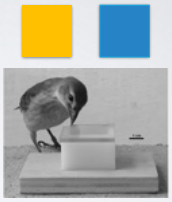
DOES DOMAIN-SPECIFIC INTELLIGENCE (E.G., TOOL USE) LEAD TO DOMAIN-GENERAL INTELLIGENCE?



PHYSICAL VS. "GENERAL" COGNITION





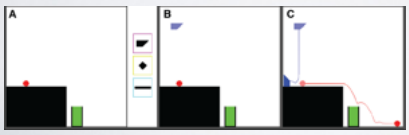


Conclusion: If you're a finch with a hammer, all things look like nails

Teschke, I., Cartmill, E. A., Stankewitz, S., & Tebbich, S. (2011). Sometimes tool use is not the key: no evidence for cognitive adaptive specializations in tool-using woodpecker finches. *Animal Behaviour*, 82(5), 945-956.

MEASURING AND MODELING PHYSICAL COGNITION ACROSS SPECIES

- Virtual tool task
  - Components selected?
  - Composite strategies?
  - Extend embodied understanding to virtual world




Josh Tenenbaum


Kelsey Allen


Daan Laméris


Kevin Smith

https://sites.google.com/view/virtualtoolsgame/home

HUMAN PERFORMANCE

- "Aha" moments of insight
- Structured, object-oriented initial attempts
- Few-shot trial-and-error learning

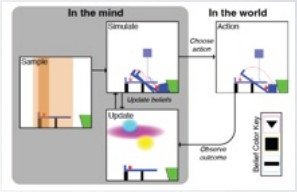
WHAT ABOUT OTHER ANIMALS?

- Testing bonobos at Planckendael Zoo
- 6-8 have passed training phase (progressively lower probability of random success)
- Testing on near and far transfer tasks

VIRTUAL TOOLS WORKING GROUP

Sample, Simulate, Update (SSUP) model

- **Sample**: An object-oriented initial hypothesis space of promising actions
- **Simulate**: An approximate internal physics simulator, or world model, allowing an agent to imagine the effects of their actions
- **Update**: A guiding mechanism that allows an agent to learn from both their imagined and real actions

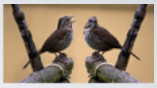


Allen, K. R., Smith, K. A., & Tenenbaum, J. B. (2020). Rapid trial-and-error learning with simulation supports flexible tool use and physical reasoning. PNAS, 117(47), 29302-29310.

PHYSICAL VS. SOCIAL COGNITION

WHY STUDY SOCIAL COGNITION?

- Excellent evidence for representations
- Have to make predictions based on non-visible information
- Can be studied non-verbally
- Broad distribution across species
- Ecologically-relevant
- Changes over human development
- Ranges from very simple to very complex behavior
  - Can I mate with you?
  - Are you going to eat me?
  - I recognize that you are doing X because you want me to learn Y
  - Social behavior can be hardwired, emergent, or conscious



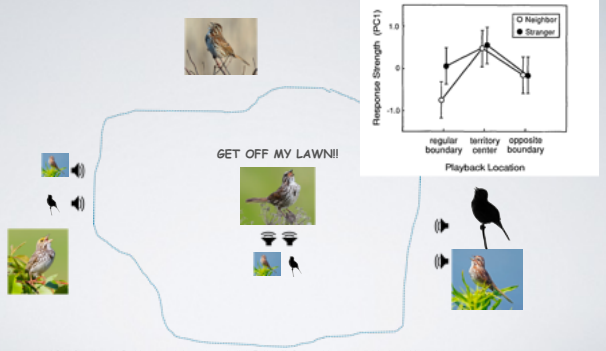
REPRESENTING OTHERS

Why do it?

- Identify members of own species
- Distinguish between potential mates
- Avoid inbreeding or fighting with close kin
- Recognize allies, partners, and offspring
- Avoid conflict
- Rise to power!!!

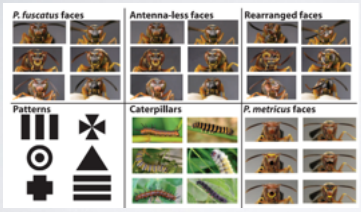
RECOGNIZING OTHERS

- Most social species have some degree of individual recognition
- Many different modalities / sources of info
  - Songs (e.g., birdsong studies with neighbor playbacks)
  - Pheromones (e.g., infant/parent/sibling recognition)
  - Facial markings
  - Recognizing others requires some type of memory/model/representation



Stoddard, P. K., Beecher, M. D., Horning, C. L., & Campbell, S. E. (1991). Recognition of individual neighbors by song in the song sparrow, a species with song repertoires. *Behavioral Ecology and Sociobiology*, 29, 211-215.

RECOGNIZING OTHERS



Sheehan, M. J., & Tibbetts, E. A. (2011). Specialized face learning is associated with individual recognition in paper wasps. *Science*, 334(6060), 1272-1275.

GAZE DETECTION

- Many animals change their behavior when others are watching
- Might be low-level response to eyes – doesn't imply understanding of ***gaze***

E.g.

- Freeze / startle responses
- Audience effects
- Caching

GAZE FOLLOWING

Follow another's direction or gaze

Useful for finding food, avoiding danger, acquiring info others have

Can be more or less based on actual gaze

- Body orientation
- Head position
- Eye direction

Follow to proximal or distal targets

- 6-month-olds follow to 1st target seen
- 9-month-olds follow to distal targets

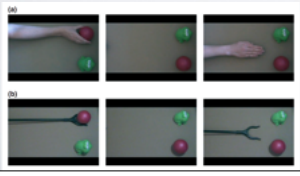
Kaminski, J., Riedel, J., Call, J., & Tomasello, M. (2005). Domestic goats, Capra hircus, follow gaze direction and use social cues in an object choice task. *Animal behaviour*, 69(1), 11-18.
Ruiz, A., Gómez, J. C., Roeder, J. J., & Byrne, R. W. (2009). Gaze following and gaze priming in lemurs. *Animal cognition*, 12, 427-434.

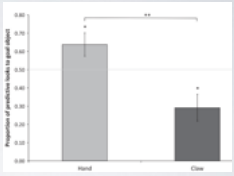
ANTICIPATING ACTIONS

What is being predicted?

- Goal / Path / Location / Movement / Action

E.g., Human infants predict targets differently for biological agents and robots





Cannon, E. N., & Woodward, A. L. (2012). Infants generate goal-based action predictions. *Developmental Science*, 15(2), 292-298.

Ganglmayer, K., Attig, M., Daum, M. M., & Paulus, M. (2019). Infants' perception of goal-directed actions: A multi-lab replication reveals that infants anticipate paths and not goals. Infant Behavior and Development, 57, 101340.

REPRESENTING RELATIONSHIPS

Test of social relationship understanding in female monkeys A, B, C

1. Wait until infants are out of view
2. Play scream of A's infant
3. B and C look at A
4. Then A approaches speaker

Cheney, D. L., & Seyfarth, R. M. (1980). Vocal recognition in free-ranging vervet monkeys. *Animal Behaviour*, 28(2), 362-367.

REPRESENTING MINDS

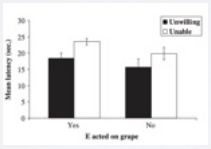
Why do it?

- Better able to predict behavior of others
- Advantage in competition
- Allows for cooperation
- Calibrate behavior to other individuals
- Empathy (and revenge)

REPRESENTING INTENTIONS

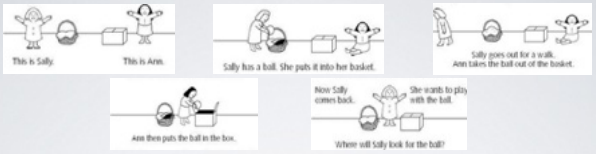
- Recognizing others' intentions: behaving differently in relation to others' actions based on their motives
- E.g., chimpanzees distinguish between **desire** and **ability**

More patient with clumsy experimenters than mean ones



Call, J., Hare, B., Carpenter, M., & Tomasello, M. (2004). 'Unwilling' versus 'unable': chimpanzees' understanding of human intentional action. *Developmental Science*, 7(4), 488-498.

KNOWING WHAT OTHERS KNOW



Children pass the original version around 4 years old

Criticisms – too verbal, projections to puppets, no reason to care

Things that push age of passing younger:

- more engaging paradigms
- familiar characters
- non-verbal methods (e.g., eye-tracking, facial expressions)

Now pass at ~2 years old

Apes can do this too!

Krupenye, C., Kano, F., Hirata, S., Call, J., & Tomasello, M. (2016). Great apes anticipate that other individuals will act according to false beliefs. *Science*, 354(6308), 110-114.

KNOWING WHAT YOU KNOW

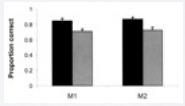
Thinking about thinking

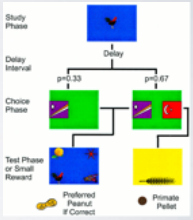
Non-verbal tasks focus on uncertainly judgements

- Awareness of absence of knowledge
- Acting differentially based on confidence

Possible measures:

- Opt-out task
- Latency of reward anticipation
- Selectively seeking new knowledge



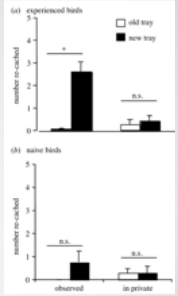


Hampton R (2001) Rhesus monkeys know when they remember. *PNAS* 98(9):5359–5362

INTEGRATING OWN EXPERIENCE INTO JUDGMENTS OF OTHERS

In some case, animals (and children) integrate their first hand experiences into their predictions of others' behavior

- Jays recache food based on whether they have stolen from others in past
- Apes (and children) use their past visual experiences to predict what others can see
- Apes also use past interactions to choose whether to cooperate or defect



Emery, N. J. & Clayton, N. S. 2001 Effects of experience and social context on prospective caching strategies in scrub jays. *Nature* 414, 443–446.

REQUIRE REPRESENTATIONS?

Can seemingly-complex things like perspective-taking be explained by simple heuristics driven by associative learning?

Does the ability to modify interactions with others based on shared past experiences require robust representations of self and other?

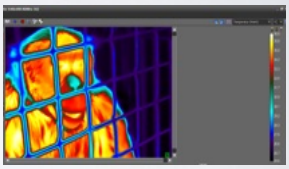
How are representations of others stored?

- Projectable models?
- "Temperature" ratings of relationships?

Are social representations different (in a meaningful way) from representations of objects?

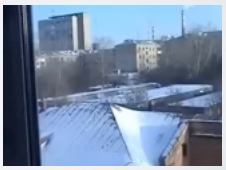
COMBINING OBSERVATIONS OF NATURAL BEHAVIOR WITH TECH

- Examples of externally-measurable biometrics:
  - Hormones
  - Gaze (Eye-tracking)
  - Pupil dilation (pupillometry)
  - Skin temp (thermal imaging)
  - Skin conduction
  - Heartrate
  - Respiration rate
  - Oxygen consumption
  - Bloodflow (hyperspectral imaging)
  - Neuroimaging (fMRI, PET, EEG)



PLAY AND CREATIVITY

- Biological agents can set their own goals
  - Play
  - Explore/exploit
  - Games



Setting and reaching goals can lead to learning, but it can also be fun!

Importance of affect / experience?

LEARNING ABOUT OTHERS THROUGH PLAY

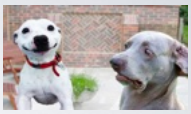
- In humans, **non-verbal** joking behavior emerges around 12 mos
  - Offer + withdrawal
  - Provocative non-compliance
  - Disrupting others' activities

Reddy, V. & Mireault, G. (2015). Teasing and clowning in infancy. Current Biology, 25(1), R20-R23.

SOCIAL PLAY & SOCIAL UNDERSTANDING

Johanna Eckert

Sasha Winkler



Like infants, apes play very simple jokes

Based on social relationships

Eckert, J., Winkler, S. L., & Cartmill, E. A. (2020). Just kidding: the evolutionary roots of playful teasing. *Biology Letters*, 16(9), 20200370.

NAVIGATING AMBIGUITY IN PLAYFUL TEASING

Isabelle Laumer

Sasha Winkler

Federico Rossano

Laumer, I. B., Winkler, S. L., Rossano, F., & Cartmill, E. A. (2024). Spontaneous playful teasing in four great ape species. *Proc Roy Soc B*, 291, no. 2016: 20232345.