The Ontogeny of Socially Guided Attention

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Social agents are responsible for the information complexity that is so demanding of attention.

What makes James’ “blooming, buzzing confusion”?
What allows us to manage in the confusion?

Social agents also facilitate the development of attention.
Attention in primates: Roots of ‘social looking’

Arboreal lifestyle requires depth perception & binocular vision,

but front-facing eyes limit vision.

Social information allows “seeing-by-proxy” and social-signaling
Learning To Attend: The Social Side

‘What is important’ is partly culturally determined (i.e., depends on social experience)
Attention and Learning

• Attention: ‘considering or taking notice of s.t.’
  – Circular definition, but...
  it denotes functional states of behavior and physiology that impact learning

• Attending also is learned
  – Filter; adjust ‘gain’; priming
  – Behavioral control; planning

• How do we learn to attend?
Social Cuing of Attention in Early Development

• What social information drives action in young mammals?

  Multimodal: chemosensation, somatosensation, vision, audition

Logan et al, Cur Bio 2012

Novitski et al, 2007
Social Cuing of Attention in Early Development

From birth, social cues can drive attention - and can shape attention!

Many mammals: olfactory cues
Humans: early shaping by auditory stimuli
How do we use *visible* social cues to guide attention?
Social looking in human infants

*Peek-a-boo*  *Book-reading*

*Social referencing*  *Spoon-feeding*

*Requesting*  *Social rituals (‘patty-cake’)*

*Naming (“Look at the…”)*  *Playing with toys*

*Watching people do things*  *Taking turns*
Attention-Sharing

Attending to (st) because another person is, or getting another person to attend to what you’re attending to

Why is it important?

– Necessary for teaching & learning
– Facilitates shared understanding
– Builds cooperative, coordinated action
What *visible* social cues guide infant attention?

*Gaze-following, point-following:* most studied

- Gaze-following emerges, improves from 6 - 18 months (Butterworth & Grover 1980; Butterworth & Jarrett 1991)

- Eventually point-following becomes more effective (Deák et al, 2000)

*How do these sensitivities emerge?*
Gradual learning of gaze-, point-following

Longitudinal study of 42 infants: laboratory measure of ‘motivated following’

One purpose: address controversy about “early” vs. “late” gaze-following

Deák, Robledo, Triesch, Sasson, in prep
Paradigm

1. Demonstrate reward locations.
2. Twenty test trials:
   - 6 gaze cues
   - 6 point cues
   - 6 gaze + point cues
   - 2 ‘baseline’ trials

Every month, 4 to 12.

Different quasi-random trial order & reinforcer/locations combos

$N = 42$ infants

$(n= 24$ to 35 per month finished 18-20 trials)
A line graph illustrates the proportion of cues followed across different age ranges from 5-6 months to 11-12 months. The graph compares three conditions:

- **Gaze**: Represented by a blue line with data points.
- **Gaze & Point**: Represented by a green line with data points.
- **Baseline**: Represented by a black line with data points.

The x-axis represents the age in months, labeled as 5-6mo, 7-8mo, 9-10mo, and 11-12mo. The y-axis represents the proportion of cues followed, ranging from 0.00 to 1.00.

*Note: The graph includes error bars to indicate variability in the data.*
How are these responses learned?

1. Theoretical framework
   - What is the mechanism?
   - simulation experiments

2. Ecological description
   - What is the information available?
   - cognitive ethnography, micro-behavioral analysis
A model PLeASES

Early-emerging traits *sufficient* for attention sharing
(Deák & Triesch, 2006; Deák et al, 2014; Triesch et al 2006, 2007)

- **PERCEPTUAL** traits
  - orient & shift attention; discriminate faces & objects

- **LeARNING** traits
  - TD-reinforcement learning (Sutton & Barto, 1998)
  - visual habituation

- **AFFECTIVE** traits
  - enjoy human faces; toys and hands, too

Information sufficient to learn attention-sharing

- **SOCIAL ENVIRONMENT STRUCTURE**
  - during everyday dyadic interactions
Can PLeASES explain development?

Does computational model predict behavioral data?
(Triesch et al, 2006; Triesch et al, 2007; Teuscher & Triesch, 2007; Jasso et al, 2012)
Learning algorithms

Temporal Difference Reinforcement Learning
- relates perceived head/eye angle to own attention-shifting program
- learning speed, stimulus values, discounting (SARSA), shift-cost, ‘temperature’

Habituation: induces ‘sampling’
- slope, offset, rate
How it works (informally)

A: Looking at CG’s face yields reward.

B: CG’s profile, habituation: less reward. Explore. Toy yields moderate reward.

C: CG’s head pose associated w/ action: shift that brought toy into view
Results

Simulates many infant behaviors

red: attention shifts to parent
blue: shifts to parent’s looking-target

Triesch & Carlson, 2003
Simulates some infant behaviors

- Effects of target location & number of targets (Jasso et al, *TAMD* 2012)
- Gaze-alternation (Jasso et al, *TAMD* 2012)
- Social referencing (Jasso et al, *TAMD* 2012)
- Effects of sensitive vs. insensitive parenting (Teuscher & Triesch, 2007)
- Emergence of gaze-sensitive cells w/ mirroring properties (Triesch et al, 2007)
  - later discovered in macaque LIP (Shepherd et al, 2009).
These results are consistent with PLeASES model.

But they don’t capture the social environment’s structure.

That requires cognitive ethnographic data.
How/when does attention-sharing emerge *in situ*?

Home observations: 35 infant-mother dyads (3-11 months, cross-sectional; Eng-speaking, mid-SES)

Deák, Krasno, Triesch, Lewis & Sepeda, *Dev Sci* 2014; in revision
What are the available social cues?

(Perceptible to infant, per minute)
From most to least frequent:

<table>
<thead>
<tr>
<th>Mother Action</th>
<th>Count/Min (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaze Shift</td>
<td>5.1 (2.1)</td>
</tr>
<tr>
<td>Verbal Bids</td>
<td>4.8 (1.6)</td>
</tr>
<tr>
<td>Object Manipulation</td>
<td>3.7 (2.0)</td>
</tr>
<tr>
<td>Sound (object)</td>
<td>2.4 (1.6)</td>
</tr>
<tr>
<td>Pointing</td>
<td>1.9 (1.2)</td>
</tr>
</tbody>
</table>

(I’ll return to this, after describing attention-sharing states)
How much attention-sharing occurs?
Which cues are followed?

Within 5 sec...

Percentage Cues Followed

Gaze | Point | Gaze & Point | Object Manipulation

Converging evidence: infants do not follow adults’ gaze in naturalistic interactions.

But by 8-10 months, they will sometimes follow gaze in ‘stripped down’ laboratory tasks.

What’s going on? Is gaze-following non-normative? If so, why is it easy to elicit?

*How is it learned?*
One possible answer: Cues don’t work alone

Number of Cue Types w/in 7 sec of Attention-Following

- Single cues
- Three+ cues
- Two cues (other)

Manip. & Gaze
Manip. & Vocal.
Gaze & Point
Gaze & Voc
Parents action-structure might indirectly teach gaze-following

Problems:

1. Infants mostly look at mother’s hands, not her face
2. Mothers usually look at infant’s face
Solution: Parents’ ‘Active Vision’ Provides Correlated Signal

• Weak but reliable: when mothers weren’t looking at infant, they often looked at their hands.
  – when infants glanced at mother’s face and she wasn’t looking at them

• Next thing infants usually looked at?
Saw mom’s face, then object-handling (same-place)

Saw mom’s face, then static object (same place)

Deák, Krasno, Triesch, Lewis & Sepeda, *Dev Sci* 2014

Saw mom’s face, then static or held object *in a DIFFERENT location.*
Inference: gaze-following could be learned by watching the hands – if your parent uses active vision!

Contingencies between seeing parent’s gaze direction and rewarding sights are rare, but systematic.
Does this work in the PLeASES Model?

- 3D simulation environment (Lewis, Deák, Jasso, Triesch, 2010)
- Virtual caregiver replicated looking & manual action sequences of real parents
Result:
Given ‘real’ sequences of adult actions, infant-agents could learn to follow gaze by watching the hands.
The original question

• What is the role of visual behavioral cues in guiding infant attention?
  – Theoretical model?
  – Account of the available information?

• Evidence suggests that infants learn head direction cues before their first birthday.
  – Parents’ actions are informative, assuming (a) parents use active vision; (b) infants are rewarded by watching adults handle objects.
  – Parents often produce redundant cues that might direct infant’s attention. Object-hndling has highest cue value.
Theoretical account:

- Relies on highly conserved, neurobiologically defined learning mechanisms
  - Learning is coordinated with other orienting and attention-regulating mechanisms
- Unknown how the CNS represents high-level visual events (e.g., head turning towards high-contrast area)
- But: only shown partial sufficiency, not necessity, of the elements of the PLeASES model. Incomplete.

• Important Caveat #1: No theory of how infants eventually gain conceptual access to social cues
• Important Caveat #2: Visual social cues co-occur with other, especially auditory, cues to attention (speech)
Teaser: Chang, de Barbaro, & Deák

MESA Longitudinal home observations of dyadic object play.

Coded:
- Gaze
- Manual actions
- Maternal vocalizations

Reveals changing patterns of timing: When mothers say object name, what is infant looking at? What is infant manipulating? What is mother looking at and manipulating?

Patterns change a lot from 4 to 9 months, as infants gain pre-linguistic skill and manual motor skill.
Collaborators: Lucas Chang, Kaya de Barbaro, Ross Flom, Joanne Jao, Hector Jasso, Anna Krasno, Josh Lewis, Yu Liao, Scott Makeig, Anne Pick, Marybel Robledo Gonzalez, Leigh Sepeda, Jochen Triesch, Christof Teuscher


NSF (HSD and TDLC), M.I.N.D., NAAR

Thanks to fantastic collaborators and centers!