Exploratory Behavior in the Development of Perceiving, Acting, and the Acquiring of Knowledge

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Presenter: Oliver Wang

Agenda

1. Introduction
2. Three Phases of Development
3. Phase 1 — Birth to 4 mos
4. Phase 2 — 5 to 8 mos
5. Phase 3 — 8+ mos
6. Discussion

Eleanor J. Gibson

- American psychologist
    - Smith College (BA, MS), Yale (PhD)
    - Researcher and Professor at Cornell
- Married to James J. Gibson
- Contributions in the field of perceptual learning
    - Differentiation theory
    - Visual cliff experiment

Previous Work on Child Cognition

- Behaviorism
    - All behaviors learned through interaction with environment, little influence from innate/inherited factors
- Curiosity and development in stages
- Learning driven by the need for competence
    - Need to “see clearly, hear distinctly”
- “Random” action (0-1 yrs) -> Directed activity (1+ yrs)
- Self-exploration, not attachment
- Affordances
    - Links perception to action

Affordances are Learned

- Children explore in the first year of life to learn new affordances
    - Cycle of exploration -> new affordances -> more complex exploration
- Distinction between exploratory and executive action

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Exploration is Foundational

- Information gathering, adjustments to perceptual system
  - Perceptual aspect, motor aspect, knowledge-gathering aspect
- Babies born with urge to explore and attention to environment
- Preference for novel information

"Cognition begins as spontaneous exploratory activity in infancy"

Three Phases of Development

Three phases of infant development:

1. Birth to four months
    - Attention to motion
    - Multimodal exploration (mouthing, audio-visual)
    - Absorbing foundational information
2. Five to eight months
    - Grasping, reaching for objects
    - Selective exploration
    - Depth perception
3. Eight months and beyond
    - Self initiated locomotion
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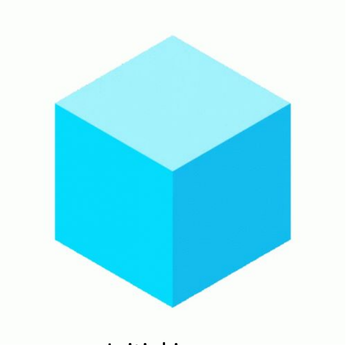
(0-4 mos) - Attention to Motion

- Moving targets
  - Wider and farther visual field for moving objects
- Static targets when the baby itself is moving
- Tracking disrupted if background moves in the same way

(0-4 mos) - Corresponding Objects

- Infants habituated to the same 3D object rotating on different axes, but dishabituated to a new rotating object
  - Did not habituate if a static object was shown first
  - **Habituation**: the diminishing of a physiological or emotional response to a frequently repeated stimulus
- Evidence of the importance of kinetic information
- Common movement of parts -> unity of objects



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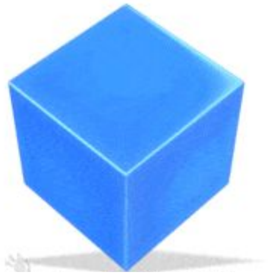
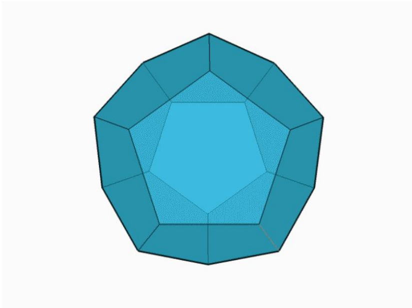


Habituated



Dishabituated

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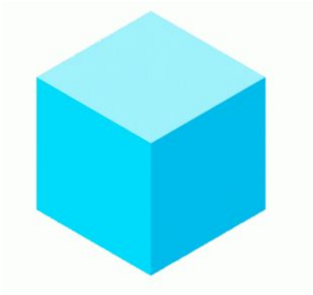

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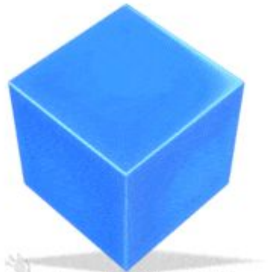
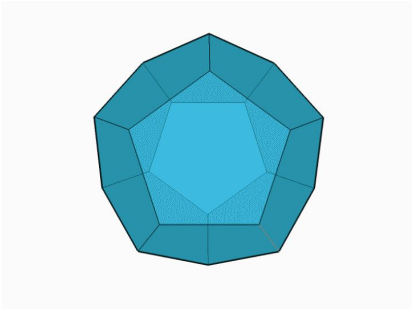


Dishabituated



Dishabituated

(0-4 mos) - Multimodal Consistency

- "ahh" "eee" video paired with sound
  - 73.6% of time fixated on face matching the audio (n=32)
  - Coordination between audio-visual systems

"ahh" or "eee"

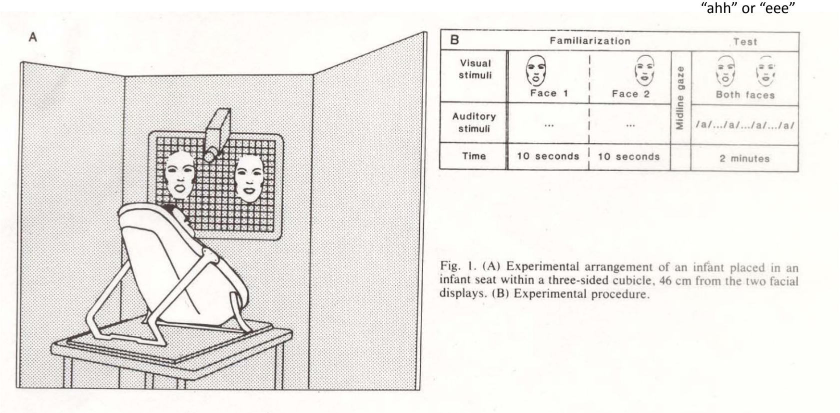


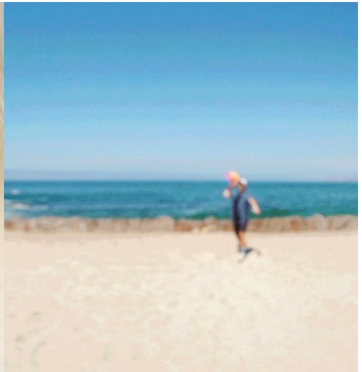
Fig. 1. (A) Experimental arrangement of an infant placed in an infant seat within a three-sided cubicle, 46 cm from the two facial displays. (B) Experimental procedure.

Kuhl PK, Meltzoff AN. The bimodal perception of speech in infancy. Science. 1982 Dec 10;218(4577):1138-41. doi: 10.1126/science.7146899. PMID: 7146899.

(0-4 mos) - Basic Affordance

- Infants show avoidance to looming object
- Different behavior for objects on a “miss” course
- Aperture experiment

Signals understanding of affordance perception to external events, even at a young age

(0-4 mos) - Non-Nutritive Sucking

- Experiments showing that infants suck faster to see an interesting image
    - Will speed up or slow down sucking rate to see clear video—whichever speed keeps the video in-focus is maintained
- Evidence of controlled behavior

(0-4 mos) - Takeaways

- Importance of motion
  - Correspondence
  - Attention
- Modify behavior to see interesting characteristics
  - Non-nutritive sucking
- Searching for new information and consistency in the world, learning new affordances that lay the foundation for further investigation

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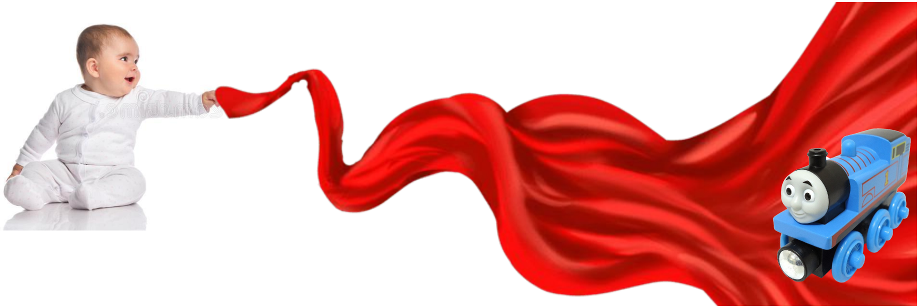
(5-8 mos) - Physical Manipulation

- Habituation from vision to touch and vice versa
- Can now reach things of their own accord
  - Reduced dependence on motion to provide information
- New opportunities for affordance learning
  - Development of muscular components for reaching, grasping, fingering

@6mos, not much intentional use of carpet

@8mos, nearly all infants easily retrieve the toy



Willats, P. 1985. Development and rapid adjustment of means- end behavior in infants aged six to eight months.

(5-8 mos) - Physical Manipulation

Table 1

Experiment 1: Mean (SD) Proportion of Trials on Which the Toy Came Within Reach, Was Retrieved, or Fell on the Floor, and Mean (SD) Cloth–Toy Contact Intervals in Seconds

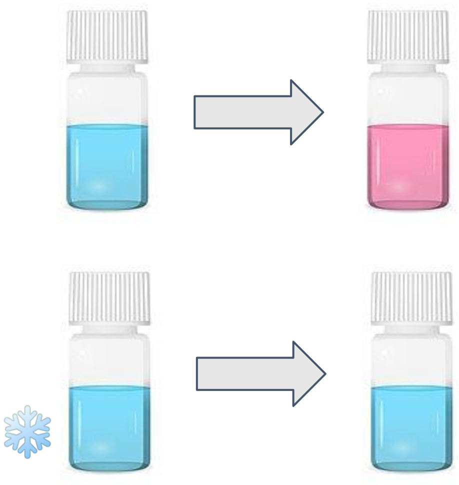
	Age (in months)		
Measure	6	7	8
Toy			
In reach	.91 (.13)	.97 (.01)	.93 (.20)
Retrieved	.61 (.31)	.69 (.31)	.78 (.28)
Fell on floor	.06 (.13)	.18 (.22)	.09 (.16)
Full-intention retrievals[a]	.40 (.38)	.67 (.34)	.82 (.29)
Full-intention retrievals[b]	.39 (.36)	.70 (.33)	.87 (.23)
Contact interval			
All trials[c]	15.82 (7.02)	10.59 (6.99)	8.64 (6.65)
Trials with toy contact[d]	11.84 (5.51)	6.80 (4.87)	5.08 (3.17)
Partial-intention trials[e]	14.12 (4.60)	9.74 (5.22)	11.39 (7.05)
Full-intention trials[f]	6.33 (4.18)	3.93 (1.58)	3.79 (1.99)

[a]Means for all infants (6 months: n = 30, 7 months: n = 30, 8 months: n = 31). [b]Means for infants included in the analysis (n = 28). [c]Means for all infants (n = 32). [d]6 months: n = 31, 7 months: n = 32, 8 months: n = 31. [e]6 months: n = 26, 7 months: n = 23, 8 months: n = 14. [f]6 months: n = 19, 7 months: n = 27, 8 months: n = 29.

Willats, P. 1985. Development and rapid adjustment of means- end behavior in infants aged six to eight months.

(5-8 mos) - Selective Exploration

- Exploration geared towards perceived affordances
- Different properties make different objects “interesting”
  - Rubbing on texture diffs, mouthing + manual handling on shape diffs



Habituated, no increase in exploratory behavior

Dishabituated, increased touching, looking

(5-8 mos) - Takeaways

- Definite intentionality in exploration
  - No longer dependent on motion-seeking or actions of others
- Learning physical properties of objects
  - What features make something unique?
- Exploratory activity has important cognitive consequences
  - Strong correlation between “exploration score” and cognitive function at 24 months (study on prematurely born infants)
  - Differences in exploratory behavior from children with Down syndrome and those without

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(8+ mos) - Vision Guiding Locomotion

- Optical flow important for locomotion
- Learning properties of the ground
    - Most crawling infants will avoid the “visual cliff”

Gibson, E. J., Walk, R. D. 1960. The "visual cliff." Sci. A m. 202:64-71

(8+ mos) - Vision Guiding Locomotion

- Optical flow important for locomotion
- Learning properties of the ground
  - Most crawling infants will avoid the “visual cliff”
  - Choosing to walk over wood rather than a water bed

Walking infants ponder the difference between water bed and wood plank for longer, choose to walk more often over solid wood, crawlers did not differentiate as strongly

Gibson, E. J., Walk, R. D. 1960. The "visual cliff." Sci. A m. 202:64-71

(8+ mos) - Mapping Layout

- Letting children see a target from one position before moving them
  - Could identify correct direction more than chance
- Self exploration > passive and guided exploration
  - Own movement specifies optical flow patterns

(8+ mos) - Carrying Objects

- Young walkers interested purely in the act of carrying
  - Carrying objects is motivating in and of itself
- Refining understanding of transportability

(8+ mos) - Takeaways

- Infants of this age typically begin moving around their environment of their own accord
- Vision as a main facilitator of locomotion
  - In conjunction with body affordances
- This self-locomotion opens up a new world of exploration
  - Understanding of layouts
  - Affordances of different surfaces
  - Carrying objects

Conclusions

- Initial exploratory activity and observation is likely purely utilitarian
  - Cognition comes after learning basic features of surfaces, events, etc.
- "Spiralling process" of affordance learning
  - Earlier affordances support later ones
  - Continually building a richer cognitive understanding
- **Progressive "fanning out" of actions** as a child develops

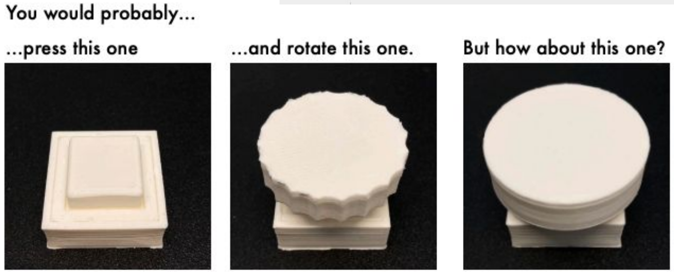
Discussion

Question: How do humans decide which cues are important to generalize affordance to previously un-encountered objects?

Jemuel Stanley Premkumar 47 minutes ago

One way to incorporate 'innate abilities' is to use techniques such as transfer learning, which allows the system to leverage prior knowledge from similar tasks to improve performance on the current task. Another obvious approach is to use reinforcement learning to learn affordances. Related papers: Rediscovering Affordance: A Reinforcement Learning Perspective.

In the context of manipulation of real world objects, it is well known that the task goes beyond locating and grasping the item of interest. A lot of current works in this field either focus on achieving the task by concentrating on a single task and object of interest or by using explicit human demonstrations (Imitation learning); but ultimately fail to generalize. The authors of the paper Learning Dexterous Grasping with Object-Centric Visual Affordances propose a new approach in order to shift from *person-centric* physical demonstrations to *object-centric* visual affordances by learning the regions of objects most amendable to human interaction in the form of an visual affordance prediction model in which the agent is rewarded for touching the afforded regions. Hence, the agent already has a 'human based prior' for how to approach an object, but is free to discover its exact manipulation strategy through closed loop experience. This prior is used to influence the learned policy and is also claimed to generalize to unseen objects as this visual affordance prediction can also anticipate the affordance regions.



Discussion

- What would be the “starter skills” for a machine learning model to be pre-programmed with?

Alan Van Omen 4 hours ago
I found it interesting how the author discussed that while many of an infants abilities must be learned through exploration, some concepts are already "programmed" or in place. Like a baby already knows how to breathe, blink, cry, sneeze, etc. Generally, machine learning systems are completely blind and have no prior knowledge regarding their problem space. But maybe their performance could be improved by somehow pre-programming them with basic concepts.

Discussion

- What do you think the “objective function” for human infants is?

Discussion

Question: Do you think complex affordances are composed of simpler affordances or is their representation separate? Do complex affordances inherit from simpler affordances? Something else?