49 Cognitive Abilities of Infants

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Visual depth perception = is innate (present & functional at birth)

I entered psychology at an exciting time. An extraordinary scientist, Eleanor Gibson, had shown that a capacity for visual depth perception is innate: It is present and functional on first encounters with a visible environment.

Development of perception = development of knowledge (e.g., can infants "organize arrays of surfaces into meaning objects and events"?

Gibson, one of my two graduate advisors, thus settled a longstanding question concerning the development of perception, and she raised a broader possibility concerning the development of knowledge. Do infants not only perceive *where* surfaces are, but also *what* they are? Do they organize arrays of surfaces into meaningful objects and events?

My other graduate advisor, Ulric Neisser, was one of the founders of the modern field of cognitive psychology. At the time, he was studying the processes by which adults attend selectively and adaptively to events. He and others (especially Anne Treisman and Daniel Kahneman) discovered that attention tends to focus on discrete objects (whether people or things), rather than arrays of surfaces – so much so that if college students are watching a competitive ball game, they follow the players and the ball so well that they may miss a gorilla crossing the room. But are we built to perceive, attend to, and understand objects, or do these abilities develop as we explore objects and observe their behavior? I became fascinated by this question.

Research question: ability to perceive/ understand objects INNATE or DEVELOPED?

Research question: Can infants have "separate or unitary experiences of objects' associated sights and sounds"?

One of my first experiments asked whether infants who can't yet manipulate objects have separate or unitary experiences of objects' associated sights and sounds. To find out, I made simple, short movies of a person playing "peekaboo" and of a hand making a rhythmic pattern with a baton and tambourine. When both movies played side by side and each soundtrack was heard in alternation through a central speaker, four-month-old infants looked primarily at whichever movie currently accompanied the sound. Later studies in other labs showed that infants are exquisitely sensitive to the relations between sound and movement that accompany human speech, and that they detect some relations between sounds and visible objects even at birth. Thus, infants do not simply look and listen to people and things; they relate these separate sensory impressions to one

4-month-olds looked at the movies that had accompanied sound than those not

Research questions: "Do infants perceive object as we do?"

another. But do babies perceive objects as we do? As a new assistant professor, I began to address this question with students in my own lab.

Object perception is fascinating, because visual arrays of objects are complex. No opaque object is ever fully in view (its back is hidden), and most objects sit upon, beside, or behind other objects that partly hide them. Nevertheless, adults perceive arrangements of solid objects, not patchworks of visible surfaces. What do infants perceive? Philip Kellman and I took advantage of the fact that infants, like adults, get bored if they see the same thing repeatedly, and they perk up if it changes. We showed four-month-old infants a rod that moved back and forth behind a block that hid its center, until their looking declined. Then we took away the block and alternately presented one long connected rod and two short rods separated by a gap where the block had been. Infants looked longer at the latter display, suggesting that they found this display to be new and had perceived the visible ends of the original rod as one connected object. Like adults, infants appeared to perceive objects as solid bodies that continue behind other bodies. Many further experiments in my lab and others followed, confirming that suggestion and revealing that this aspect of object perception is present at birth.

Spelke & Kellman: Infants "get bored if they see the same thing repeatedly, and they perk up if it changes"

Findings: 4-month-olds looked at the "two short rods separated by a gap where the block had been" longer because they felt that they were new compared to the expected long connected rod.

==> Proving that "object perception is present at birth"

My students and I then began to wonder whether infants' understanding of objects goes beyond perception. Experiments with Renee Baillargeon tested for "object permanence" in infants, inspired by the compelling demonstrations by the Swiss developmental scientist Jean Piaget that infants have limited abilities to act on hidden objects. If an interesting object moves behind a boring one, young infants fail to push the unwanted obstacle out of the way, but do they realize that the hidden object still exists? We used the same looking-time methods to address this question. First we familiarized infants with a screen rotating repeatedly on one of its edges, and then we placed a small block behind the screen – a block that disappeared completely when the screen rotated upward to vertical.

Research question (Spelke & Baillargeon): Is it true that infants "have limited abilities to act on hidden objects" according to Piaget's theory?

"If an interesting object moves behind a boring one" and the infants could not "push the unwanted obstacle out of the way," "do they realize that the hidden object still exist?"

Although infants could no longer see the block, their looking patterns suggested that they remembered its existence and expected the screen to stop when it reached the block. Infants looked more when the screen underwent a superficially familiar but "magical" rotation that passed through the block, than when the screen stopped at the hidden block's location. These findings suggest that infants knew that a fully hidden object was still present in the scene, and that they understand on some level that objects don't wink out of existence or pass through other objects. Many experiments now support these suggestions, including one new finding: When infants are shown an event that violates the solidity of an object, as did the rotating screen, they tend to bang the object against other objects, actively attempting to reproduce the apparently magical event.

Findings: Infants looked longer at the situation when the screen magically rotated "through" where the "block" was supposed to be located than at situation when the screen "stopped at the hidden block's location."

==> Proving that infants at 4 months have a sense of "object permenance"

As adults, our understanding is organized around abstract concepts. Understanding of material objects and their interactions is organized around concepts of *mass* and *force*; understanding of other people is organized around concepts of *belief* and *desire*. And basic concepts of mathematics – of *number* and *geometry* – organize and enrich our understanding of diverse domains. When in development do abstract concepts emerge?

We and others have found seeds of these abstract concepts in human infants. One experiment with Veronique Izard, probing infants' number concepts, brings me back to my first method. We presented newborn infants with auditory sequences of matched duration containing either four or twelve syllables. As the sequences played, infants were shown alternating visual arrays of four and twelve objects. Just as in the peekaboo studies, infants looked longer at the visual array that corresponded to the syllable sequences, although here the correspondence occurred at the level of abstract number. Sensitivity to number is present at birth.

Spelke & Izard: "infants looked longer at the visual array that corresponded to the syllabus sequences" than the kind that did not.

Thus far, it may sound as if babies share all our concepts and cognitive abilities, but that is far from the case. Each of the above lines of research has revealed striking gaps in infants' perception and understanding. For example, infants distinguish between numbers that differ by large ratios but fail to distinguish numbers that differ by smaller ratios: Children's sense of number remains imprecise until they learn number words and symbols. As a second example, young infants expect objects not to pass through walls or float in the air without support, but they do not expect that a ball, released on a slanted surface, will roll downward rather than upward. Infants share only a small but crucial part of our knowledge.

What, in general terms, do infants know? Research suggests that they conceive of objects as bodies that exist and move continuously through space and time and that interact on contact: the kernel of our mature, commonsense understanding of physics. Infants also conceive of animals, including people, as agents who act so as to change the world and themselves, and who direct their actions efficiently toward goals. Infants conceive of people not only as agents, but also as social beings who engage with them and with one another, sharing their attention and emotion. And infants have numerical and geometrical concepts that guide their emerging navigation and their sensitivity to the statistical structure of the environment. Evidence from my lab and others suggests that these conceptions are products of distinct, early emerging systems that humans share with other animals: what I have called systems of *core knowledge*. The core knowledge found in infancy serves as a foundation for later learning and remains central to our thinking throughout life. Thus, research on cognition in infancy sheds light on aspects of mature cognition and cognitive development.

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Studies of cognition in infancy raise many questions for future work. We have learned quite a bit about what infants perceive and know, but we don't know how knowledge is represented and processed in infant brains, or how it is extended by learning. Infants are prodigious learners: They come to recognize the significant people and places in their environment, to interpret and produce actions such as eating from a spoon, to categorize diverse kinds of objects, and to distinguish and interpret the words and rules of their language. As part of the National Science Foundation's Center for Brains, Minds, and Machines, my lab has begun to participate in an interdisciplinary effort to create and test computational models of infant minds. I hope that these models will deepen our understanding of the foundations of human knowledge. Conversely, I hope that the effort to create artificially intelligent systems will benefit from research on infant learners, as the visionary and pioneering computer scientist Alan Turing suggested long ago. Studies of cognition in infancy also may serve to improve education, through curricula that build on young children's cognitive strengths and address gaps in their knowledge. I am especially hopeful that the insights from this research will inform programs to enhance the readiness of preschool children to learn science and mathematics. As in medical research, however, these efforts will require a new wave of controlled experiments, bridging from laboratories to classrooms.

Science is full of surprises: Although we can control the process of an experiment, we have no control over its outcome. This lack of control makes science exciting. Some of my best moments have come from utterly unexpected findings, showing that my thinking was wrong. Science also is a collective enterprise. Although this book focuses on specific people, discoveries always depend on legions of people with different ideas, working in different disciplines, living in far-flung places, and united by their unstoppable curiosity. When I was a young member of this diverse community, I was able to share the wisdom of an older generation; now I can share the energy of younger generations. I am perpetually amazed that work can be so much fun.

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