



Building Blocks

BY ELIZABETH ROSDEITCHER

IU Distinguished Professor **Linda Smith** seeks to unravel the complex, interconnected chain of events that explains any single infant behavior.

17-month-old Evelyn Wolf participates with Linda Smith in an experiment session.

MARC LEBRYK

If you wanted to design a robot that could learn and develop like a human infant, to gain the skills and abilities of a human child, you would do well to talk to IU experimental psychologist Linda Smith—as roboticists around the world have done.

Among the many questions you would need to answer are two that Smith addresses every day in the lab she has directed for 38 years and counting: What are the building blocks of human cognition? How does human intelligence take shape?

For children who are slow to break into language, her answers have led to research on new treatments. (And for roboticists like Angelo Cangelosi at the University of Plymouth in England and Cynthia Breazeal at MIT, Smith’s answers have led to new strides in making the first developmental robots.)

Behind this success is a new and groundbreaking perspective on children’s development that Smith has played a major role in shaping and a large body of innovative scientific work to investigate precisely how our cognitive capacities—the ability to think and engage with the world—emerge.

Smith began to work out this new developmental perspective in the 1980s and ’90s as part of an extended collaboration with her then-IU colleague Esther Thelen. Together and in tandem with many others, they helped to construct a new empirical foundation for the study of human development, which ultimately, as her IU colleague Robert Goldstone puts it, “converged on a new and radical view of cognition.”

As Smith sees it, “Many scholars of human cognition have begun with the notion that people are intellectually special. They want to find what it is that makes us unique, as beings one down from a higher being and one up from the animals.”

For Smith, the better question is not “What is it that makes us special?” but “How is human cognition made, in development? How do we go from babies who cannot walk, or talk, or play chess to adults who can do all those things and more?” With these questions she sets out to trace the sequence of events and milestones through which such cognitive abilities as visual attention, object recognition, and early word-learning first take shape.

“I think the better way to talk about these functions is to talk about change,” she explains. “Babies are not like us, 3-year-olds are not like us, teenagers are not like us. But we were them.”

The Logic (and Magic) of Shapes

As a parent, grandparent, or someone who has day-to-day contact with a small child, perhaps you have witnessed it: the sudden shift that occurs between the ages of 2 and 3 when, after the gradual, occasional learning of a few isolated words, a child’s vocabulary takes

off and accelerates at lightning speed.

Smith explores how this shift happens, tracing it to a series of earlier sensory and motor developments not typically considered essential to language. Pivotal to the process is a unique visual ability to recognize the global shape of objects.

“Here’s the idea,” says Smith. “Toddlers first learn object names slowly. This object is called a ball; this other object is also

a ball. From this they learn that balls are round and can generalize the object name to all sorts of balls. They also slowly learn the name for cup and that several different kinds of cups are all called “cup” and that cups are all cup-shaped; and then they can generalize the name for cup.

“After some number of objects names have been slowly learned (about 25), the magic happens. It is as if a certain logic kicks in: balls are round, cups are cup-shaped, shoes are shoe-shaped; there-

fore all noun categories must name things similar in shape.”

From this point on, a child can be shown a single instance of an object and will be able to pick out all other instances of the object, despite the enormous variations that exist. They learn to home in on a few common geometrical properties that define an abstract, not overly specific, shape. “That speeds up the rate at which you form object categories. You learn how to learn words,” Smith says.

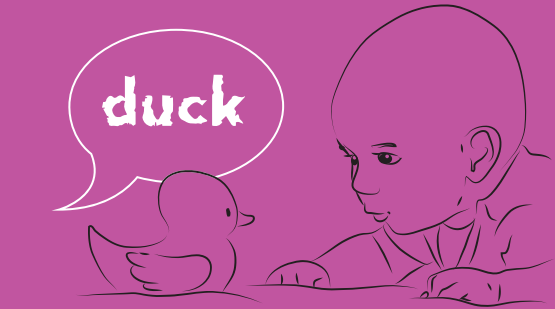
This little story, she explains, also has a mathematical theory behind it, as well as models that reveal statistical regularities in the visual properties of these first learned objects. Central to the story, too, is the visual definition of shape. For example, all chairs are chair-shaped. But being chair-shaped is an abstract structural similarity that can apply to rocking chairs, kitchen chairs, and stuffed living room chairs, among others. Before children can develop a shape bias, they have to learn how to perceive the abstract shapes of objects, and this ability “depends on hands and eyes and play.”

In collaboration with her IU colleague in Psychological and Brain Sciences, Karin James, Smith has shown that playing with and handling three-dimensional objects is critical to developing shape bias.

“When children handle objects,” she says, “they generate multiple views of those objects, and that dynamic visual input drives the development of visual shape processing and the representa-

Play Time

It’s one thing to study and learn the ways toddlers develop their cognitive capabilities. It’s quite another thing to raise children in a complex world. Here are some tips from world renowned cognitive scientist Linda Smith, a Distinguished Professor in IU’s Department of Psychological and Brain Sciences, on giving children the best chance to develop successfully and at the right pace.



Give babies toys and talk.

Even before babies can reach and grasp objects, give them objects to bat at, and put objects in their hands. Early activity with objects builds interests and skills.

Toddlers learn the names of objects they are holding more than they learn the names of objects parents hold and show. Why? One reason is that they are interested in objects they are holding and likely to learn about objects that are in-

teresting to them.

Linda Smith’s work with IU colleague Chen Yu also suggests that holding stabilizes visual attention on the object and that sustained visual attention is key to connecting the heard name and seen thing well enough that the baby can remember it later. So, encourage holding and handling objects, and name objects when the child is holding and looking at them.

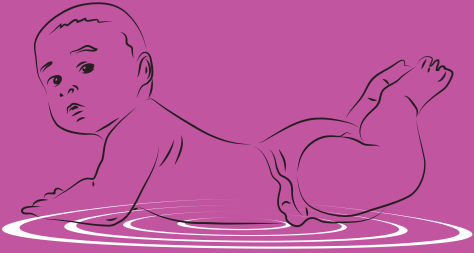


Go beyond shape.

The shape bias — and the development of the visual processes that support it — are not all that children need to learn how to learn words. Shape is relevant to basic object names, but not for names of substances, like butter or applesauce. Nor is shape relevant to verbs.

Smith’s research, and that of other child language researchers, has shown

that children learn the statistical regularities that support different kinds of word categories, and they learn through active engagement. Playing with substances — when hands are in the applesauce or sand — is the ideal time for learning substance names too. And doing — jumping, rolling, giving — aids in the learning of basic verbs.



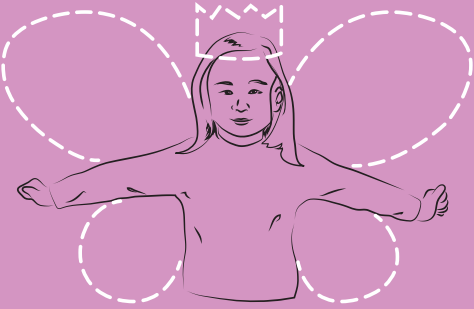
Take some tummy time.

Everything is connected in development. For example, if one wants to support early object name learning, parents and grandparents can begin early — as early as your first day home from the hospital.

The “back to sleep” movement has led to the reduction of Sudden Infant Death Syndrome (SIDS). But putting babies to sleep on their backs has also reduced play time on their stomach, which is needed

to build the head and trunk control that supports stable sitting. Putting babies on their stomach supports sitting; sitting supports learning about object shape.

Pediatricians now recommend putting babies on their stomach for playtime — with the parent right there. This helps the baby build the skills to lift her head, roll over, get up on all fours, and sit. (Also, take babies out of their carriers.)



Pretend!

There is a kind of play that has intrigued developmental psychologists for a long time that is known as “object substitution.” This is the kind of play in which an 18-month-old uses a pot for a hat, or a slipper as a boat or a teddy bear, or spoons as drum sticks.

The play is not just really cute, it is also intellectually intriguing, because it predicts future language learning. If you have

a late talking child who engages in this kind of play, prospects are good that the child will “catch up.”

Smith’s work also shows that this kind of play is deeply related to the development of abstract shape perception. Pretend play — in which a structurally similar object is used to substitute for another known kind — is good to encourage and to demonstrate.



Be aware and encourage.

Babies learn with and from social partners — moms, dads, and people who love them and pay attention to their momentary interests to create learning moments. A large literature shows that “responsive parents” — parents who observe their children’s interests and can talk about, expand upon, and encourage sustained attention to them — have children who

develop more robust language skills. This does not mean “spoiling the child” or “making the child the center of attention.” All children need to learn limits. But it does mean that when one is playing with the child, one should try to see the world through the child’s eyes: Notice what children are trying to do and trying to master, and encourage them.

tion of the abstract geometric shapes common to everyday object categories.”

The theory of shape bias has played an important role in understanding how children learn—and fail to learn—language. Children with language delays, who were originally thought to have language specific difficulties, have now been shown by multiple research teams across the country to also have difficulties in visual shape processing. Likewise, children with autism show altered or delayed sensory-motor development, including object manipulation. This may later prevent the learning of object names that depends on the development of visual shape processing, which in turn depends on object manipulation. It’s a hypothesis now under test.

Smith and another colleague in IU Psychological and Brain Sciences, Chen Yu, recently began a collaboration with University of Pittsburgh researchers in a study designed to look for infant behaviors that may predict a later autism diagnosis. The study looks at the baby siblings of children with autism, who, it has been shown, have a 20 percent chance of developing autism themselves. By observing these children at the ages of 9–12 months, Smith, Yu, and others hope to better understand the sensory and motor delays, which are the first signs of autism.

In this way, Smith unravels the pathways from sensory and motor to cognitive developments. Stabilizing the head, sitting, manipulating objects, playing with a parent—these are some of the milestones that set the stage for language.

Moment by Moment

In tracing the way cognition takes shape, Smith’s work has overturned some of the common assumptions about development. Traditional distinctions between motor and cognitive abilities, doing and thinking, have no place in her theory. Rather, each new milestone in motor development—reaching, sitting, crawling, walking—opens up new opportunities for perceptual, cognitive, and social

development. So, for example, an infant’s trunk control, hand-eye coordination, and head stabilization—all aspects of motor development—are “major players in social, emotional, perceptual, and cognitive abilities and functions.”

Likewise with the conventional nature/nurture divide. In their place is a view of a “dynamical system,” a set of relationships between the body, brain, and environment that render such distinctions, for practical purposes, obsolete.

If you consider each moment as the cumulative effect of all previous moments, “It’s not even a reasonable thing to think about dividing them up between nature and nurture. It’s a dynamical system with multiple threads. What you can make of one moment depends on your history up to that point. At the same time, what you make of that moment changes you and determines what you learn tomorrow.”

“I think about language, attention, and the neuro-processes in the brain as built in time, out of both our intrinsic processes and our experiences,” Smith says. “There’s no dividing it up into 50 percent nature and 50 percent nurture or 60 percent nurture, 40 percent nature. That is a very old question based on very old ideas with no place in the 21st century.”

As the cognitive scientist Lawrence Barsalou at Emory University has put it, “In the world of developmental psychology, Smith epitomizes the perspective that cognition and its development are grounded in dynamical and embodied systems. She is perhaps *the* person most known for this position. As such her work unravels the pathways that link sensory-motor development to language.”

History-dependent, cascading interactions, embodied, overlapping, and multi-causal systems that proceed along different timeframes (in milliseconds or months) and on different levels of analysis (from molecular to behavioral to social)—these are the makings of Smith’s pioneering view of individual development and the framework for her scientific investigations.

“Development,” Smith has stated, “like evolution and culture, is a process that creates complexity by accumulating change.”



MARC LEBRYK

A Celebrated Career

Internationally recognized as one of the leading cognitive scientists in the world today, and one of the top experimentalists, Distinguished and Chancellor’s Professor Linda Smith in the Department of Psychological and Brain Sciences, and the Program in Cognitive Science, has received most of the major honors and awards in her field and the university.

Among the highpoints are:

- An American Psychological Association award for Early Career Contributions in 1985 for her work on attention in 4–7-year old children
- Indiana University’s Tracy M. Sonneborn Award in 1997, which honors those who have achieved distinction as both a teacher and a scholar
- Election in 2007 to fellow status in the American Academy of Arts and Sciences
- The David E. Rumelhart Prize in Cognitive Science in 2013 for groundbreaking theoretical contributions to the foundations of human cognition
- An APA award in 2013 for Distinguished Scientific Career Contributions

Since receiving her PhD in 1977, Smith has had one faculty position, and that position is at Indiana University, though she has given invited addresses, workshops, and seminars across the globe and in virtually every major university in the U.S. When in 2013 the American Psychological Association launched the first of a series of TED-style videos featuring psychology’s leading researchers, they chose Smith to inaugurate the series with its first video talk.

Smith has also made her mark as a highly effective administrator. She served as the associate dean for undergraduate education in the College of Arts and Sciences (2000–03) and as chair of the Psychological and Brain Sciences Department for seven years (2005–12), overseeing the department’s name change from Psychology to Psychological and Brain Sciences, among other important shifts that, as she would say, keep the department “ahead of the curve.” As director of the Cognitive Development Lab, she has brought into the university nearly \$12 million in external grant funding over these years.

As her colleagues describe her, Smith is quite simply a “dynamo,” a “force of nature,” a no-nonsense northern New Englander who sees right to the heart of any issue.

She is “one of the most celebrated, respected, and productive cognitive scientists in the world today,” says her colleague Richard Shiffrin, Distinguished Professor and Luther Dana Waterman Professor of Psychological and Brain Sciences.

She is also a deeply revered teacher and mentor with a singular ability to instill confidence in those around her. As one former student puts it, she is “a wonderful role model and a great source of inspiration, both as a scholar and as a person.”



Tina Wolf, with daughter Evelyn, talks with lab manager Charlotte Wozniak, BS'80, left, and Linda Smith in the research lab. Monitors allow researchers to record and analyze the child's interactions.

A Career Built on Building

In 1969, at the age of 17, Linda Smith entered Northeastern University in Boston as a freshman on scholarship in engineering. One of seven women in a class of about 800 to 1,000 freshmen, she was not prepared for the kind of instant celebrity her minority status gave her among faculty and students at the school.

"I was not at all comfortable with it," she says. "Now I could do it. But as a young kid, it was a little creepy to walk into a lecture hall where every head turned as you entered the room."

By the second semester of her sophomore year, she left the program, becoming a math major "just long enough to get an elective" and took her first psychology class. "I thought, 'This is science! This is interesting!'" And I was way more comfortable." She soon transferred to the University of Wisconsin in Madison, where she majored in psychology and then headed to graduate school.

As Smith sees it, she traded an interest in the nuts and bolts of jet engines and radar for the nuts and bolts of human cognition. Yet, in some ways her interests remain similarly grounded in

laws of math, physics, and the physical constraints of the body. Perhaps her innovative use of such technology as head cameras on infants, which have subsequently been used in laboratories around the world, is an echo of her own early interests. Perhaps even her emphasis on the role that hands play in the development of such cognitive processes as visual object recognition to social attention to language shares something of her earlier interest in how things are made. They're made with your hands.

"If you really understand how something works, you ought to be able to build it," she remarked in October 2013 during a talk at the 125th anniversary celebration of the IU Psychological and Brain Sciences Department, in whose history she has played a prominent and defining role.

It is no surprise then perhaps that roboticists have literally built on her theories. Now, however, she has built upon theirs to test new theories about infants. In a recent study she compared the way infants learn new words to the way the robots created by Anthony Morse at the University of Plymouth learn new words—both through an association with the body's spatial position.

Throughout her career, and at any one moment, Smith's

projects and her collaborations have ranged widely. She began her career studying attention in 4- to 7-year-old children in work that continues to be influential and earned her a prominent American Psychological Association Early Career Award in 1985. Then came something that, she says, "started out as a fun collaboration and a friendship" with her colleagues Susan Jones, now retired from Indiana University, and Barbara Landau, now a professor at Johns Hopkins, Smith began to focus on the phenomenon of shape bias. She has been involved in the topic ever since.

Currently her work centers on the period from birth to 3 years: how babies hold objects and other early motor developments, visual shape processing in 18-month-olds, and the "joint attention" between parents and 1-year-old children. She has studied the way words direct visual attention in 3-year-olds and the way differences between English and other languages, such as Spanish, Japanese, and Tamil, influence children's development.

This is only a sample. Yet, each of these topics offers a glimpse into one brief point in a dynamical, embodied system. "You can't divide it up into pieces and get very far," she insists. It's the connections between the parts that matter if you want to make a difference.

Despite the challenge of unraveling such a complex, interconnected chain of events to explain any single behavior, Smith suggests, there is genuine cause for optimism. Within that complexity is opportunity, many points at which to create "workarounds," and multiple pathways to the same end.

For example, a child who does not develop trunk control at the appropriate age and cannot sit stably is consequently limited in the extended object manipulation that supports visual shape perception and ultimately rapid word-learning. But you can provide the physical supports needed for sitting stably and in this way make possible subsequent developments that depend on this early milestone.

Like evolution, culture, history. "It's not like 'a' causes 'b' causes 'c,'" Smith explains. "Multiple stuff causes 'a'; 'a' influences 'b,' but a bunch of other stuff influences 'b'; and 'b' and a bunch of other stuff influences 'c.' That's what human development looks like."

And in your next conversation with a chatty 3-year-old, it is truly something at which to marvel. ■

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