Everything I need to know about AI I learned from my baby

I have been witnessing something truly miraculous. A little over 16 months ago, my daughter came into the world, her soft skull full of neurons but few connections, her eyes unable to focus or perceive color, her movements jerky and uncoordinated. Her repertoire of skills was very short: she knew how to nurse, turn her head in the direction of my voice, extend an arm in a "fencing position" when her head was turned, and that's about it. Of course, she also knew how to charm the socks off her parents. Less than a year and a half later, she had acquired the ability to take light signals and transform them into concepts of other things and people. She has figured out that other people have desires different from hers, and may indeed conflict with them. She is able to transform sound waves into individual words, independent of the speaker (or language), turn words into concepts, and concepts into meaning. She is now even mastering her vocal cords to produce correct sounds that correspond to different concepts. Her personality is emerging, with distinct passions and aversions, a budding sense of humor, and a shoe fetish! She has gone from a helpless flailing sack of protoplasm to a miniature human, who can walk, run, climb, pick up cheerios, throw a ball, turn pages of a book, etc. – with a reasonable proficiency. All this that AI has been collectively striving for over the past several decades, was achieved in a fraction of an average grad student's lifetime.

So, what has been happening inside my daughter's brain and nervous system, and what can AI researchers learn from it? Surprisingly, developmental psychologists have began studying infants only about 30 years ago, and biologists began to study the neurological basis for learning later still. The picture that has emerged of the learning process is far from complete, but already extremely fascinating.

My reading list has lately reflected this fascination. One of the more interesting books I read was *The Scientist in the Crib*. The authors, pioneers of infant developmental psychology, claim that three factors make possible the incredible progress children make in the first few years of life: innate knowledge, superior learning ability, and dedicated teachers evolved to be ideally suited to the teaching task. The evidence that children are already born knowing certain things is extensive. For example, babies seem to be aware from birth of some of the physical properties of objects. A newborn infant will follow a moving object behind a screen and anticipate where and when it will reappear. She will recognize a series of different smiling faces as being similar to one another and different from a sad face. Even more intriguing are the observations that infants, as young as few hours, will mimic facial expressions of adults, for instance, copy an adult sticking out his tongue. Think of the capabilities involved in imitation: the baby not only has to figure out that an adult's face is like hers, she has to make the association between the adult's tongue and her own and to know that she moved her tongue outside her mouth.

The second cog in the triumvirate of early learning – the powerful learning mechanism – is not addressed by the authors in great detail. Other books, such as *What's Going on in There* and *Magic Trees of Mind* do a much better job explaining the decades of neuroscience research about babies brains. I will come back to this in a later.

The final learning advantage that babies have are wonderful teachers – their parents – designed by millions of years of evolution to act in ways that enable babies to learn better and faster. How do adults function as teachers? There are many examples – the most compelling from language learning. Until about the age of six months, babies can differentiate sounds much better than adults. For example, scientists can play a sound corresponding to "r" and slowly morph it into a sound corresponding to "l." English speakers will hear a sharp transition in this smooth sequence from one sound to another. Japanese speakers will often fail to detect a difference in sounds altogether. Young infants will actually hear each frequency in the range as a different sound… until the age of six months when they start hearing the same sounds as adults in their culture. What happens? It is the exposure to the local language, specifically the "motherese" in which adults, and even young children, instinctively address infants, that wires the brain to hear particular sounds. The comical sounding baby talk, with its exaggerated vowels and frequent repetition, offers a far purer and better example of the local language than the often sloppy speech we use when communicating with other adults.

Although babies come into this world well equipped for learning, thanks to their plastic brains and dedicated teachers, the authors of *The Scientist in the Crib* give most of the credit to babies themselves. As the title suggests, they advance a hypothesis that a baby is really like a scientist (and a scientist like a baby), forming ideas about the world, doing little experiments to test them, and refining or discarding ideas in light of experimental results. Indeed, the authors believe that babies are driven by a need to explain, to understand, and this drive manifests itself during every stage of baby's development. Play gives children an opportunity to practice the scientific method, for example, by pouring sand or stacking cups. A cantankerous two year old reaching for the forbidden power cord while watching his parent, is actually conducting an important psychological experiment, to learn about the nature of other minds. It is just an unfortunate consequence of the "terrible twos" that it is the parents who are the subjects of these experiments.

Neurological basis of learning is perhaps of greatest interest to an AI researcher, because it can serve as a model for artificial forms of learning, or at the very least provide insights into how to achieve it. In this regard, one of the more interesting findings to come out of neurobiology is that our genes do not encode all the knowledge that we have. Instead, we have evolved to be supremely adaptable through the mechanism of neural plasticity. Experience (and environment) shapes the brain. A baby is born with (almost) all of her neurons, but very few connections between them. The baby spends first few years (especially the first two) growing these connections, called synapses – **many millions a second** – and also busily pruning them. Only those synapses that are stimulated by experience or practice will be preserved – the rest will be eliminated. In fact, enrichment studies of rats have shown that different types of environment will lead to significant differences in the thickness of the cortex, which is a measure of the number of neural connections. Another interesting observation is that the brain matures in phases, from the back of the brain, where the senses are perceived, to the front, where emotions and reasoning reside. The order of maturation, and hence the structure of the brain, has been carefully honed over millions of years of evolution. Each part has a critical period of growth and myelination. If repeated experience is not provided during the critical period, that portion of the brain will forever loose its functionality. Thus, for example, the auditory portion of the brain of deaf babies is not wired for hearing at all. Instead, it responds to visual stimuli. This is true not only of the senses (5 senses + vestibular system and motor skills) but also of language, emotion and reasoning skills.

The back-to-front maturation of the brain also explains why babies achieve their milestones in a certain progression (morphology explains etiology of behavior?). A baby is able to feel emotions around 6 months when frontal lobes begin to mature. This is synchronized with motor development – baby first experiences attachment and separation anxiety right around the time she begins to crawl (so as not to get too far from mommy)! It also explains why toddlers use nouns (telegraphic speech) first, and grammar much later, why they are so (infuriatingly) slow to do things (they should speed up once myelination of the motor cortex is complete) and why their personalities oscillate from angelic to demonic and back again (maturation alternates between hemispheres).

After witnessing the awe-inspiring learning proficiency of a human child, the task of artificially reproducing such a capacity seems more daunting than ever. Can early child development be a useful guide for AI researchers? I believe so. Human beings seem to come into the world with some amount of innate knowledge required to bootstrap the learning process. The vast portion of early learning, however, appears to take shape from the bottom up, acquired through repeated observation, repetition, and experimentation, made possible by a wondrous learning algorithm we are still waiting to discover, and lots of love. The last point is worth repeating – without positive emotional support, it appears that no baby can fully develop her intellectual potential. It is not clear what love's role is, but it is clearly important.

Resources

"*The Scientist in the Crib*" by Alison Gopnik, Andrew N. Meltzoff and Patricia K. Kuhl.

"*What's Going on in There: How the Brain Develops in the First Five Years of Life*" by Lise Eliot, PhD

"*The Magic Trees of Mind*" by Marian Diamond and Janet L. Hopson