Studying Learning in the Womb

Behavioral scientists are using established experimental methods to show that fetuses can and do learn

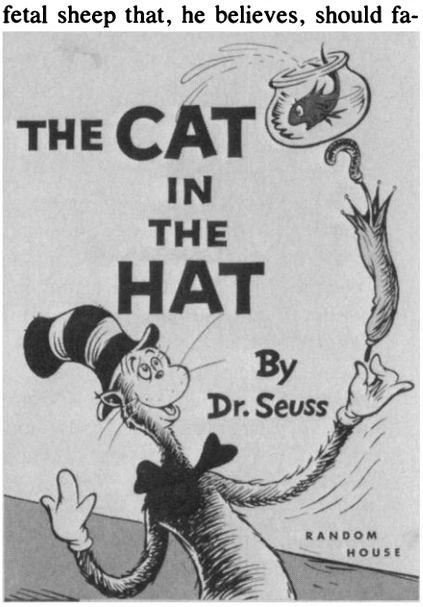
Research scientists who study the behavior of human infants believed until recently that the baby's world was, as psychologist William James wrote, a place of "booming buzzing confusion." But the picture now emerging is quite different. Babies have been shown to respond to their environment from the first day of postnatal life. They can discriminate between objects that they see and can even recognize their mother's voice. How and when does a baby learn these things? A relatively new body of data indicates that the learning begins before birth. This idea suggests a whole series of questions about how and when an unborn baby can learn.

These questions are now being addressed by a small group of developmental psychologists and behavioral neurobiologists who are studying fetal learning by using established techniques that can measure learning in adult animals. Their research, says Norman Krasnegor, chief of the human learning and behavior branch of the National Institute of Child Health and Human Development in Bethesda, Maryland, is of great practical as well as theoretical importance.

Research on prenatal learning offers a way to assess the development of premature infants, Krasnegor says. Babies weighing as little as 1000 to 1500 grams at birth (about 2.2 to 3.3 pounds) are now routinely cared for in newborn intensive care units, but physicians frequently find it difficult to predict which of these babies will develop normally and which will not and how to help those whose behavioral development is abnormal. By learning when during gestation different types of learning can occur, developmental behavioral neurobiologists hope to gain a new understanding of the functional organization of the brain prior to birth. Such research, Krasnegor remarks, should help psychologists and therapists to assess and to teach babies whose brains are injured as a consequence of premature birth.

In addition, the studies will undoubtedly be useful to research on behavioral teratology—the investigation of substances that produce birth defects of the mind. A few such substances, such as antiepilepsy drugs and large amounts of alcohol, are known. But to identify others researchers need refined knowledge of how the mind develops and whether there are critical prenatal periods for the learning of certain kinds of behaviors.

So far, the studies of in utero learning are mixed. One group of investigators is looking at the abilities of human babies to recognize voices and even poems that they first heard before they were born. Others are studying classical conditioning in fetal rats and mice. Still another researcher has a new way of observing fetal sheep that, he believes, should facilitate research on in utero learning. What each of these investigators is finding is that every time they look for fetal learning, it is there.



The babies' favorite

Babies who heard The Cat in the Hat *prenatally preferred it after birth.*

Anthony DeCasper, a psychologist at the University of North Carolina in Greensboro, says he began his studies of fetal learning a few years ago when he wondered why newborn human babies perceive sound so well. "I asked myself, 'Why do we come into the world like that?' Maybe we listen in the womb." DeCasper and his associate William Fifer tested ten newborn babies with a system in which the babies could suck on a nipple that was attached to a tape recorder. By sucking in one pattern of longer and shorter sucks, a baby would hear its own mother's voice and by sucking another way the baby would hear another woman's voice. The babies, DeCasper and Fifer found, tended to suck so as to hear their own mothers.

Fifer also found that this preference for mothers' voices occurred no matter whether the babies were breast fed or bottle fed and no matter whether they were less than 36 hours old or more than 72 hours old. DeCasper wondered, however, if babies might not just learn to prefer any voice that they heard from birth onward. So he and his colleague Phyllis Prescott asked six men to participate in another experiment.

These men, who had been present at the birth of their baby daughters, were asked to talk to their babies as much as possible. By the time the testing began, five of the men had spent about 4 hours each talking to their daughters and one man had spent 10 hours. "These babies had negligible contact with any other male voice," DeCasper and Prescott report.

When the babies were 2 days old, DeCasper and Prescott tested them with the nipple and tape recordings to see if they preferred their father's voice to that of another man. Apparently the babies did not. But, the two investigators learned, the babies could discriminate between male voices—they just did not seem to especially prefer to hear the voice of their own father at 2 days of age. Within a few weeks, however, they did prefer to hear their father's voice.

Next DeCasper asked himself what babies hear in the womb. "They hear their mother's stomach noises, her heartbeat, and her voice. What they don't hear well is their father talking in a normal conversational voice," he says. "We predicted that the newborn babies ought to suck so as to hear those sounds." DeCasper and his associate Robin Panneton tested this prediction with 12 babies by rigging up their sucking test so that the babies could hear either a male voice or a maternal heartbeat, depending on which way they sucked. The babies sucked so as to hear the heartbeat significantly more often than they sucked to hear the male voice.

At this point, DeCasper sat down and reviewed all of his data. "It looked like auditory preferences after birth are influenced by what is heard prenatally," he concluded. "In animals, we could test this idea directly by doing a deprivation experiment. Obviously, we can't do that in humans. But we can provide a unique auditory experience to the fetus and then ask what the fetus learned." The audi-

tory experience he and Melanie Spence selected was hearing the children's book *The Cat in the Hat*. Sixteen pregnant women were asked to read this book to their fetuses twice a day for the last 6 ½ weeks of their pregnancy. By the time the babies were born, DeCasper calculates, they had heard the story for about 5 hours.

When the babies were born, DeCasper and Spence used their sucking test again. This time, the babies could suck to hear a tape recording of their mothers reading *The Cat in the Hat* or to hear their mothers reading another children's book, *The King, the Mice, and the Cheese*, which is also a poem but which has a very different meter. The babies sucked to hear *The Cat in the Hat*. "A deprivation experiment allows you to say that a certain prenatal experience is necessary for a certain behavior. We can't say that but we can say that prenatal auditory experience is sufficient to influence postnatal auditory preferences," DeCasper concluded.

William Smotherman and his associates at the Oregon State University are using rats to study a different type of prenatal conditioning. One method of looking at aversive learning in adult animals is to give them lithium chloride paired with a neutral or even pleasant stimulus. The lithium chloride, which causes vomiting in humans, makes rats sick. If lithium chloride is paired with something pleasant, such as apple juice, adult rats avoid drinking the apple juice because they learn immediately to associate it with the lithium chloride–induced illness.

Smotherman decided to try the same sort of experiment with fetal rats. He began by injecting lithium chloride into the amniotic fluid surrounding 20-day-old fetuses and then injected apple juice into the amniotic fluid before delivering them by cesarian section at 22 days of gestation—the normal time of birth. Sixteen days after birth, he tested them by painting a nipple that they preferred to suck with apple juice to see if they remembered the lithium chloride. The rats switched immediately to another nipple, but control rats that had not been given lithium chloride in utero did not. "We were somewhat surprised," Smotherman recalls.

He then tried a variation on the experiment by teaching the rats to go down a runway to suckle an anesthetized female. Next, he opened a vial of apple juice beside the female. The rats that had been given lithium chloride and apple juice when they were fetuses started down the runway, sniffed the apple juice, and turned right around again. The control rats continued down the runway to suckle.

Now Smotherman and his colleagues are using a new technique to observe in utero behavior. Late in gestation, they give pregnant females spinal anesthesia and make an incision in their abdomens that exposes the fetuses, although the fetuses are still attached to their mothers. They then suspend the females up to their armpits in a saline solution, so the fetuses float free in the liquid and can be observed. Using this technique, Smotherman gave 16 rat fetuses a mint solution, which they perceive as a pleasant odor. The fetuses began moving, rotating and making mouthing motions. Then he gave eight of them lithium chloride. This compound made the fetuses stop moving. When Smotherman then came back to these fetuses 2 days later—at day 19 of gestation—and gave them the mint solution again, they stopped moving, just as though they had been given lithium chloride. The control fetuses continued to behave as though the mint were a pleasant taste. What this shows, Smotherman concludes, is that "fetuses are capable of learning at the earliest age we looked—day 17—and they can express their learned responses in utero." He is now planning to use his saline bath technique to deliver milk to rat fetuses and see whether they can be operantly conditioned.

Elliott Blass, a psychologist at Johns Hopkins University and Patricia Peterson, who is now at Yale University, also studied prenatal conditioning in rats, but with a different test system. Infant rats start suckling only after the mother smears her nipples with amniotic fluid. "Peterson and I thought it was interesting that amniotic fluid causes this first attachment [to the mother's nipples]," Blass says. "Mammalian fetuses, including human fetuses, swallow and excrete amniotic fluid in the last trimester of pregnancy. We thought that perhaps this [effect of amniotic fluid on suckling] reflects experiences before birth."

So Blass and Peterson obtained a lemon-scented solution of citral that has no taste but, he says, has a distinct lemon scent. They injected the solution into the amniotic sacs of 20-day-old rat fetuses. When the rats were born, they would suckle even a mother that was washed free of amniotic fluid if her nipples were coated with the citral. Rats that had not been exposed to citral in utero would not suckle such a female.

A favorite animal for fetal research is sheep because a great deal is known about the physiology and anatomy of fetal sheep and because fetal sheep are large—a newborn sheep is about the same size as a newborn baby. Henrique Rigatto, a pediatrics professor at Women's Hospital in Winnipeg, is observing fetal behavior such as breathing, swallowing, and eye movements in fetal sheep with a new technique he has developed. What he does is implant a plexiglass window in the flank of a pregnant sheep during the last trimester of gestation. After establishing that the method works by trying it with 34 sheep, he plans now to start implanting during the second trimester. (Sheep, he says, are very resistant to going into labor so the implantation does not disrupt the pregnancy.) He can observe the entire head and part of the neck of the fetus through the window and has been making videotapes of the fetal behavior.

What is most significant about this surge of research on fetal learning, says Krasnegor, is that the experiments are rigorous and controlled and are being done by scientists who are experienced at looking at the behavior of both infant and adult animals. For those who want to study the origins of behavior, Krasnegor remarks, "in utero learning is the new frontier."—**GINA KOLATA**

Sucking for sounds

Day-old infant sucks a "nonnutritive nipple" to hear her mother reading The Cat in the Hat *or* The King, the Mice, and the Cheese.

Additional Readings

1. A. J. DeCasper and W. P. Fifer, *Science* **208**, 1174 (1980).
2. W. P. Smotherman, *Physiol. Behav.* **29**, 769 (1982).