Changes in brain chemicals mark shifts in infant learning

October 26 2009

When do you first leave the nest? Early in development infants of many species experience important transitions—such as learning when to leave the protective presence of their mother to start exploring the wider world. Neuroscientists have now pinpointed molecular events occurring in the brain during that turning point.

Based on animal studies, the findings may shed light on the strength of attachments in many species—including the conundrum of why human children form strong attachments to even abusive caregivers.

"This is one of the few times we know what causes this type of early transition," said psychologist Gordon A. Barr, Ph.D., of The Children's Hospital of Philadelphia, co-author of a study that appeared online Sept. 27 in Nature Neuroscience. Barr performed the studies in rats with a longtime collaborator, neuroscientist Regina M. Sullivan, Ph.D., of the Nathan Kline Institute and New York University Langone Medical Center.

The youngest rats, called pups, first experience the mother's presence with both positive and negative stimuli. Even if the mother does something unpleasant, like stepping on or biting a pup, the baby rat stays close by the mother, something called preference learning. "From an evolutionary standpoint, this makes sense," said Barr. "The dependent baby has a better chance of survival if it doesn't stray from the mother's side."

However, at about ten days of age, the rat pups experience a transition to so-called aversion learning, in which they learn to avoid unpleasant stimuli. Said Barr, "Once an animal is better able to move around, it needs to be able to escape from stressful situations, again in the interests of its survival." The maturing rat learns a type of safe behavior while away from parental protection.

For neuroscientists, one puzzle has been how to understand the underlying biological events in the changeover from preference learning to aversion learning. In a series of studies reported in the current paper, the authors focused on neurotransmitters in the brain, then manipulated those chemical messages to mimic their natural effects in rats.

They conditioned the rat pups to associate a new odor with a negative event—a mild electric shock. In adult rats, but not in immature rats, a shock induces a telltale increase in levels of the stress hormone corticosterone. Increased corticosterone, in turn, causes the amygdala, a learning center in the brain, to have increased levels of the neurotransmitter dopamine.

Using microarrays (to detect changes in dopamine-related gene expression) and microdialysis (to measure changes in dopamine levels), the study team confirmed that changes in dopamine levels were linked to changes in learning patterns.

On about their tenth day of life, rat pups start to make the transition from preference learning to aversion learning. Based on their corticosterone/dopamine findings, Barr and Sullivan were able to chemically manipulate the learning transition. By injecting eight-day-old rat pups with corticosterone, the scientists advanced the animals' learning behaviors—the young rats avoided the new (shock-associated) odor, just as older rats did. Eight-day-old control rats did not show such avoidance behavior.

Injecting dopamine directly into an eight-day-old rat's amygdala had a similar effect, switching their usual preference learning to aversion learning typical of older animals. The researchers also toggled the switch in the other direction. By blocking dopamine receptors in eight-day-old rats already treated with corticosterone, the rats showed preference learning instead of the aversion learning induced by corticosterone.

The neural mechanisms they found, said Barr, may also apply to infant behavior in dogs, rats and people. "For humans," said Barr, "the findings may shed light on the pathologically strong attachment that children are known to have even for abusive caretakers." In addition, he said, the findings suggest that scientists may detect neural mechanisms at the heart of other developmental transitions, such as an infant's switch from breastfeeding to eating solid food.

Source: Children's Hospital of Philadelphia (news : web)