Embargoed until November 16, 2 p.m. ET
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LOVE IS IN THE AIR: STUDIES EXPLORE THE BIOLOGICAL BASIS OF LOVE AND ATTRACTION

A growing body of research shows importance of senses like smell and taste in emotion

Washington, DC — What is love? Research released today is creating a deeper understanding about the biological basis of attraction, with new studies showing how the human brain responds to a long-term mate and how a parasite can change fear into attraction in animals. The findings were presented at Neuroscience 2008, the Society for Neuroscience annual meeting and the world's largest source of emerging news about brain science and health.

These findings add to a growing body of research on the emotional brain. Much of this research shows that sensory input, especially smells and tastes, are intimately involved in both positive and negative feelings.

The new findings show that:

- Whether they have just fallen in love or have been married for decades, people who are intensely in love show some similar brain responses to their mates. In addition, those in long-term relationships show activation of brain circuits involved in monogamy, while those in short-term relationships show activation of brain circuits involved in obsession (Bianca Acevedo, abstract 297.10, see attached summary).
- A parasite that makes rodents attracted to rather than fearful of the scent of cats, their natural predators, changes its victims' emotional response to a single stimulus. *Toxoplasma* infection alters the stress response and brain circuit activation evoked by cat odors without affecting other behaviors or responses (Patrick House, abstract 92.12, see attached summary).

Other research findings being discussed at the meeting show:

- Researchers have identified the first genetic link to odor perception in people. People carrying a gene variant perceived a human compound that is a pheromone in animals to be pleasant, whereas others found it to be noxious (see attached speaker's summary).
- The amygdala, the emotional center of the brain, and the cortex are involved in making good-tasting things taste bad — after a bad experience like food poisoning — and bad-tasting things taste good after positive experiences and associations (see attached speaker's summary).
- Research in mice is revealing how pheromones cause sex-specific behaviors, especially those involved in mating (see attached speaker's summary).

"The brain makes sense of the world by using all available information, including senses and remembered experiences," said press conference moderator Leslie Griffith, MD, PhD, of Brandeis University, who studies the cellular mechanisms of complex behaviors like courtship in fruit flies. "By weighing this information, the brain makes value judgments that are manifested as emotions like love and anger."

– more –

Related Presentations:

Presidential Special Lecture: **Sex and Smell**
Tuesday, November 18, 5:15–6:15 p.m., Washington Convention Center, Hall D

Minisymposium: **New Directions in Chemical Senses**
Sunday, November 16, 1:30–4 p.m., Washington Convention Center, Room 202B

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Abstract 297.10 Summary

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Similar Brain Responses in Those in Love for Many Years or Just Several Months

Long-term love also stimulates brain activity in regions involved in pair-bonding and pain relief

New imaging research identifies a neural basis for life-long romantic love. The study, presented at Neuroscience 2008, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health, shows that people who are intensely in love after many years of marriage show brain responses to their partners that are similar to those of people who have just fallen in love.

Researchers used functional magnetic resonance imaging to scan the brains of 10 women and seven men who reported that they were still intensely in love with their spouses after an average of 21 years of marriage. While being scanned, participants were shown images of their spouses and other individuals. The researchers previously performed a similar study with 10 women and seven men who had fallen in love on average seven months before the experiment.

For participants in long-term and short-term relationships, viewing images of romantic partners stimulated activity in brain regions that are associated with motivation to win rewards, like the caudate and putamen, and the ventral tegmental area, a brain region activated by addictive drugs.

However, only those in long-term relationships showed activity in brain regions that have been shown in animal studies to be important for the formation of monogamous pair-bonds. In addition, those in long-term relationships showed activity in brain regions associated with feelings of calmness and pain suppression, whereas those in short-term relationships showed activity in brain regions associated with obsessive thought and intense focus.

"These results suggest that those who experience long-term romantic love continue to crave union with their spouses and remain highly motivated to maintain, enhance, and protect their relationships — like those in early-stage, intense romantic love. Their spouses continue to be sources of reward and well-being," said Helen Fisher, PhD, at Rutgers University, who was involved in the study.

Scientific Presentation: Sunday, November 16, 2–3 p.m., Washington Convention Center, Hall A-C

297.10, Neural correlates of long-term pair-bonding in a sample of intensely in-love humans
B. P. ACEVEDO[1], A. ARON[1], H. FISHER[2], *L. L. BROWN[3]; [1]State Univ. of New York, Stony Brook, Stony Brook, NY; [2]Anthrop., Rutgers Univ., New Brunswick, NJ; [3]Dept Neurol., Albert Einstein Col. Med., Bronx, NY
TECHNICAL ABSTRACT: This study examined neural correlates of romantic love among individuals in long-term pair-bonds using functional magnetic resonance imaging (fMRI; BOLD response). One question was how being "in love" in a long-term relationship (> 10 years) differs from the early stages of intense romantic love (1-17 mos.; Aron et al., 2005; Bartels & Zeki, 2000). Procedures used in Aron et al. (2005) were replicated and additional stimuli were used to control for closeness and familiarity. Ten females and 7 males (mean ages: 51 and 55 years, respectively) who reported being intensely in love with a long-term spouse (married mean of 21.4 ± 5.89 years) underwent fMRI scanning while they viewed face images of their partner and controls, interspersed with a distraction-attention task. Control images were a high-familiar, neutral person; a low-familiar, neutral person; and a close friend or sibling. Group activation specific to the long-term partner compared to each of the control conditions occurred in dopamine rich regions associated with reward and motivation in mammals. Specifically, significant activations appeared in the right ventral tegmental area, and the ventral striatum/pallidum. Other activations occurred in serotonin-rich areas, the median and dorsal raphe nuclei, consistent with data from monogamous pair-bonding studies in voles (Lim, Nair, & Young, 2005). The results show that in some human individuals, being "in love" with a long-term partner is similar to early-stage romantic love because ventral midbrain areas were affected under the various control conditions. In addition, activation was found in brain areas implicated by animal studies to be involved in mammalian pair-bonding, or more generally, social affiliation. These additional areas may be part of a human attachment system. We conclude that this group of individuals revealed both early attraction and attachment brain systems whose activity is important for reproductive behavior and the establishment and maintenance of pair-bonds in humans.

Abstract 92.12 Summary

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Research Investigates How Parasite Converts Fear to Attraction

Findings may help explain biological basis of emotion

New animal research shows how a parasite converts fear to attraction. The study, presented at Neuroscience 2008, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health, addresses the brain mechanism by which the single-celled parasite *Toxoplasma gondii* makes infected rodents attracted to, rather than fearful of, the scent of their natural predators, cats. The findings may help explain the biological bases of two different emotions.

Toxoplasma infection affects rodent behavior in a targeted way — altering their behavioral response only to cats and their scent. "*Toxoplasma* turns a strongly innate, hard-wired behavior on its head, and in its place leaves a suicidal attraction toward one of a rat's most feared, ecologically relevant predators," said Patrick House, from Stanford University, who was involved in the study. This behavioral effect is beneficial to *Toxoplasma* — infected rodents are presumably more likely to be caught and consumed by cats, and *Toxoplasma* relies on the cat digestive system for reproduction.

Rats exposed to cat odor normally show increases in the stress hormone corticosterone. However, the researchers found that rats exposed to *Toxoplasma* showed reduced corticosterone responses to cat odor and environments associated with cats. Infected rats also showed altered activation of brain regions involved in fear and increased activation of brain regions involved in attraction.

"These findings support the idea that for the rat, *Toxoplasma* is shifting the emotional salience of the detection of the cat. They also suggest that fear and attraction might lie on the same spectrum, or at least that the emotional processing of fear and attraction are not entirely unrelated," House said.

Many humans carry *Toxoplasma*, largely due to consumption of undercooked meat or unwashed vegetables, but potentially also due to contact with cat litter. In humans, *Toxoplasma* exposure is most dangerous to developing fetuses. However, some research links exposure to *Toxoplasma* with schizophrenia and risk-taking behavior.

The research was supported by the Stanley Medical Research Institute.

Scientific Presentation: Saturday, November 15, 4–5 p.m., Washington Convention Center, Hall A-C

92.12, Latent Toxoplasma infection in rodents reduces corticosterone secretion in response to cat pheromones
P. K. HOUSE, *A. VYAS, R. M. SAPOLSKY; Dept Biol, Stanford Univ., Stanford, CA
TECHNICAL ABSTRACT: The Protozoan parasite Toxoplasma gondii converts the innate aversion of rats for bobcat urine into attraction, which should increase the likelihood of a cat predating a rat. This is thought to reflect adaptive behavioral manipulation by Toxoplasma, in that the parasite, while capable of infecting rats, reproduces sexually only in the guts of cats. Exposure of rodents to predator odor induces secretion of glucocorticoids, the adrenal steroid hormones released during stress. Corticosterone is the primary glucocorticoid hormone in rats; and has been postulated to play an important part in organizing behavioral response to predator odor. We investigated if behavioral manipulation of anti-predator behavior by Toxoplasma involved manipulation of corticosterone secretion.
Male Long-Evans rats were injected with 7.5 million tachyzoites. Blood was collected through tail vein puncture 9 weeks after infection. Infection reduced the amount of circulating corticosterone, both at baseline and after exposure to cat odor. Moreover, infection reduced corticosterone secretion in condition place aversion tasks, even when no actual predator odor was present. We are currently expanding these observations by measuring activation of paraventricular and ventromedial hypothalamus, using immediate early gene markers. Our observations are in agreement with idea that Toxoplasma infection causes a specific change in emotional processing of predator odor.

Speaker's Summary

Speaker: Hiroaki Matsunami, PhD **(919) 684-2777**
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Genetic Variation and Human Odor Perception (204.3)
Minisymposium: New Directions in Chemical Senses
Sunday, November 16, 1:55–2:15 p.m., Washington Convention Center, Room 202B

Androstenone and the related compound androstadienone are sex steroid-derived compounds that are proposed to be human pheromones, chemicals that can affect innate behaviors or hormonal levels. Androstenone is a known pheromone in pigs, is present at high concentrations in the saliva of male pigs, and facilitates a receptive mating stance of females in heat. Androstenone is also present in human secretions such as saliva, sweat and urine. Olfactory exposure to androstenone and androstadienone can induce physiological responses in both men and women. The evidence that androstenone and androstadienone act as pheromones to modulate human behavior is intriguing, but controversial.

Individual differences in the perception of various odors can be found in everyday life. One of the most striking examples of variability in smell perception is that of androstenone, which is variously perceived by different individuals as offensive ("sweaty, urinous"), pleasant ("sweet, floral") or odorless. While experience can greatly influence olfactory perception, there is evidence that prior exposure is not the whole story. Observations of very young infants show they pay selective attention to different smells, suggesting an innate predisposition for some olfactory responses. In addition, as reported from twin studies, sensitivity to androstenone may have a genetic basis: The ability of one monozygotic twin to detect androstenone is highly predictive of the same ability in the second twin. Studies on the loss of perception to certain odorants provide perhaps the best evidence for an effect of genes on variability in smell perception. In addition, as androstenone and androatadienone have been endorsed as a potential pheromone in humans, understanding their olfactory reception can also shed light on their pheromonal aspect and possibly demystify the authenticity of human pheromonal responses.

We asked whether variation of a single human gene can affect olfactory perception. We focused on genes encoding odorant receptors that bind to volatile chemicals in the olfactory neurons in the nose. Using a cell culture system, we showed that a human odorant receptor, OR7D4, is selectively activated by androstenone and androstadienone. Furthermore, we found two common types of this receptor, that we designate "RT" or "WM". While the "RT" type is activated by androstenone and androstadienone, the "WM" type showed severely impaired function. Since every person has two copies of the gene, each person can have one of three different combinations of the types, RT/RT, RT/WM, or WM/WM. With the help of over 400 subjects, we showed that humans with RT/WM or WM/WM genotypes were less sensitive to androstenone and androstadienone and found both odors less unpleasant than the RT/RT group, people with two copies of the functional gene. In addition, we found that humans with RT/RT tend to use words including "sickening" and "urine" to describe androstenone while humans with RT/WM or WM/WM tend to use the words like "vanilla" and "sweet" to describe the same chemical. This study demonstrates the first link between human odorant receptor gene variants and odor perception. The identification of a gene strongly correlated with the perception of these putatively phernomonal odors will permit future analysis of olfactory-induced behavioral and hormonal responses in humans. It will be interesting to ask whether people with the non-functional OR7D4 type, WM, differ from people with the OR7D4 RT/RT type in the neural and psychological effects induced by these odorous steroids. Our findings could also lead to the identification of chemical compounds that either block or activate OR7D4, and may have direct commercial relevance.

Speaker's Summary

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Dynamics of Taste Responses (204.5)
Minisymposium: New Directions in Chemical Senses
Sunday, November 16, 2:35–2:55 p.m., Washington Convention Center, Room 202B

Sometimes Bad Ain't Bad: Taste Perception and the Central Nervous System

A curious fact that has long been known about human beings: most will, from time to time, eat something decidedly unappetizing and declare it to be simply delicious. Witness (just two examples of many instances) the Dutch preoccupation with bitter licorice, and the insistence of many that coffee is best drunk unsweetened. These observations provide ample evidence that our judgments about a taste's palatability often have more to do with factors surrounding a tasting experience — memories of similar meals eaten previously, the ambiance of the restaurant in which the current meal is being eaten, or peer pressure — than with the taste itself.

Research from the lab of neuroscientist Don Katz at Brandeis University shows that the massive integration of information from which taste perception emerges is supported by a great deal of neural circuitry in cortex and the limbic system (notably the amygdala, the heart of the "emotional" brain). Activity in these brain regions, guided by but in turn transforming information from the tongue, determines whether an animal will decide to ingest a food or spit it out.

The Katz lab examines the ways in which a rat's amygdala and cortical neurons respond to tastes, and relates these responses to the animal's decisions about taste palatability. Katz and colleagues have shown that processing in these higher brain regions is indispensible for proper functioning of an animal's ability to recognize that a once palatable taste is in fact noxious — to recognize that a taste that causes food poisoning is to be avoided at all costs.

This amazing and evolutionarily important ability is summoned after a single bad experience with a taste. Many college students, for example, demonstrate exactly this ability after a night of bingeing on tequila. The students enjoy the tequila largely because their friends expect them to do so, end up vomiting (often repeatedly), and in later attempts are unable to stomach the taste or even smell of the drink.

In the process of learning from food poisoning, the amygdala leads the charge, telling the cortex what to think. It signals the updated palatability of the taste — from positive to negative — within 250 milliseconds of taste-to-tongue contact, and then communicates this update to cortex over the course of the next half second.

Katz and coworkers have shown that attention also has an impact on palatability (albeit a non-intuitive impact), and have gone on to show that, just as with the changes wrought by food poisoning, this impact arrives late in cortex. If a "day-dreaming" rat gets a taste on its tongue, it responds more strongly to that taste's palatability than it would if it were paying attention to that taste — another defense measure that helps an animal to avoid potentially deadly stimuli. As is true following food poisoning, the cortex gets the news of this updated palatability only after the taste has been processed for several hundred milliseconds.

Even palatability decisions that precede a rat's first experience with a taste require amygdala and cortex. For instance, if a rat smells a food on another rat's breath — that is, if the other rat ate something and lived to tell the tale — the smeller will later prefer and enjoy the food that it detected on the breath of the smellee. Even if the new taste is very bitter, the rat will find it to be simply delicious. For the rat, much as for the human, the appreciation of a taste is a function of a host of factors much broader than the sensation of taste itself. And again, the Katz lab's research demonstrates that this appreciation is impossible without a properly functioning amygdala and cortex.

Future work in the Katz lab will continue to break things down, by identifying the neural substrates of each of the myriad factors involved in the tasting experience, and at the same time will build a picture of the full system, by characterizing how each part of the taste system works with the others to provide a seamless, holistic experience of taste.