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HEARING COLORS, SEEING SOUNDS: NEW RESEARCH EXPLORES SENSORY OVERLAP IN THE BRAIN

Studies reveal brain underpinnings for auditory and visual illusions, and everyday experiences

SAN DIEGO — New research indicates that the integration of senses and functions in the brain is common. About two percent of the population has a condition called synesthesia, in which two different sensations, like color and sound, are experienced at once. Although this condition is rare, the new findings suggest the brain is wired in complex and sometimes overlapping ways to help people interpret and understand their environments. The research was presented at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news on brain science and health.

Today's new findings show that:

- Researchers have pinpointed the brain region responsible for the McGurk Effect, an auditory phenomenon in which viewing lips moving out of sync with words creates the perception of other words. A brain area known to play a role in language and eye gaze processing is the hub of the sensory overlap (Michael Beauchamp, PhD, abstract 400.2, see attached summary).
- People adjust the perceived location of sensory stimuli faster than previously thought. Results show that exposure to light for only a fraction of a second alters the perceived source of a subsequent sound. The findings have implications for the development of hearing aids and rehabilitation from brain injury (Ladan Shams, PhD, abstract 125.1, see attached summary).

Other recent findings discussed show that:

- Synesthetes who describe colors as either inside their minds or outside in the world have distinct brain structures and processes (Romke Rouw, PhD, see attached speaker's summary).
- People who share one type of synesthesia, in which letters and numbers create the experience of color, describe drastically different sensations from one another. This indicates that synesthetic experiences are more idiosyncratic than is commonly realized (Avinash Vaidya, see attached speaker's summary).
- In people with synesthesia, scientists found the brain's color-processing area was active five to 10 milliseconds after the visual processing areas, suggesting synesthesia occurs through direct communication between the senses (David Brang, see attached speaker's summary).

"While synesthesia reflects an extreme manner in which the senses communicate, there's evidence that synesthesia operates through mechanisms present in all individuals," said press conference moderator Vilayanur Ramachandran, MD, PhD, of the University of California, San Diego, an expert on visual perception and behavioral neurology. "Understanding these mechanisms can help us answer fundamental questions about how the brain works."

This research was supported by national funding agencies, such as the National Institutes of Health, as well as private and philanthropic organizations.

– more –

Related Presentation:

Minisymposium 720: **Colored Numbers and Tasted Sounds: What Synesthesia Reveals about Neural Crosstalk**
Wednesday, Nov. 17, 8:30–11 a.m., PST
# # #

Abstract 400.2 Summary

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Brain Region Responsible for Speech Illusion Identified

Study explains how visual cues disrupt speech perception

Watching lips move is key to accurately hearing what someone says. The McGurk Effect, an auditory phenomenon in which viewing lips moving out of sync with words creates other words, has been known since the 1970s; now researchers have pinpointed the brain region responsible for it. The findings were presented at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health.

Scientists at the University of Texas Medical School found that the superior temporal sulcus, known to play a role in language and eye gaze processing, is the hub of the sensory overlap. In the study, researchers first had volunteers experience the McGurk Effect while undergoing functional magnetic resonance imaging (fMRI). The fMRI showed the authors which part of the brain was active during the effect.

The activity in that region was then disrupted using transcranial magnetic stimulation, while participants remarked on what they heard during the speech and vision tests. The researchers discovered that the McGurk Effect disappeared when they targeted the superior temporal sulcus. As importantly, the participants perceived other sounds and sights normally.

"These results demonstrate that the superior temporal sulcus plays a critical role in the McGurk Effect and auditory-visual integration of speech," said Michael Beauchamp, PhD, who led the study.

Research was supported by the National Science Foundation and the National Institute of Neurological Disorders and Stroke.

Scientific Presentation: Monday, Nov. 15, 9–10 a.m., Halls B–H

400.2, FMRI-Guided Transcranial Magnetic Stimulation Reveals that the Superior Temporal Sulcus is a Cortical Locus of the McGurk Effect
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TECHNICAL ABSTRACT: A compelling example of auditory-visual multisensory integration is the McGurk effect, in which an auditory syllable is perceived very differently depending on whether it is accompanied by a visual movie of a speaker pronouncing the same syllable or a different, incongruent syllable. Anatomical and physiological studies in human and non-human primates have suggested that the superior temporal sulcus (STS) is involved in auditory-visual integration for both speech and non-speech stimuli. We hypothesized that the STS plays a critical role in the creation of the McGurk percept. Because the location of multisensory integration in the STS varies from subject to subject, the location of auditory-visual speech processing in the STS was first identified in each subject with fMRI (figure part A). Then, activity in this region of the STS was disrupted with single-pulse TMS as subjects rated their percept of McGurk and non-McGurk stimuli. TMS of the STS significantly reduced the likelihood of the McGurk percept (figure parts B and C) but did not interfere with perception of non-McGurk stimuli. TMS of the STS was only effective at disrupting the McGurk effect in a narrow temporal window from 100 ms before auditory syllable onset to 100 ms after onset (figure part D), and TMS of a control location did not influence perception of McGurk or control stimuli. These results demonstrate that the STS plays a critical role in the McGurk effect and auditory-visual integration of speech.

Abstract 125.1 Summary

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What You See Changes Where You Hear

Study finds exposure to light for only milliseconds alters perceived source of sound

New research shows that the perceived location of a noise depends in part on the sights noticed before the sound. The findings were presented at Neuroscience 2010, the annual meeting of the Society for Neuroscience and the world's largest source of emerging news about brain science and health. The results have implications for the development of hearing aids and rehabilitation from brain injury.

"The auditory map of space is not static like the world atlas," said lead author Ladan Shams, PhD, of the University of California, Los Angeles. "Instead, it can change from one moment to the next."

People navigate their surroundings based on maps built by sensory perceptions from their eyes, ears, and other senses. The brain combines these maps into a single experience. What happens, however, when one perception is flawed and becomes out of sync with the others? Studies show that when one of the sensory maps is wrong, the others will recalibrate to make it consistent and more accurate. But while previous studies held that this correction only occurs after hundreds or thousands of errors, new research shows that recalibration happens only a fraction of a second after an incident.

In this study, the researchers exposed 146 participants to 35-millisecond bursts of radio static-like noise, as well as flashes of light. In some trials, the lights and sounds were simultaneous; in others, there was static only. The researchers found that the perceived location of a sound was influenced by the direction of the flash in the previous trial. For example, if in the previous test the flash was to the left of the sound, the volunteer's perception of the sound alone in the next test was shifted to the left.

"This is the first evidence that sensory recalibration can occur rapidly, not after days or even seconds, but after milliseconds of exposure to discrepancy," Shams said. "This indicates that the recalibration of auditory space does not require a large amount of evidence to become triggered, and instead operates at all times."

Research was supported by the University of California, Los Angeles, and the National Institute of Biomedical Imaging and Bioengineering.

Scientific Presentation: Sunday, Nov. 14, 8–8:15 a.m., Room 33C

125.1, One-shot recalibration of auditory space by vision
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TECHNICAL ABSTRACT: Background: It is known that human sensory systems continue to adapt to the environment, even in the mature stage of life. For example, after repeated exposure to auditory and visual stimuli with a certain spatial offset, the perceived auditory space gets shifted in the direction of the previously experienced visual stimuli. However, this class of recalibration has been reported only as a result of an extensive amount of exposure (hundreds/thousands of trials) to discrepant stimuli. Purpose: Here we investigated whether recalibration requires a substantial amount of evidence for error to be triggered or whether recalibration can occur even after a single exposure to discrepancy. Methods: Unisensory stimuli (presented at varying locations) and auditory-visual stimuli (with varying degrees of spatial discrepancy) were randomly intermixed across trials. Thus, on bisensory trials, discrepancy randomly changed from trial to trial in both magnitude and direction. Auditory and visual stimuli were noise bursts and white disks on a dark background presented simultaneously for 35ms at one of five spatial locations along azimuth. The locations of auditory and visual stimuli were independent; i.e., could have a discrepancy varying from 0 to 26 degrees. Fifteen trials of each of the 35 stimulus conditions (10 unisensory conditions and 25 bisensory conditions) were presented in a pseudorandom order. The observers (N=146) reported the location of the stimulus by moving a cursor on the screen. The initial location of the cursor was randomized. No feedback was provided. For each unisensory auditory trial, "the auditory aftereffect" was measured as the difference between the response on that trial and the observer's average response for the given auditory stimulus location. We plotted the "auditory aftereffect" as a function of the AV spatial discrepancy on the previous bisensory trial. Results: The analysis revealed a significant aftereffect that increased in magnitude as a function of previous trial discrepancy. For all non-zero discrepancy conditions, a significant aftereffect was found in the direction of the preceding visual offset. Conclusions: These results suggest that crossmodal sensory recalibration can occur after a single presentation of a brief stimulus lasting just a few

milliseconds, and can occur in the absence of feedback or reinforcement. These findings suggest an impressive degree of plasticity in a basic perceptual map induced by a crossmodal error signal. Therefore, it appears that modification of sensory maps does not necessarily require accumulation of substantial amount of evidence of error to be triggered, and is continuously operational.

Speaker's Summary

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Neural Basis of Individual Differences in Synesthetic Experiences (720.3)
Minisymposium: Colored Numbers and Tasted Sounds: What Synesthesia Reveals about Neural Crosstalk
Wednesday, Nov. 17, 8:55–9:15 a.m., San Diego Convention Center, Room 33C

In synesthesia, a particular experience (e.g. seeing the letter "a") evokes a separate additional perceptual experience (e.g. a bright red color). Synesthesia is not only interesting to study in its own right, but also offers an extraordinary opportunity to study cognitive and neurological mechanisms involved in perceptual experiences. Currently, we still know little about how the properties of our private mental world relate to the physical and functional properties of our brain.

Studying synesthesia offers the unique opportunity to study phenomenological experiences as a stable trait in normal, healthy people. One form of synesthesia is grapheme-color synesthesia, where a particular letter or number evokes a particular color experience. Research shows how these additional experiences can be traced in structural and functional differences in the brains of synesthetes, as compared with the brains of non-synesthetes.

Furthermore, individual differences in the subjective nature of the experiences provide an opportunity to study the neural basis of subjective experiences. In particular, we studied individual differences in the location of the synesthetic color. Some synesthetes report that the synesthetic color is experienced only "in the mind" (associator synesthetes), while others report that the location of the synesthetic color is "in the outside world" (projector synesthetes). Behavioral (questionnaire) studies show that these differences are stable over time in synesthetes. Furthermore, it relates to the subjective nature of the experience, but not to having synesthesia in general.

We looked both at structural properties of the brain and at functional properties of the brain, in associator and projector synesthetes. Results indicate partly shared mechanisms for all grapheme-color synesthetes; particularly in posterior superior parietal lobe, which is involved in the integration of sensory information. In addition, the contrast between projector and associator synesthetes was found related to distinct neural mechanisms. The "outside world" experience is related to brain areas involved in perceiving and acting in the outside world (visual cortex, auditory cortex, motor cortex) as well as frontal brain areas. In contrast, the experience that was reported only "in my mind," was found related to brain regions in and near the hippocampus. This brain region is known to be important in memory.

Thus, the different subjective experiences are related to distinct neural mechanisms. Moreover, the properties of subjective experiences are in accordance with functional properties of the mediating brain mechanisms. Brain regions involved in acting and perceiving in the "outside world" are related to synesthetic experiences "in the outside world," while brain regions known to be involved in the internal action of "remembering something" were found related to experiences that were only "in my mind." Apparently, the private event of the nature of a subjective experience can be 'caught' by using modern brain imaging technology.

Speaker's Summary

Speaker: Avinash Vaidya
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Seeing T's of Green, Red O's Too, 'I' and 'C' Are Blue, Same for 'E' And 'U': The Wonderful World of Synesthesia (93.15)

Poster Session: Perception and Imagery: Auditory, Somatosensory, and Supramodal Processing
Saturday, Nov. 13, 3–4 p.m., San Diego Convention Center, Halls B-H

Should this text appear in vibrant, colorful clouds or evoke the smell of burnt toast, you might have a condition known as synesthesia. Individuals with this condition report experiencing an unusual blending of the senses, such that sounds or smells may evoke the feeling of a touch, or visions of luminous shapes.

Our study, conducted at Ursinus College in Pennsylvania, focused on a particular sub-type of this condition in which letters and numbers produce the experience of color. Interestingly, we found that these sensations differed drastically between individuals with this type of synesthesia. Namely, some of these synesthetes experienced powerfully visual, automatic sensations, whereas others had a more associative process for relating colors with letters and numbers. Additionally, we have found that electrical activity from the brain, detected at the scalp with electroencephalography, supports these findings. This indicates that synesthetic experiences are considerably more idiosyncratic than is commonly realized.

Although past studies have distinguished between synesthetes who see colors as projected in their visual field and those who witness them in their "mind's eye," our research suggests even further differentiation. We asked five synesthetes to complete a test in which they were asked to memorize a set of letter/number-color pairings. Some of these pairings matched the synesthetes' own experiences, while others did not. The synesthetes were then asked to recall the associated color by selecting one of two color swatches. These swatches were either very similar or complementary, making the choice very difficult in one condition and very easy in the other.

While we expected all synesthetes to benefit in trials with colors that matched their synesthetic experience, this was not the case. Projection of synesthetic colors in the visual field either interfered with performance in these trials or provided an advantage in trials with mismatching colors. Although synesthetes who saw synesthetic colors in their "mind's eye" benefited in such trials, we found major differences in the automaticity of their experiences. Synesthetic colors appeared to exert a greater effect on the performance of synesthetes who reported immediately seeing a color after presentation of a letter or number. Other synesthetes, who reported an associative process, did not show such dramatic effects. Electroencephalography data also indicated that these synesthetes relied more on semantic associations and memory than on immediate visual sensations like their counterparts.

Since this study involved a very small group of synesthetes, we were able to conduct an in-depth analysis and comparison of each synesthete's experience. Further exploration of differences among a larger group of synesthetes might prove valuable for future research. However, a large concurrent study of the neural basis of the differences among synesthetes supports our findings. This might help explain some of the variability in research on the origins of synesthetic color sensations in the brain. Several researchers have suggested that all people experience some degree of synesthesia, though not as dramatic as the examples described here. Combining information from the senses might be an important process for the brain to construct a coherent perspective of the world. Thus, we hope that learning about the brains of these synesthetes will allow us to better understand how the mind normally integrates the senses and produces a coherent experience of consciousness.

Speaker's Summary

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Functional Predictions Made by the Cross-Activation Theory (720.7)
Minisymposium: Colored Numbers and Tasted Sounds: What Synesthesia Reveals about Neural Crosstalk
Wednesday, Nov. 17, 10:15–10:35 a.m., San Diego Convention Center, Room 33C

Our research provides the first confirmation that synesthesia occurs through direct communication between the senses, subject to a delay of only five to 10 milliseconds.

Synesthesia is present in roughly two percent of the population, and has been related to artistic ability, creativity, and language. Further, while synesthesia reflects an extreme manner in which the senses communicate, it has been argued that synesthesia operates through mechanisms present in all individuals. Our results suggest that the initial communication between the senses occurs through direct connections in the brain, not mediated by additional processing.

In order to test the pattern of activity in synesthesia, we used magnetoencephalography (MEG), a powerful yet non-invasive method that can record neural activity with millisecond accuracy, and is also able to spatially distinguish activity from neighboring regions in the brain. Four grapheme-color synesthetes (for whom numbers and letters evoked vivid colors) as well as four age- and handedness-matched controls were scanned while performing a simple detection task. In synesthetes and controls, neural activity flowed from early visual areas to visual processing regions, in order to recognize and identify the letter or number. In the brains of synesthetes but not controls however, this activity then travelled to brain's color area (known as V4) only five to 10 milliseconds later, providing the first confirmation of how synesthesia occurs.

While this research demonstrates the first step in the synesthetic experience, that is, the initial activation of color from a number or letter, we know context and expectation can change this experience, just as it can for non-synesthetes. In one simple example, the letter "l" can be read as the number one or as a letter depending on context, and in each instance our mind can "flip" back and forth from seeing it as an "l" or a "1." The same is true in synesthetes, and the color appropriately oscillates in the same manner. Accordingly, the present findings suggest the while direct communication between the senses is necessary in the initial experience of synesthesia, it may not be sufficient to explain the broad spectrum of synesthetic qualia.