Embargoed until Nov. 16, 1:30 p.m. PST
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COMMUNICATION ENGAGES COMPLEX BRAIN CIRCUITRY AND PROCESSES

Research offers new insights into communication problems like stuttering

SAN DIEGO — New human and animal studies released today uncover the extensive brain wiring used in communication and provide new insights into how the brain processes and produces language, accents, and sounds. The research also explores the brain abnormalities in people with speech and language problems, such as stuttering, suggesting future treatment avenues. The new findings were 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.

Communication involves a complex series of tasks, from processing and comprehending sounds to producing jaw movements. Better understanding of the brain circuitry involved may benefit the more than 46 million Americans who suffer some form of communication impairment.

Research released today shows that:

- The network of brain connections vital to understanding language is more extensive than previously thought. Researchers identified new speech-related pathways by mapping language areas in the brains of people with and without language difficulties (Nina Dronkers, PhD, abstract 837.13, see attached summary).
- People who stutter show abnormal brain activity even when reading or listening, which suggests stuttering is due to problems in speech processing, not just production (Kate Watkins, PhD, abstract 563.19, see attached summary).
- People process words spoken in their native accent differently compared with other accents, which may explain perceived communication difficulties and social inferences attributed to foreign accents (Patricia Bestelmeyer, PhD, abstract 169.13, see attached summary).
- Men who stutter show different brain connections than women who stutter. These findings may help explain why five times more adult men stutter than women (Soo-Eun Chang, PhD, abstract 790.9, see attached summary).
- Brain cells in songbirds are tuned to communicative sounds and respond even when those sounds are mixed with background noise. These findings provide insight into how people can focus on a conversation in a loud room, also known as the "cocktail party effect" (Frederic Theunissen, PhD, abstract 275.17, see attached summary).

"Communication is our means of expressing thoughts, feelings, and emotions — and today's research not only provides valuable clues to how the brain tackles this vital task, but also gives insight into how we might address and treat communication problems," said press conference moderator Steven L. Small, MD, PhD, of the University of Chicago, an expert on language and the brain.

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

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Abstract 837.13 Summary

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Newly Identified Brain Pathways Vital to Understanding Language
Study uses novel techniques to map connections

A complex network of brain connections necessary for language comprehension has been mapped in new detail, according to recent research. These newly charted pathways will help scientists understand how language is processed in the brain, and how brain injuries disrupt the system. The research was 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 question of how the brain understands language has puzzled scientists for generations," said senior author Nina Dronkers, PhD, of the Veterans Affairs Northern California Health Care System and the University of California, Davis. "We found rich connections throughout the brain that have not traditionally been associated with language, but are now found to tie together key areas important for understanding language."

Language and speech disorders affect millions of Americans and include a variety of problems, in both spoken language and in reading. In this study, Dronkers and co-author And Turken, PhD, used structural and functional brain imaging techniques on healthy and injured brains to compose a more complete picture of language processes.

Sixty-four people with problems understanding language due to brain injury were scanned with magnetic resonance imaging. The structural images were used to build a digital atlas of the brain regions thought to be associated with their disorders. The researchers then merged this information with new brain scans of 25 healthy volunteers to illustrate the pathways between brain areas. Finally, functional images of another 25 healthy individuals showed the connections between brain regions actually used for language.

"The results revealed a far more extensive network for language functions than current models would predict," Dronkers said. The network included a core region within the left mid-temporal lobe of the brain, and extended to the frontal and parietal cortex in both halves of the brain — all connected by long distance communication pathways. The next step for scientists is to explore whether other language abilities, such as talking, reading, and writing, also have such dynamic networks.

Research was supported by the Department of Veteran Affairs' Office of Clinical Sciences Research and Development and the National Institutes of Health.

Scientific Presentation: Wednesday, Nov. 17, 4–4:15 p.m., Halls B–H

837.13, White matter pathways subserving the language comprehension network
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TECHNICAL ABSTRACT: While traditional models of language comprehension have focused on the left posterior temporal cortex as the neurological basis for language comprehension, lesion (Dronkers et al., 2004) and functional imaging (Binder et al., 2009) studies indicate the involvement of an extensive network of cortical regions. Here, we assessed the structural and functional connectivity of the regions that were to be found to be critical for auditory sentence comprehension in a voxel-based lesion-symptom mapping analysis (Dronkers et al., 2004), which identified the left middle temporal gyrus (MTG), anterior superior temporal gyrus (STG), posterior superior temporal sulcus (STS) and Brodmann's area 39, the orbital part of inferior frontal gyrus (BA 47) and the middle frontal gyrus (BA 46) as key nodes in this network. We used diffusion imaging and resting state functional MRI data from healthy subjects to explore the extent of the structural and functional connectivity of these regions and to assess their roles in a distributed network. Fiber tractography and functional connectivity analyses indicated that the MTG, anterior BA 22, STS/BA39 and BA 47 are part of a richly interconnected network, which includes frontal, parietal and temporal regions in the two hemispheres. The inferior fronto-occipital fasciculus, the arcuate fasciculus and the middle and inferior longitudinal fasciculi, as well as the transcalloscal projections via the tapetum were found to be the white matter pathways that are critical for language comprehension (Figure 1). The left posterior MTG showed an extensive structural and functional connectivity pattern (Figure 2), which is consistent with a core role for this region in lexical-semantic processing. These findings

highlight the importance of long association fiber systems for the integrated functioning of the cortical regions which together support comprehension, and have implications for the diagnosis and recovery of aphasic patients with comprehension deficits.

Abstract 563.19 Summary

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People Who Stutter Show Abnormal Brain Activity When Reading and Listening

Study suggests abnormalities exist in speech processing as well as production

A new imaging study finds that people who stutter show abnormal brain activity even when reading or listening. The results suggest that individuals who stutter have impaired speech due to irregular brain circuits that affect several language processing areas — not just the ones for speech production. The research was 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.

Stuttering affects about one in every 20 children; most grow out of it, but one in five continues to struggle. While the particular cause of stuttering is still unknown, previous studies showed reduced activity in brain areas associated with listening, and increased activity in areas involved in speech and movement. In the new study, researchers considered whether irregular activity would also be apparent when stuttering speakers silently read.

"If those patterns are also abnormal, the differences could be considered typical of the stuttering brain and not just the result of the difficulties that people who stutter have with speech production," said senior author Kate Watkins, PhD, of the University of Oxford.

Using functional magnetic resonance imaging (fMRI), Watkins and her team compared the brain activity in 12 adults who stutter with 12 adults who do not. The researchers conducted the scans in three trials: in one, volunteers simply listened to sentences; in the second, they read sentences silently; in the third, they read sentences silently while another person read the same sentence aloud. The authors found the stuttering volunteers' brains were distinctly different from non-stuttering speakers in all three tests. The people who stuttered had more activity in auditory areas when listening only. When reading, there was less activity in motor areas, specifically a circuit involved in the sequence of movement.

"Our findings likely reflect that individuals who stutter have impaired speech processing due to abnormal interactions in brain circuits," Watkins said. "In future studies, it will be important to examine changes in these brain areas in young children to find out if these interactions result from a lifetime of stuttering or point toward the cause of stuttering itself."

Research was supported by the U.K. Medical Research Council.

Scientific Presentation: Tuesday, Nov. 16, 10–11 a.m., Halls B–H

563.19, Abnormal brain activation patterns in developmental stuttering during listening and covert reading

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TECHNICAL ABSTRACT: Previous functional imaging studies involving overt speech tasks have identified abnormal activity in the language and motor areas of people who stutter (PWS). One study using PET in four PWS suggested that stuttering-related brain activation patterns could be replicated using covert speech (Ingham et al., 2001). Abnormal brain activity observed during covert speech could be considered characteristic of the stuttering brain rather than simply reflecting differences related to the motor symptoms that accompany stuttered speech. The present brain imaging study was designed to examine whether covert speech produced the same abnormal brain activation patterns as overt speech in PWS. In twelve PWS and 17 controls, functional MRI was used to investigate the neural correlates of (i) reading covertly, (ii) passive listening and (iii) reading covertly while listening to the same sentence. In overt speech, stuttering frequency can be dramatically reduced when reading in unison with another speaker, so the third condition was used to mimic this 'chorus effect' for covert speech. For group comparisons, peaks were considered significant at a voxel threshold of $Z>2.3$, $P<0.001$, uncorrected. The reading covertly condition revealed reduced activity in the inferior frontal gyrus (IFG) bilaterally and in the left sensorimotor cortex in PWS relative to controls. While listening to speech, PWS showed increased activity compared to controls in the superior temporal gyrus (STG) bilaterally. During chorus reading, PWS showed reduced activity relative to controls in the putamen and the supplementary motor area (SMA) bilaterally as well as in the left IFG, pars triangularis. The observation of increased activity in the STG bilaterally contrasts with findings from previous studies that robustly report a reduction of activity in the STG in PWS relative to controls during overt speech tasks. It is assumed that this reduction is due to inhibition of auditory areas during self-produced speech. Our findings suggest that the auditory cortex in PWS is abnormally overactive

during speech perception alone. The abnormal activity observed in the putamen and the SMA of PWS is consistent with the hypothesis that stuttering is associated with impairments of the basal ganglia and specifically its outputs to the SMA (Alm 2004). Our data support the conclusion that abnormal neural activation in PWS in speech areas, the basal ganglia and premotor areas can be observed even during covert speech tasks. Yet, these stuttering-related activations and deactivations are different from the neural signatures of stuttering observed previously during overt speech tasks.

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Listeners' Brains Respond More to Native Accent Speakers

Imaging study suggests accents are subtle "insider" or "outsider" signal to the brain

The brains of Scots responded differently when they listened to speakers with Scottish accents than to speakers with American or British accents, a new study has found. Understanding how our brains respond to other accents may explain one way in which people have an unconscious bias against outsiders. The research was 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.

"Many positive and negative social attributes are inferred from accents, and it's important to find the underlying cognitive mechanisms of how people perceive them," said lead author Patricia Bestelmeyer, PhD. "Accents affect perceptions of competence or trustworthiness, important attributes for salesmen and jobseekers alike."

Research conducted at the University of Glasgow suggests that people process words spoken with their own accent more quickly and effortlessly than other accents. In the study, 20 Scots listened to recordings of nine female speakers (three American, three British, and three Scottish) while their brain activity was measured with functional magnetic resonance imaging (fMRI). The authors suspected that brain activity in an area associated with accent processing would decrease as accented words were repeated and the brain became accustomed to them. However, they found this occurred only when the Scots listened to American or British accents, and not to Scottish accents, suggesting the listeners had to adapt to outsiders' accents, but not their own.

"The pattern of neural activity differed strikingly in response to their own specific accent compared with other English accents," Bestelmeyer said. "The initial results suggest that such vocal samples somehow reflect group membership or social identity, so that 'in-group' voices are processed differently from the 'out-group.'"

Research was supported by the U.K. Economic and Social Research Council and the U.K. Medical Research Council.

Scientific Presentation: Sunday, Nov. 14, 8–9 a.m., Halls B–H

169.13, Neural correlates of non-native accent perception

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TECHNICAL ABSTRACT: Recent behavioral data from our laboratory show that speakers of Scottish English are better and faster at recognizing their native accent compared to Southern British or American English. Using an adaptation paradigm (continuous carry-over design; Aguirre, 2007) we were interested in the neural correlates involved in the processing of native and non-native accents. Twenty healthy, Scottish participants took part in this fMRI study. We employed a continuous carry over design with type-1-index-1 sequence of serially balanced stimuli. Participants listened to recordings of nine female speakers (three American, three southern English and three Scottish) each uttering three different four-digit codes. The codes were selected so as to provide clear cues to the speaker's accent. Participants engaged in an orthogonal task while they were being scanned in a Tim Trio Siemens (3T) scanner. Analyses were conducted using SPM8. We estimated three separate models to investigate the effects of adaptation versus no-adaptation to each accent. In addition to the adaptation paradigm we measured the location of the temporal voice areas (TVAs) in all participants. Comparing adaptation to no-adaptation trials we observed adaptation to Southern English and American accent in the posterior parts of the superior temporal gyri ($p < .0001$, uncorr). These areas overlapped with bilateral TVAs. In contrast, in our sample of Scottish native speakers we found no evidence of adaptation to the Scottish accent. Results show that the processing of non-native accents involves bilateral temporal voice areas. Our results are consistent with the notion of a central, experience-dependent vocal prototype possibly based on an average of voices heard in the participant's individual history. At the same time, they suggest that such prototypes somehow reflect group membership or social identity, such that in-group voices are processed differently from the out-group.

Abstract 790.9 Summary

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Women Who Stutter Have Different Brain Connections than Men Who Stutter

Findings may help explain why more men than women stutter

According to new research, women who stutter show brain patterns that are distinct from men who stutter. Finding diagnostic brain markers that are unique to people who stutter could help scientists develop treatments that target those areas in the future. The research was 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.

About five percent of young children stutter, but up to 80 percent of them recover. Of those who don't, most are men; about five times more men than women stutter. These new findings show one difference in brain connections that may explain the striking sex difference in chronic stuttering.

"Girls who continue to stutter past childhood may have greater deficits that are not overcome during development," said lead author Soo-Eun Chang, PhD, of Michigan State University. "Knowing the sex-based differences in brain development that underlie stuttering may help us find sex-specific neural markers for it."

Chang and her colleagues mapped participants' brains using two imaging tools: functional magnetic resonance imaging (fMRI), which showed brain areas active during speech, and diffusion tensor imaging, which provided structural information on connections between brain regions. They tested 18 volunteers who stutter and 14 who don't. The images showed that speakers who stutter had fewer connections between the motor planning and execution areas in the left hemisphere of their brains, as well as increased connections between hemispheres. In addition, the women who stutter had distinctly greater connectivity between the motor and sensory regions in both hemispheres than men who stutter. These findings may indicate that the link between motor control and sensory functions may be abnormal in women who stutter.

"These results need to be replicated in young children to examine whether this is the case at stuttering onset or whether it later appears only in adult females who continue to stutter," Chang said.

Research was supported by the Intramural Research Programs in the National Institute of Neurological Disorders and Stroke and the National Institute on Deafness and other Communication Disorders.

Scientific Presentation: Wednesday, Nov. 17, 8–9 a.m., Halls B–H

790.9, Sex differences in brain connectivity underlying chronic stuttering

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TECHNICAL ABSTRACT: Sexually dimorphic brain development may lead to differential vulnerability between the sexes for sustaining neurodevelopmental disorders such as persistent developmental stuttering. Developmental stuttering occurs with near equal sex distribution at symptom onset but becomes much more prevalent in males than females during later childhood. Most young girls who stutter recover naturally, leaving many more boys with persistent stuttering in adolescence and adulthood. In this study we examined sex-specific differences in structural and functional connectivity within the left perisylvian regions using DTI tractography/FA analyses and functional connectivity (Psychophysiological interaction; PPI), respectively. Based on previous findings we hypothesized that there would be attenuated connectivity between the left ventral premotor-motor regions along the left superior longitudinal fasciculus (SLF) in stuttering individuals. We expected that females with chronic stuttering would have an exaggerated pattern of this deficit, as most females who stutter recover from stuttering during childhood. 18 stuttering (10M) and 14 (7M) healthy adults participated in this study. DTI tractography and PPI analyses were conducted using subject-specific "seeds" in the left inferior frontal gyrus (LBA44) derived from peak voxels in an fMRI study involving overt speech production. The DTI tractography, FA, and PPI data all supported attenuated connectivity between LBA44 and the left precentral gyrus in stuttering compared to the control group regardless of sex. Stuttering females additionally had FA decreases (indicating less white matter integrity) in the right SLF homologue area and greater decreases in FA in the left frontal area of SLF compared to their male counterparts. The male stutterers had more right-sided FA increases in the precentral region of the SLF. Female stutterers had more FA increases in the SLF in the temporoparietal regions. Functional connectivity was also increased between the left IFG and the

temporoparietal area in stuttering females for speech production. Both males and females exhibited increased FA in the body and splenium of the corpus callosum compared to gender-matched controls. These findings suggest that left-sided connectivity decreases and increased bilateral involvement of the two hemispheres are common for both male and female stutterers and that female stutterers may additionally have over-connectivity between the frontal motor and temporoparietal regions. This may indicate greater reliance on sensory feedback for speech motor execution that may be detrimental to achieving efficient speech processing.

Abstract 275.17 Summary

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Study Helps Explain Why You Can Listen at Cocktail Parties

Research shows songbirds' individual brain cells are tuned to particular sounds

Nerve cells in the brains of songbirds are sensitive to specific sounds, and only respond when those sounds occur during communication, a recent study shows. The finding helps explain people's ability to listen to a conversation while in a noisy environment — the "cocktail party effect." The research was 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.

"While the cocktail party effect has been well-documented, it is not clear exactly how our brains are able to separate different voices so well," said senior author Frederic Theunissen, PhD, of University of California, Berkeley. "In fact, background noise is a constant challenge for engineers who design hearing aids and voice-recognition systems. Knowledge about how our ears and brains solve this task could lead to substantial improvements in hearing aid performance."

To explore how people filter out different sounds, the researchers focused on the hearing processes of songbirds. The ways that humans learn to speak and birds learn to sing is strikingly similar, and there are also similarities in their brains' auditory structures.

The authors played sound recordings for zebra finches and noted the responses of individual auditory nerve cells. The neurons were exposed to bird songs, non-communicative noises, and combination of the two. Results showed that certain cells responded almost identically to a song note played in quiet and to the same note played over the noise. The study helps identify how these neurons extracted sounds in a challenging environment. "Our group has demonstrated that individual nerve cells can be very good at picking vocalization out of background noise," Theunissen said.

Research was supported by the National Institute on Deafness and Other Communication Disorders.

Scientific Presentation: Sunday, Nov. 14, 1–2 p.m., Halls B–H

275.17, Hearing the song in noise: Masking noise-invariance in single neurons

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TECHNICAL ABSTRACT: The neural basis of auditory scene analysis remains for the most part unknown. From an engineering standpoint, even the simplest task in sound source segregation, detecting a behaviorally relevant signal from background noise, requires sophisticated algorithms that are often customized to a very specific situation. As auditory neuroscientists, the solution that is used by the auditory system is therefore of particular interest, not only to understand the computations performed by the brain but also for potentially offering technical solutions to this complex problem. In our research, we examined how neurons in the primary and secondary auditory forebrain regions of songbirds process song, a behaviorally relevant sound, embedded in masking noise. The masking noise was white noise that was low-pass filtered to temporal modulations below 50 Hz and spectral modulations below 2 cyc/kHz. The signal to noise ratio was 3dB. This modulation-limited noise was used because it is a model for environmental noise and, in general, it is a very efficient stimulus for driving cortical auditory neurons. We recorded the single unit activity of auditory neurons to playbacks of song alone, noise alone and song plus noise in anesthetized zebra finches. One of our striking results is the discovery of neurons that exhibit noise invariant responses: the neural responses to song and song plus noise were very similar as quantified by the correlation coefficient of the two PSTHs obtained for each stimuli. The goal of this study was thus to examine in detail the stimulus-response function of these noise invariant neurons in order to better understand the underlying computations. We first computed the linear spectro-temporal receptive field (STRF) from uncorrupted instances of song, and showed that these STRFs could predict to a certain degree the response to the song plus noise stimulus and therefore the observed invariance. By examining the structure of the STRFs we showed that neurons that are particularly sensitive to higher spectral modulation frequencies and lower temporal modulations were the most noise insensitive. In addition, our functional analysis revealed that the non-linear component of the functional responses played an additional role in enhancing the behaviorally relevant sound over the background noise. Thus both linear and non-linear computations are at play in segregation signal from noise in the auditory system. The relevant linear filtering can be understood by analyzing sounds and filters in the modulation domain and our analysis also begins to provide insights on the nature of the non-linear computations.