The power of speech

Dr Yana Yunusova has dedicated her research to understanding the effects neurologic disease can have on speech communication. Here, she discusses her personal motivation for working in this area and the gratification she receives from working closely with patients

What initially sparked your interest in the effects of neurologic disease on speech production?

Early in my life I hardly realised how important our ability to speak and communicate is, or how easily it can be diminished or destroyed by a disease or an accident. I took my ability to speak for granted. When I moved to North America as a young adult, I quickly became aware of how hard it is to have a normal life without being able to communicate easily – I didn't speak a word of English then. This limitation pushed me to work hard, learn the language and ultimately get a graduate clinical degree in speech-language pathology.

During my studies, I realised how complex speech production is – it involves the contraction of up to 100 muscles involved with breathing, the larynx, face and mouth at the same time, and at very fast rates. I became fascinated by the role of the brain and the nervous system in performing such a complex behaviour, and by the effect of brain diseases on speech production.

What led you to the world of research?

Working as a clinician, I noticed the limitations of our knowledge and the need to advance clinical practice in speech-language pathology with new assessment methods and treatment techniques. The decision to obtain a PhD was an opportune one; I received my clinical training and practiced at the University of Wisconsin-Madison, the powerhouse of speech science research at the time. Professors Gary Weismer, Raymond Kent and John Westbury have been and remain influential figures in the field, and they were inspirational during my studies.

Do you work closely with the patients under investigation over the course of your experiments?

The research we are conducting is longitudinal in nature, so over time there is ample opportunity to establish relationships with patients and their family members. Working with patients is both immediately gratifying in its own right, and also provides a learning opportunity. In addition, it allows us to collect observations that over time become testable hypotheses.

One can always learn from examples of human resilience, kindness and care for others, even when faced with a terrible disease.

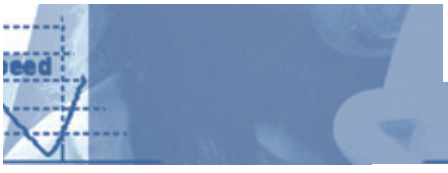
How well understood are the areas of the brain involved in the control of speech? Could you provide a brief history of this topic?

A lot of what we know about how the brain controls speech came from patients and lesion studies. For example, in the 1860s Paul Broca, a French surgeon and anthropologist, documented two cases of patients whose ability to speak but not to understand speech deteriorated over time. Their autopsies revealed lesions in the inferior frontal lobe on the left side. This part of the brain is now known as Broca's area, and it is responsible – alongside other areas – for speaking abilities.

In the late 1960s, a group of clinician-researchers at the Mayo Clinic in Rochester, Minnesota, developed a framework linking the perceptual attributes of disordered speech to various lesion sites in the brain (eg. cortex, basal ganglis, cerebellum), empowering speech-language pathologists to participate in a diagnostic process alongside neurologists. Recently, since the explosion in brain imaging methodologies, there have been significant advances in understanding how the units of speech are organised into speech sound strings and which regions of the brain are responsible for speech production. However, detailed studies of brain activation for speech in patient populations are still confined to the future.

Can you describe some of the technologies you utilise to achieve in-depth analyses of motor speech disorders?

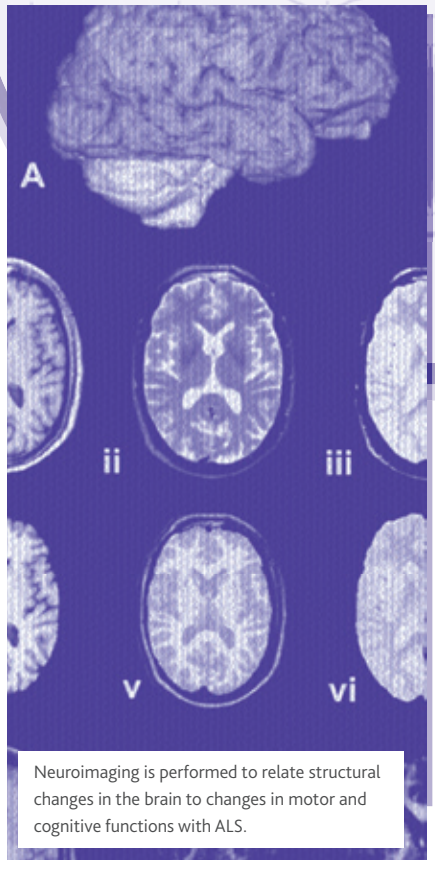
Since graduate school, I have been focusing primarily on motion tracking methodologies to study motor speech disorders. In the short time since I entered the field, the technology has changed from a massive X-ray microbeam – housed in two rooms at a research centre in Madison, Wisconsin, and operated by two engineers – to a laptop-operated electromagnetic field generator of an articulograph. Large or small, these devices are crucial because they can be used to track the tongue, which is hidden from view in the mouth. The tongue function is significantly affected in many neurologic diseases, particularly in amyotrophic lateral sclerosis. An articulograph is the basis for novel assessment procedures and most importantly for the development of a new treatments for individuals with speech disorders. When the device is interfaced with a gaming module, a sensor attached to the tongue with dental glue can become a 'joystick' to play a game with the goal of recovering tongue function.



Overcoming speaking **barriers**

Ongoing research at the **University of Toronto** is beginning to dissect the pathological mechanisms underlying speech deterioration in bulbar amyotrophic lateral sclerosis

The loss or deterioration of one's capacity for speech is devastating – it not only interferes with daily life and work, but can also be deeply frustrating and isolating for the person affected



Neuroimaging is performed to relate structural changes in the brain to changes in motor and cognitive functions with ALS.

A 3D electromagnetic articulagraph (Wave Speech System, NDI, Canada) is used to measure the range of tongue and jaw movements in speech.

SPEECH AFFORDS HUMANS with an almost limitless capacity for communication, self-expression and creativity – a feat that is often taken for granted. The importance of speech within society is reflected in the intense debate that surrounds its uniqueness to humanity; vocal communication is common to many species, but it lacks the complexity of human speech. The loss or deterioration of one's capacity for speech is therefore devastating – it not only interferes with daily life and work, but can also be deeply frustrating and isolating for the person affected.

It has been clear since studies of brain lesions in the 19th Century that using and understanding speech is a function of specific areas of the brain. What is more, this function can be compromised due to a variety of pathologies that affect particular brain networks. These can be the result of focal lesions, as might arise after traumatic head injury, stroke or brain surgery, but can also result from complex neurodegenerative diseases, infection or global ischaemia.

Driven by a fascination for speech, Dr Yana Yunusova from the Department of Speech-Language Pathology at the University of Toronto is studying the effects of disease on this crucial human trait. She hopes to better understand speech production in the context of amyotrophic lateral sclerosis (ALS), a neurodegenerative condition that causes muscle spasticity and wasting, and ultimately results in the loss of motor functions. Moreover, for some patients, ALS also results in changes to cognitive functions. Yunusova's group focuses on bulbar ALS, a subtype that is characterised by degeneration in the brainstem, resulting in speech and swallowing deterioration. Generally the prognosis for those with the bulbar form of ALS is poor, and this is partly due to the timing of diagnosis, which normally only occurs after speech deterioration has become obvious to the untrained ear: "These diagnostic delays often prevent patients from accessing life-prolonging clinical services," Yunusova reveals.

DETECTION AND DIAGNOSIS

Yunusova's research follows three main goals: to improve the diagnostic assessment of bulbar ALS; better understand the underlying neuroanatomical mechanisms of bulbar motor and cognitive functions; and improve the quality of life and prognostic outlook for patients with neurodegenerative diseases through provision of better treatments.

The first arm of this research includes testing a full-scale research protocol and identifying, from hundreds of possible speech-related parameters, the most relevant indicators of ALS progression and bulbar degeneration. These initial parameters have been chosen because of their promise as quantifiable and objective measures of disease progression. The final set will include only those that can be used to detect ALS in its earliest stages.

The project Yunusova's group has outlined primarily focuses on four different subsystems of speech control, each of which is affected differently in ALS. The respiratory subsystem includes the role of breathing in speech, and is measured by recording oral pressure and airflow, as well as by analysing pauses. Phonatory subsystem assessment considers the larynx and is measured using high-quality voice recordings, while analysis of acoustic signals in the nasal and oral cavities is used as a measure of resonance in speech. Finally they also consider the articulatory subsystem of speech, which includes the movements of the lips, jaw and tongue. These are all assessed using cutting-edge technology that tracks subtle motion at high temporal and spatial resolution, and relates this movement information to high-quality acoustic recordings taken during speaking.

By quantifying the performance of each of these subsystems independently, it should become possible to detect smaller changes in overall

speech performance that are linked to early ALS progression, thereby improving the timing and quality of ALS diagnosis. The group also considers the predictive power of these parameters, to see if they can be used to indicate the rate of disease progression and help stratify patients into subgroups for clinical trials.

Their longitudinal study, conducted in collaboration with Dr Jordan Green at the MGH Institute for Health Professions in Boston and funded by the US National Institutes of Health (NIH), has so far allowed them to build profiles of bulbar impairment in 100 individuals with ALS. Since the disease is rare, reaching large cohort sizes often requires multicentre collaboration. As a result, this aspect of the research has been carried out in close partnership between ALS clinics at the Sunnybrook Health Science Centre in Toronto (Director – Dr Lorne Zinman) and MGH (collaborator – Dr James Berry): "Between our two sites, we can recruit more patients, collect more data, conduct more analyses and educate more students," Yunusova enthuses.

DESCRIPTION AND DEVELOPMENT

The next logical step in understanding the condition is to attempt to characterise intermediate phenotypes associated with the disease. This means clarifying the neuronal correlates that underlie pathology observations in the hope that this will open up further therapeutic strategies to slow, stop or reverse disease progression. This depends on the group's first arm of research, because the heterogeneity of the disease may reflect different pathological presentations. One of the end goals of the second arm of research will be to characterise the endophenotype of ALS with bulbar presentation, in order to identify the genetic loci that are associated with the condition and elucidate the underlying mechanisms of the disease and take this further to devise novel therapeutic strategies for bulbar ALS.

As a third direction, Yunusova's research focuses on the development of a therapy technique that is popularised under the name of 'Serious Games'. This project has been carried out in collaboration with Drs Melanie Baljko and Petros Faloutsous, both of York University, who specialise in technology usability and computer graphics respectively. The work is conducted at UHN – Toronto Rehabilitation Institute and is focused on the recovery of the articulatory function through interactive and engaging visualisation of tongue movements during speech. The outcome of this work has yet to be determined, as the team is currently assessing the effect of these games on disease outcome in Parkinson's disease in a pilot study. It is hoped that such games may enable patients to slow or prevent the deterioration of speech caused by their condition.

COLLABORATION AND IMPACT

In the future these projects are set to expand, increasing sample sizes and working with larger organisations, such as the Neuroimaging Society in ALS and the Canadian ALS Research Network (CALS). These collaborations will provide further opportunities through shared databases, technical support, analysis and the expansion of datasets. The group has already extended their collaboration in many directions, working with computer scientists at the Callier Center for Communication Disorders in Texas including Dr Jun Wang, who is currently developing automated diagnostics and augmentative speech generation methods for patients with bulbar ALS.

They are also hoping to extend their findings to a range of other diseases, since their work has implications for a variety of neurological conditions that share the common symptom of speech dysfunction – particularly brain injury, cerebral palsy and stroke. For this relatively large subpopulation, a restored or improved ability to communicate effectively has the potential to reduce the economic and personal burden of care, as well as the severity of secondary symptoms. This work will help enable these patients to live a relatively normal life after diagnosis.

Wave is interfaced with a gaming engine to create 'serious' games.

ALS ICE BUCKET CHALLENGE

Dr Yana Yunusova discusses the impact of this viral internet campaign

"Amyotrophic lateral sclerosis (ALS) has been on the minds of many people recently due to this brilliant campaign. The outcomes were extremely significant in terms of ALS awareness and for raising research funds.

I serve on the Scientific and Medical Advisory Council for ALS Canada, and for that alone there was over CAD $16 million raised in a matter of a few months, which is almost four times more than in a typical year. A lot of this money will be dedicated to translational research initiatives that aim at making ALS a treatable disease within the next 10 years or so."

For more information, go to:
www.als.ca

INTELLIGENCE

SPEECH-LANGUAGE PATHOLOGY AND AMYOTROPHIC LATERAL SCLEROSIS

OBJECTIVES

- To achieve earlier diagnosis and effective subtyping of the bulbar form of amyotrophic lateral sclerosis (ALS) based on speech analysis
- To study the links between motor control and cognitive deterioration in ALS using neuroimaging
- To develop new treatment methods using a visual feedback paradigm for treating motor speech disorders

KEY COLLABORATORS

Jordan Green, PhD, MGH Institutes of Health Professions, Boston, USA; **Lorne Zinman, MD**, **Sandra Black, MD**, Sunnybrook Health Sciences Centre, Toronto, Canada; **Melanie Baljko, PhD**, **Petros Faloutsos, PhD**, Toronto Rehabilitation Institute, Canada; **Jun Wang, PhD**, Callier Center for Communication Disorders, University of Texas at Dallas, USA

FUNDING

National Institutes of Health – National Institute on Deafness and Other Communication Disorders (NIH-NIDCD) • Natural Sciences and Engineering Research Council (NSERC) • Canadian Institutes of Health Research (CIHR) • ALS Society of Canada • Parkinson's Society of Canada • Canada Foundation for Innovation • University of Toronto • American Speech-Language-Hearing Association

CONTACT

Dr Yana Yunusova
Associate Professor

Department of Speech-Language Pathology
University of Toronto
160-500 University Ave
Toronto, Ontario
M5G 1V7
Canada

T +1 416 978 6890
E yana.yunusova@utoronto.ca

http://bit.ly/Yana_Yunusova

YANA YUNUSOVA is an associate professor at the University of Toronto, associate scientist at the Sunnybrook Research Institute, and adjunct scientist and Communication Team leader at UHN – Toronto Rehabilitation Institute.