Modularity metric summarizes network fragmentation to explain aphasia recovery differences

August 3 2017

Dr. Leonardo Bonilha (M.D., Ph.D)Associate Professor at MUSC andDirector, Language and Aphasia ClinicDepartment of Neurology andBarbara Marebwa - a Ph.D. candidate in MUSC College of Graduate Studies. Credit: Sarah Pack/MUSC

While it is common for people who have had a stroke to experience language disturbances (aphasia), approximately 60 to 70 percent of survivors recover their ability to produce language within six months. The other 30 to 40 percent of stroke patients, however, suffer permanent aphasia.

Differences between patients in the degree to which language is eventually recovered are not well understood. Currently, the only prognostic estimate that clinicians can provide is an educated guess based largely on the size and location of the stroke lesion, which can be frustratingly inaccurate. Some researchers think variations in aphasia recovery may be caused by an undetected fragmentation or disorganization of brain networks that disrupts the transfer of information in areas that may be far from the lesion itself.

To investigate this theory, MUSC researchers, under the guidance of Leonardo Bonilha, M.D., Ph.D., associate professor of neurology, worked in close collaboration with a team led by Julius Fridriksson, Ph.D., professor of Communication Sciences and Disorders at the University of South Carolina's Arnold School of Public Health, to map entire brain networks and assess post-event connectivity in 90 people who had suffered a left hemisphere stroke.

Barbara Marebwa, a Ph.D. candidate in MUSC's Department of Neurology, and lead author, explains, "Not a lot is known about the underlying mechanisms behind differences in language recovery. We think disruption of the network structure might be responsible. So, we wanted to look at how the entire brain was connected after the stroke. Instead of focusing on the damaged region, we looked at areas they still had to work with, and mapped those networks to see associations with their aphasia severity."

Study participants underwent language testing to establish a global aphasia severity score, followed by magnetic resonance image (MRI) scanning. By dividing the brain into 189 regions and mapping each participant's stroke lesion, the investigators could identify and focus on white- and grey-matter areas outside of the directly affected region. A connectivity map (or connectome) was created for each patient reflecting existing neural networks within and between these brain areas.

The team then partitioned these connectivity maps into modules and calculated a 'modularity metric' for each participant. "This metric helps you see how well different brain regions are connected both within themselves and to other areas. The different brain areas are like people at a party - they sit and talk together in cliques based on some connection or shared similarity. Modularity shows us how tight those cliques are. Areas that are tightly connected within themselves but not to others have high modularity," says Marebwa.

Bonilha adds, "The way the brain is connected is not random or haphazard - there's a balance between how much regions need to be integrated or connected and how much they need to be separated. Modularity reflects that community structure. Isolated areas no longer work with the rest of the team. So, modularity is one number that tells you how well various brain areas are able to communicate or share information."

Language is a highly complex function. To produce speech, distant brain areas must be able to accurately share information and translate it into sounds. The study, funded by the National Institute of Deafness and other Communication Disorders and the American Heart Association, assessed the overall brain network and summarized overall brain health based on connectivity, which provided important information about why and to what degree language abilities can recover.

Modularity was significantly correlated with patients' aphasia scores, so that the higher the left hemisphere modularity, the more severe the aphasia (r= -0.42; p