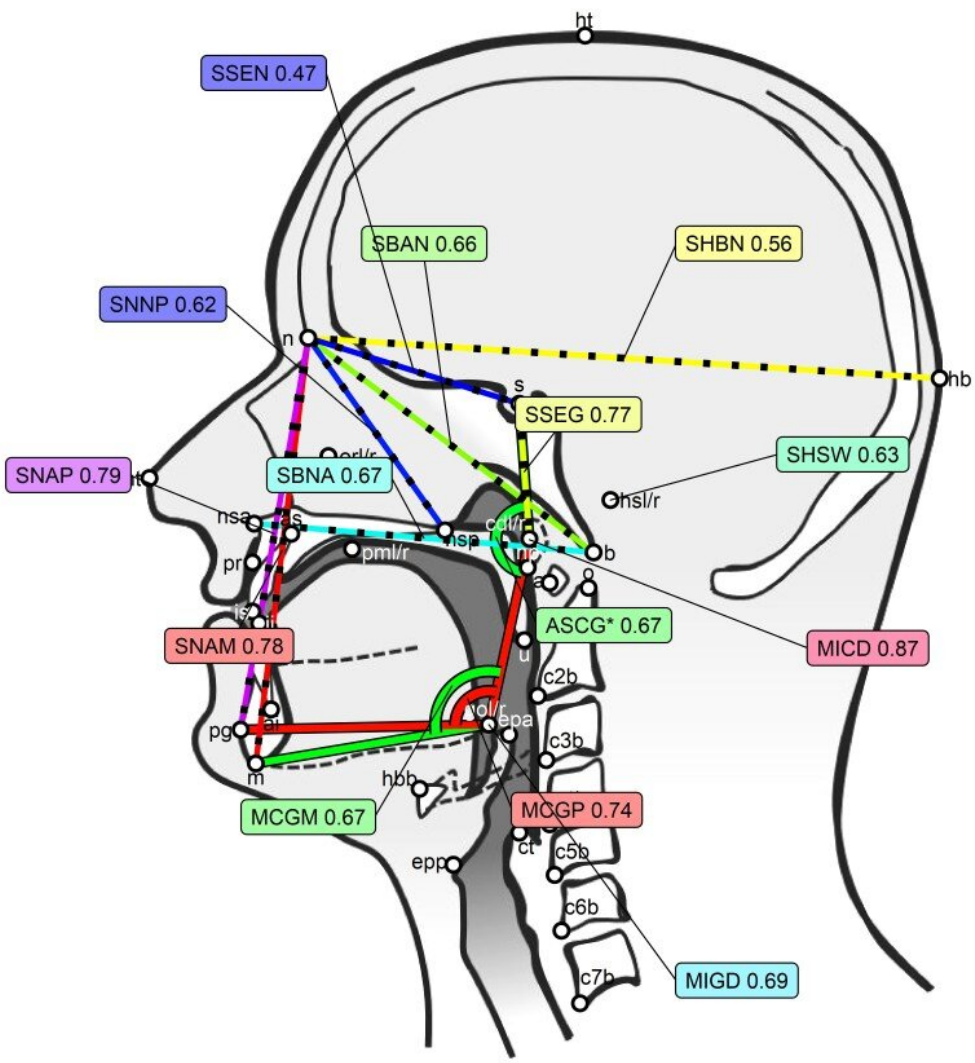
New insights on the genetic underpinnings of the vocal tract

October 10 2022



The researchers obtained a set of measurements, such as distances, angles, curvatures, proportions, etc., to capture the dimensions and shape of vocal tract structures and their inter-relationships. Credit: University of Barcelona

Despite its importance for speaking, breathing, and eating, we know relatively little about the genetic underpinnings of the human vocal tract, a system made up of cavities and organs such as the tongue, the larynx, and the lips. A new consortium of geneticists, neuroscientists and linguists, initiated by Dan Dediu, ICREA professor at the Faculty of Philology and Communication and member of the Institute of Complex Systems (UBICS) of the UB, and Dorret Boomsma, member of the Netherlands Twin Register (NTR) at the Vrije Universiteit Amsterdam, has estimated the heritability of many elements of the vocal tract based on 3D structural magnetic resonance imaging (MRI) in 632 monozygotic and dizygotic twins.

The results, published in the journal *Human Genetics*, provide new evidence on how genetic and environmental factors work together in shaping anatomical differences among people. The participants were volunteer twins not selected for health or disease.

The conclusions of the study open new perspectives for understanding the complexity of genetics, environment, and culture, which together shape our vocal tract and may help explain the phonetic and phonological differences between languages. "It is hard to find human characteristics that have not been the focus of a twin study, but remarkably this is the first large project to estimate the heritability of the human vocal tract in twins," says Dorret Boomsma, professor at the Vrije Universiteit Amsterdam.

"The next step is to relate these anatomical findings to the effects on the voice idiosyncrasy and language articulation. These results indicate that genetic and environmental factors, including the cultural ones, interact to shape the vocal tract, highlighting that each structure, even parts of a structure, has its own constellation of interactions," says Dan Dediu, who began this study at the Max Planck Institute for Psycholinguistics in Nijmegen, (the Netherlands), together with researchers from Vrije Universiteit Amsterdam, (the Netherlands); Nanyang Technological University (Singapore) and the University of Konstanz (Germany).

Benefits of twin cohorts

The study was feasible because of the data collected in five twin studies by the Netherlands Twin Register. The MRI assessment in twins makes it possible to estimate the contributions of genes and environment to the variation in the anatomy of the vocal tract. As stated by Emily Jennings, who worked in this project as part of her master's degree thesis at the Vrije Universiteit University, "the unique experiment of nature with monozygotic twins who are almost genetically identical and dizygotic twins who on average share 50% of the genome, enables the estimation of the relative importance of the genetic and environmental factors, in explaining differences between people in vocal tract anatomy."

Detailed analysis of the non-externally visible aspects of the vocal tract

To measure aspects of the vocal tract which are not visible externally, the researchers analyzed 3D structural magnetic resonance imaging (MRI), which capture the anatomical features of both soft and rigid structures of the vocal tract.

One innovative aspect of the methodology of this study is that the analysis of these images was performed by two independent researchers, who first trained in a rigorously defined protocol based on the anthropological and phonetic literature. Following this protocol, they marked, during six months of intensive work, the 3D images to identify clearly defined anatomical structures and to describe curves and surfaces. From these marks, they obtained a set of measurements, such as distances, angles, curvatures, proportions, etc., to capture the dimensions and shape of vocal tract structures and their inter-relationships.

Then, these data were analyzed by genetic structural equation models, allowing the estimation of the contribution of genes to these structures, controlling for potential confounding factors in the data such as the sex, the age or the intercranial volume of the participants, and capitalizing on the information provided by the two researchers who scored all data.

New and unexpected findings

The results provide new evidence on the relative contributions of genetic and environmental factors, sometimes initially surprising for the researchers. Among these were "the position of the larynx, which seems to be under a strong genetic influence, while several bony components, such as the dental arches and hard palate, have low heritability," notes Scott Moisik, from the Nanyang Technological University. Earlier studies indicated that they seem to change shape in response to the effects of dental treatments, type of diet and even thumb sucking when you are a toddler.

However, "other bony structures such as the nasal cavity and jaw appear to be quite resistant to such environmental influences," adds Moisik. These results show that genetics matter but not in a uniform way, "to various degrees and at various places of the vocal tract, and it means that it is worth looking for the actual genes involved. But also that genetics is not a 'jealous master' that controls everything, which means that we can start looking for the mechanisms through which biology, environment and culture interact."

This influence of culture has also been highlighted in previous studies, which, for example, showed that "the kind of food that agriculturalists and hunter-gatherers tend to eat affects their teeth, which, in turn, influences whether or not their languages use sounds such as 'f' and 'v,' which are more commonly used by agriculturalists," notes Dan Dediu.

Data and methodology open to other research groups

The methodology and software developed during the study are freely available to any interested researcher, so that "any group can apply exactly the same methodology to their samples, allowing for the replication and extension of our study," says Dediu.

"Moreover, this protocol, which was developed to quantitatively measure the vocal tract could help in the identification, diagnosis and follow-up of pathologies affecting the vocal tract in the future."

Gene search

The researchers' next aim is to start looking for genes related to vocal tract structures. To do this, the next step is to combine these data with genotype data. This will require expanding the number of samples, to identify some of the genes involved, through genome-wide association studies or polygenic scores. These genes may be studied with other methods (cell lines, animal models, organoids, etc.) to better understand the mechanisms involved in the development of vocal anatomy.

"In addition, these findings could be used to compare data from our species with, for example, the Neanderthals and the Denisovans, and see if we can also infer something about the development of their speech," concludes Dediu.

More information: Dan Dediu et al, The heritability of vocal tract structures estimated from structural MRI in a large cohort of Dutch twins, *Human Genetics* (2022). DOI: 10.1007/s00439-022-02469-2

Provided by University of Barcelona