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Electropalatography in the Analysis of Tongue Dynamics during Normal and Disordered Speech

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Speaking of tongues

It's no coincidence that languages are also known as tongues, because the way that we control our tongues determines the sound of our speech. Researchers at Queen Margaret University near Edinburgh, led by Professor William Hardcastle, have developed an innovative electronic instrument to 'map' the patterns of contact between the tongue and palate during speech. This not only helps to diagnose problems but also helps speech therapy…

It's not very often the audience sees what is happening inside the mouth of the speaker at one of the RSE's lectures, but Professor William Hardcastle is no ordinary speaker – his specialist subject is the science of speech, and the development of a revolutionary new device which improves diagnosis and treatment of speech disorders.

According to Hardcastle, at least 2.7 per cent of the UK population (about 1.6 million people) have a 'moderate communications problem' – a speech or a language disorder. This may involve a variety of problems including how we make sounds and the way we use language, and as well as congenital problems (Down's Syndrome, cleft palate, etc.), they can also result from a stroke (e.g. aphasia and apraxia). Hardcastle also explained that speech impairment can have a negative impact on anyone's life, causing psychological and social difficulties, as well as bad effects on education and employment.

Hardcastle's research focuses on speech output or articulation – the quest to understand the inner mechanics of speech, or how we make sounds with our tongues and the roofs of our mouths. He described the different methods used to analyse problems with speech, demonstrating how every method has minus and plus points. For example, he explained, transcription of sounds can be highly subjective and unreliable, and "encourages categorised judgements." Most importantly, it does not produce precise information on the speech organs themselves.

Speech is very complex, Hardcastle explained, involving the coordination of a number of cylinders, pistons and valves – i.e. the lungs, larynx, glottis and velum, as well as the lips and tongue. The tongue (particularly the tip) is the key to the process, but we know very little about it, said Hardcastle. The challenge is how to record and analyse what is going on inside the mouth during speech, capturing the partly hidden, very rapid movements of the tongue, an organ with a unique anatomy and physiology which Hardcastle compared to an elephant's trunk or an octopus tentacle.

Professor Hardcastle then showed four films of the tongue during speech, using four different methods: x-rays, MRI (Magnetic Resonance Imaging), ultrasound and EMA (Electro Magnetic Articulography). These instrument-based methods help to analyse the physical impairment of the organs more objectively, and this in turn can lead to better evidence-based therapies.

All the methods work by showing movement while the subject pronounces particular sounds, e.g. *te*, *ke* or *ss*, or a short string of words. X-rays show what's happening inside the mouth very clearly, but can also be harmful to health. MRI is better for research but is very expensive and can be claustrophobic for many subjects. Ultrasound, using a helmet and probe, can also be costly and awkward, while EMA is invasive and often unpleasant because it involves the attachment of coils to the tongue.

The breakthrough by researchers at Queen Margaret University (QMU) is a new method called electropalatography (EPG). This involves developing an artificial palate made of acrylic, with a chequerboard of 64 electrodes (and a tiny electrical current) which detect the precise place the tongue meets the roof of the mouth during speech. Every individual subject has a custom-made palate which moulds to the roof of the mouth, and Hardcastle then demonstrated the method by plugging himself in and carrying on with his lecture, displaying his “tongue patterns” in real time so the audience could monitor the different shapes of different sounds while he spoke.

Every sound has a characteristic “quasi-static” pattern of contact, he explained – e.g. the horseshoe-shaped pattern of “*te*.” EPG enables researchers to see this pattern, as if the tongue is “printing” sounds onto the palate like old-fashioned typeface on paper. When the pattern is displayed on a computer screen, it provides instant feedback not only for researchers and speech therapists but also the subjects themselves. By displaying an idealised model pattern for particular sounds alongside this real-time display, subjects can then try to reproduce the same shape in their own speech by adjusting the sound that they make so the pattern resembles the model displayed on the screen.

For detailed analysis, researchers need a permanent record, so Hardcastle and his team at QMU produce a cine film using the EPG method to capture frames at intervals of 10 milliseconds which show the gradual changes in the patterns of a sequence of sounds. The tongue moves all the time and subtly changes its configuration every few milliseconds, and the films prove that the visual representation of sound, using the EPG method, is much more accurate than listening, using our ears. Hardcastle then demonstrated this by comparing the ‘films’ of a clear, normal speaker and one with rapid, colloquial speech. While the auditory sounds seemed almost identical, the visual patterns were clearly quite different.

The EPG films can also reveal the characteristic patterns of certain conditions like aphasia, and this is what helps diagnosis and treatment. For example, in some cases, people appear to be forming the sound of a “*te*” instead of a “*ge*,” then realise their mistake and adjust their tongue to make the correct sound – the typical signs of a certain condition which can respond to therapy.

The therapeutic benefits of EPG are currently being researched in a project which will finish at the end of this year, funded by the Medical Research Council, in conjunction with the University of Edinburgh. Thirty children with Down’s Syndrome will take part in the controlled study, with ten of them receiving no speech therapy, ten receiving conventional therapy and the other ten receiving EPG-based therapy. After the end of the project, the team has received additional funding so that the children not receiving any therapy will also get the benefits of EPG.

According to Hardcastle, many subjects – especially children – respond very well to the biofeedback they get from the graphics they see on the screen as they speak. The initial results from the study are promising, and Hardcastle hopes this will lead to the creation of a network of centres where EPG will be made much more widely available, not just in Scotland but wherever speech disorders affect peoples’ lives.

During the Q&A, Professor Hardcastle also explained that most children respond very well to the EPG palate being placed in their mouths, and very few resist it. Most of them also like interacting with computers.

The Principal of QMU, Professor Anthony Cohen, said after the lecture that Professor Hardcastle and his team of researchers deserve congratulation for the “elegance of the new method” and its practical efficacy. EPG not only provides us with a profound understanding of speech disorders but “a simple diagnostic device whose genius is its simplicity and ease of use,” he continued, adding that the new invention was a “life-enhancing” device which would change people’s lives and help them to participate more widely in society.

Many mysteries remain in our understanding of speech disorders, said Professor Hardcastle. For example, many people who stammer can speak a foreign language very fluently, or sing well. But if EPG continues to advance our understanding, many of those mysteries may soon be solved, and many people lead more ‘normal’ lives.

Peter Barr