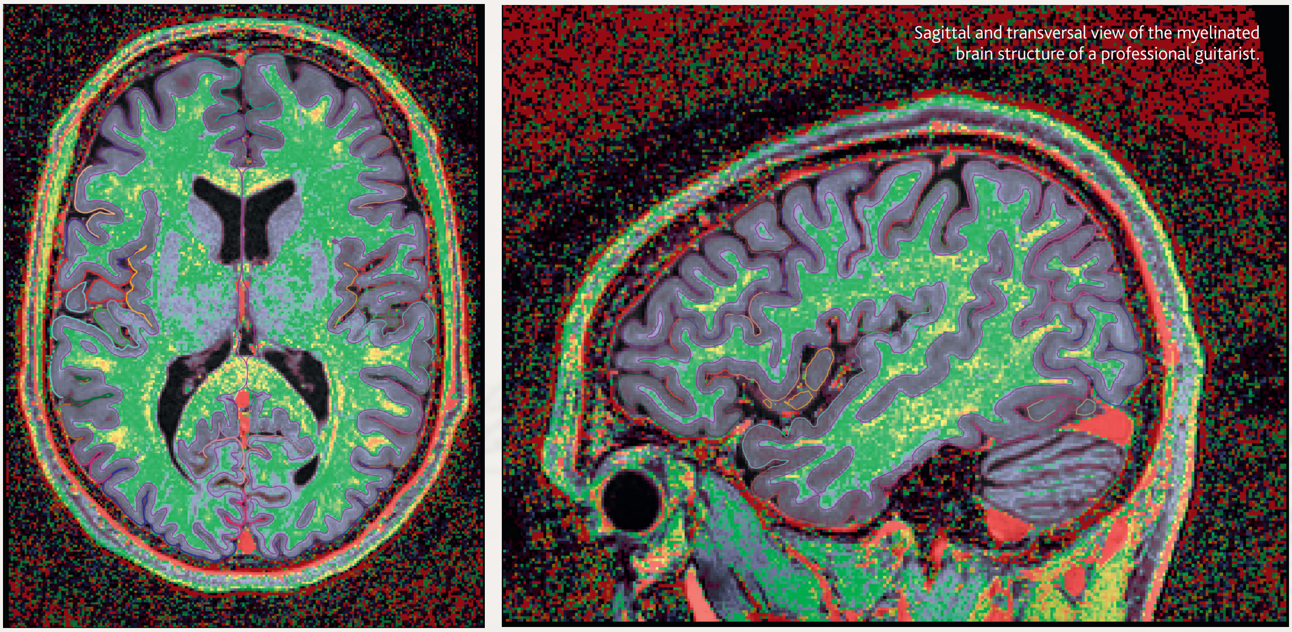
It takes many hours of dedicated daily practice to learn to play a musical instrument, yet certain pre-dispositions may also play an important role in musical ability, including the way we perceive sound. We spoke to **Dr Peter Schneider** about his research into the relationship between auditory skills and auditory dysfunctions.



Sagittal and transversal view of the myelinated brain structure of a professional guitarist.

Sound perception between outstanding musical abilities and auditory dysfunction

Many hours of daily practice and intrinsic motivation are required to learn to play a musical instrument, however musicians still rely to a certain degree on their innate aptitude or predispositions, in particular their ability to perceive sound. This is an area of deep interest to Dr Peter Schneider, Director of the Brain and Music research group at Heidelberg University Medical School in Germany. "We run several different projects looking at the relationship between auditory skills and auditory dysfunctions," he outlines. This work includes investigating physiological and neurological differences between musicians and non-musicians, using for instance magnetic resonance imaging (MRI) to look at the shape, size, asymmetry and cortical thickness of Heschl's gyrus, an important part of the auditory cortex. "Heschl's gyrus is closely involved with sound perception and its morphology also influences musical performance," explains Dr Schneider. "We've published papers describing the relationship between the overall size of Heschl's gyrus and an individual's perception and overall musicality, as well as papers describing the relationship between left and right Heschl's gyrus."

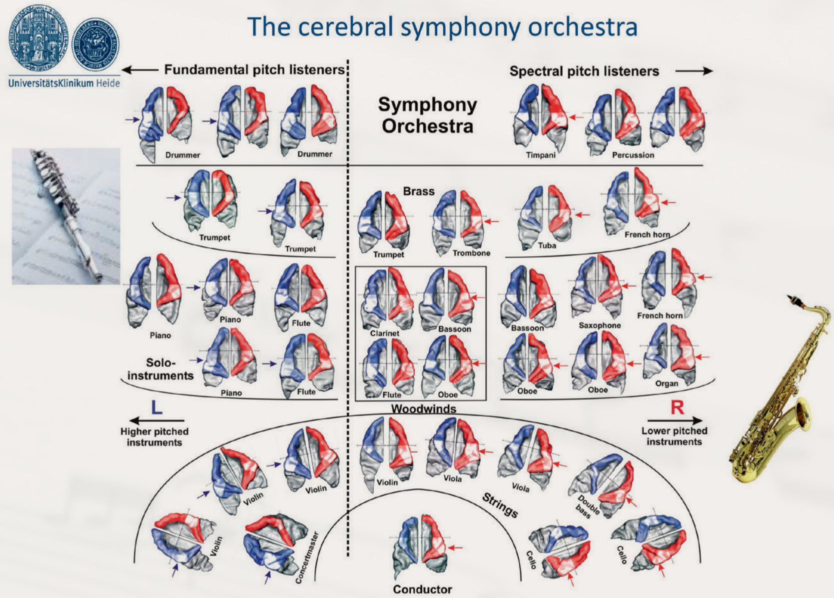
> The **shape, size, asymmetry** and **cortical thickness** of **Heschl's gyrus** is closely involved with **sound perception,** and its **morphology** also **influences musical performance.**

Pitch perception

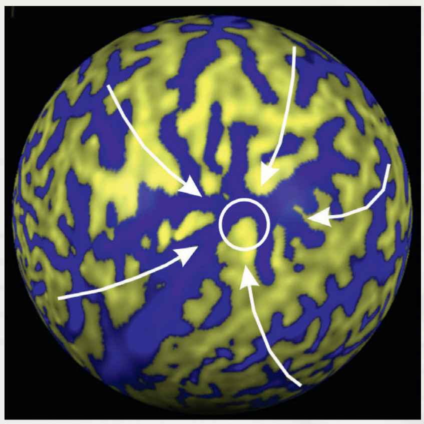
This latter point is closely correlated with an individual's pitch perception, the way in which people perceive sound. Researchers have found that people with a larger Heschl's gyrus on their right-hand side are spectral pitch listeners, while people with a larger Heschl's gyrus on their left are fundamental pitch listeners. "Spectral listeners break up sound into its different components, whereas fundamental pitch listeners perceive sound as a whole," says Dr Schneider. Previously, it was believed that the majority of people are fundamental pitch listeners, yet the findings of a paper published by Dr Schneider over a decade ago seem to run contrary. "This study showed that there are also many people who are able to break sounds down into their different components," he outlines. "Amongst musicians, we see both fundamental and spectral pitch listeners. It seems to depend to a degree on the individual listening profile, what instruments they play. For example, musicality related to rhythm perception or drum playing is very different to musicality related more to melody perception or singing."

Researchers in Dr Schneider's group studied musicians in both the Royal Liverpool Philharmonic Orchestra and the Orchestra of the Mannheimer National Theatre, with the aim of gaining a fuller picture of the neural basis of sound perception. A key part of this work centres around using different psycho-acoustic and neurological methods to get new insights into the musical brain, and the relative importance of predispositions and learning in terms of determining musical ability. "There are several different measurements. One approach we are using is designed to measure different hearing or sound perception abilities. In this case, we mainly used tests I developed on spectral and fundamental pitch perception. We see a wide variability of pitch perception," explains Dr Schneider. "In the Liverpool Philharmonic orchestra, we observed a large majority of spectral listeners, whereas in the Mannheim Orchestra, we observed mainly fundamental listeners."

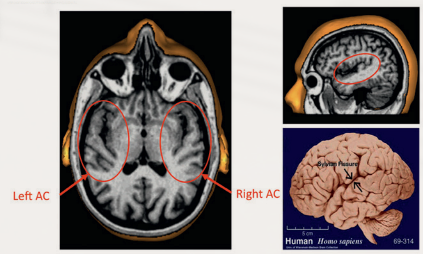
There are many different possible reasons why individuals have different pitch perception modes, and they may not necessarily be related to their musical aptitude. Alongside looking at data on professional musicians, Dr Schneider and his group are also investigating amateur musicians and non-musicians, partly based on asking people about their own musical experience. "We have a long questionnaire, with questions about an individual's musical background, what they were taught and about the musicality of their parents. There are also questions about the different musical instruments they played at different times during childhood," he explains. Childhood is a critical period in personal development, and musical training at a young age helps children to develop their skills, leading to a lifetime's enjoyment, a topic that is central to Dr Schneider's research. "We are investigating whether musical ability is genetically determined, or if it can be taught," he says.



Musicians that play higher or lower pitched music instruments are seated apart.



Projection of the brain structure of a pianist on a sphere (gyri in yellow, sulci in blue), demonstrating that the primary auditory cortex (marked with a circle) has a superior, central position.

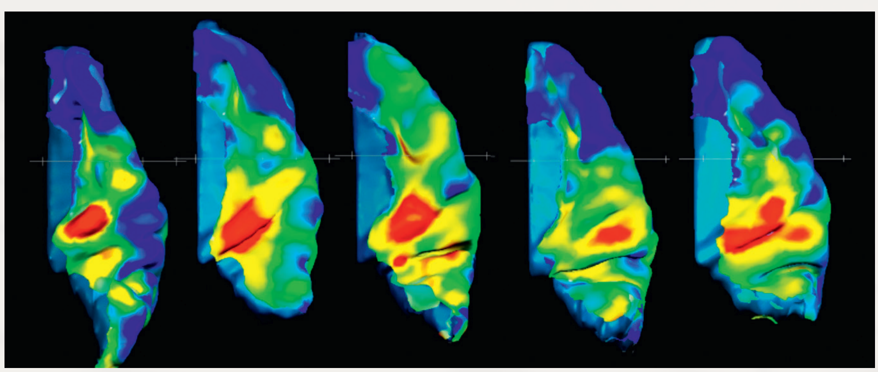


Top view on the left and right auditory cortex (left panel), embedded within the Sylvian Fissure (right panel).

Longitudinal study

The group is conducting a large longitudinal study named 'Audio- and neuroplasticity of musical learning (AMseL)', using data gathered on children and adolescents over a period of nine years to probe deeper into the roots of musical ability and look at the importance of training. In this part of the group's research, Dr Schneider and his colleagues are investigating the developmental factors visible in imaging data, and also in the psycho-acoustic data. "We have been testing our findings for these pitch perception modes. No real changes have been found, so this pitch perception seems to already be present at the beginning of musical training, at the age of around eight years old. Therefore, these pitch perception modes are preserved over time," he says. The brain is of course still developing during childhood, yet evidence suggests the size and shape of Heschl's gyrus does not change dramatically over time. "We have been collecting longitudinal data of children with four measurement timepoints from primary school age (~7-8 years old) to adolescence (16-17). In this study we found no differences in the shape or size of Heschl's gyrus during childhood," continues Dr Schneider.

This research complements the group's work with professional musicians and non-musicians, enabling Dr Schneider and his colleagues to draw wider comparisons. While the pitch perception mode is not really thought to change over time, other changes can be observed. "With electroencephalography techniques we can see changes in the activation of the auditory cortex, for example," says Dr Schneider. Researchers are also looking at plasticity and maturation effects. "We can look at how network activity evolves in an individual, looking at the developmental phases in network activation," continues Dr Schneider. "With functional MRI data, we can investigate



Five examples of individual gyration and location of primary (red) and secondary (green) auditory cortex of musically talented children.

SOUND PERCEPTION

Sound perception between outstanding musical abilities and auditory dysfunction

Project Objectives

Prof. P. Schneider has developed a unique framework to explore the neural basis of auditory processing. His combined transdisciplinary expertise as a brain researcher, physicist and musician has enabled him to develop a battery of new auditory tests to reliably measure elementary and complex hearing abilities. This new approach may succeed in explaining neural foundations of both outstanding auditory skills and auditory dysfunction, with considerable potential for pedagogic, therapeutic, diagnostic and clinical applications.

Project Funding

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Project Partners

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Prof. P. Schneider

Prof. P. Schneider has developed a unique framework to explore the neural basis of auditory processing. His combined transdisciplinary expertise as a brain researcher, physicist and musician has enabled him to develop a battery of new auditory tests to reliably measure elementary and complex hearing abilities. This new approach may succeed in explaining neural foundations of both outstanding auditory skills and auditory dysfunction, with considerable potential for pedagogic, therapeutic, diagnostic and clinical applications.

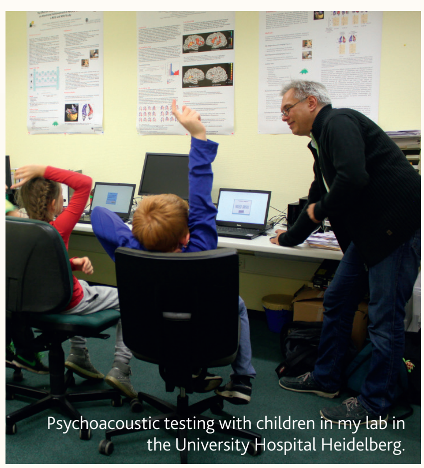
activation in the auditory cortex and explore functional connectivity and network plasticity of the musical brain. Additionally, we can look at activity in relation to other psycho-acoustic signals. We have other behavioral tests that look at the frequency sensitivity for example and more specific skills such as absolute and relative pitch, from which we can learn more about important aspects of auditory and neural plasticity."

While the primary focus within the group is on investigating the neural basis of sound perception and auditory skills, this research also touches on other areas, for example how people learn languages. Evidence suggests that individuals with an aptitude for music also tend to be good at picking up languages, another topic of interest to Dr Schneider. "Currently, we are also observing the relationship between language aptitude and music aptitude," he says. It's important to distinguish between different types of musicality in this sense. "Certain aspects of musicality are related more to language aptitude," he says. "We see relationships between language aptitude and musical aptitude for these processes that occur in the right hemisphere. Singing activates networks related to the right hemisphere, too."

Musical brain

There is not a clearly defined musical brain, nevertheless researchers can observe a general pattern of musicality in the brain, and Dr Schneider and his colleagues aim to build further on what has been achieved so far. One important outcome from the group's research will be to distinguish between pre-disposition factors and training factors in terms of determining musical ability. "We aim to have a clear idea about what factors pre-dispose an individual towards musicality, and what factors affect how they learn music," explains Dr Schneider. This could be particularly useful for musical education and the development of specific hearing therapies. "The idea is to have a more compact module of hearing tests, a battery of neuro-imaging procedures. We can then use these and other similar methods to evaluate which sorts of teaching, training and therapy are effective," continues Dr Schneider. "We work together with ear training teachers in conservatories and also with clinical audiologists to observe learning strategies and relate it to the student's or patient's hearing mode."

The age at which an individual starts learning a musical instrument is an important consideration in this respect. While some children may have a pre-disposition that means they can start playing the violin at quite a young age, for others it might be better to spend more time on general musical activities. "They can then start learning a specific instrument later on," says Dr Schneider. Further data is required in order to reach rigorous conclusions, which will remain a priority for Dr Schneider's group in future, including gathering more data on adults and older people. "Our aim is to build a more generous, larger data pool, so that we can look more closely at individual neuro-auditory profiles," he says.



Psychoacoustic testing with children in my lab in the University Hospital Heidelberg.