





Singing lessons for finches

No zebra finch emerges from the egg as an accomplished singer: each young bird first has to take singing lessons. Songbirds are therefore excellent model organisms for the study of learning processes in vertebrates. **Manfred Gahr** and his team at the **Max Planck Institute for Ornithology** in Seewiesen are conducting research into how various songbird species learn their songs and what happens in their brains during the process.

TEXT **TOBIAS HERRMANN**

It doesn't take much imagination to see where the Zebra Finch got its name.

The Max Planck Institute for Ornithology is situated on an almost 30-hectare site between Starnberg and Ammersee on the outskirts of Munich, which even has its own natural lake. 170 people work there alongside some 2800 zebra finches, 500 canaries, chickens and fish.

Manfred Gahr's office, a large room flooded with natural light, containing two desks and an open fireplace, is on the first floor of one of the buildings dotted across the site. "It used to be a living room," as Gahr explains, at a time, when Erich von Holst and the later Nobel Prize winner Konrad Lorenz moved into the former Max Planck Institute for Behavioural Physiology in 1958, it was common practice for sci-

entists to live permanently at the research site. "Unfortunately," he says, "I'm no longer allowed to light the fire, since last time, it enveloped the entire building in thick smoke."

Gahr had the choice between two research projects during his studies at the University of Kaiserslautern, one of which involved the female reproductive organs of cave-loving dwarf spiders, known among specialists as "epigynous troglobionic microphantids". The other option was to study birdsong. "Somehow," says Gahr with a laugh "the second option captured my imagination more." And so today, surrounded by beautiful nature, he is using modern technology to investigate what happens in a bird's brain when it learns to sing. >



Above Eavesdropping: the electrophysiologist Lisa Trost holds an antenna towards her birds, which carry small microphone transmitters on their backs. These pick up the vocalizations and transmit them to the antenna.

Right Trost analyzes this data on the computer and compares them with the birds' brain waves. Trost can record up to eight birds simultaneously.

In our native songbirds, it is mostly the males that sing, but there are exceptions, such as robins and starlings, where the females also sing. Warning calls, for example, are innate, but song has to be learned.

In the case of zebra finches, which originate from Australia, it is only the males that sing. They are so-called closed-ended learners with a limited learning phase. Finches have about three months in which to practice their song. Then they leave school and sing whatever they have learned up to that point for the rest of their lives. The saying “you never stop learning” is therefore not true of zebra finches.

Other species follow different strategies: the canary, for example, is what is known as an open-ended, or seasonal, learner. The young birds do their first singing exercises during their first sum-

mer of life after which they spend the whole winter working intensively on their songs, which they then sing the following spring and summer. The males then begin to add new syllables and refine their singing during the following fall. The birds therefore sing throughout most of the year, only taking a break during molt, the post-breeding plumage change phase.

PRACTICE MAKES PERFECT

However, ornithologists still disagree as to whether canaries learn their entire repertoire in the first months of life and gradually incorporate the different variants into their song, or whether they can acquire new syllables each year.

The actual learning process proceeds along very similar lines in most



Gahr, “are opportunists. In their native and arid environment, they immediately start breeding soon after rainfall, evidently in the knowledge that the rain will produce a rich buffet of seeds and grains when their young hatch.”

EACH FINCH'S SONG IS RECORDED INDIVIDUALLY

The song learning process in bird brains is similar to language acquisition in humans. The songbird’s “vocal control system” comprises several interlinked brain areas. In terms of its function, for example, the “caudomedial nidopallium” resembles the Wernicke’s area of the human brain, which is responsible for linguistic memory. Likewise, a bird’s HVC (higher vocal center), which is activated during the learning process, corresponds to the Broca’s area of the human brain. Based on these analogies, the research being conducted by the Seewiesen-based scientists is contributing to a better understanding of language learning processes in the human brain.

To study the song learning process, researchers need to know which bird is singing which syllables, when and for whom, which is why some of the zebra finches in Lisa Trost’s aviary have been fitted with a kind of backpack containing a microphone transmitter recording individual vocalizations. The signals picked up by the microphone are transmitted to a computer via antennae. This enables Trost and her colleagues from Gahr’s Department to record the songs of each bird simultaneously, while allowing the zebra finches to live in their social groups.

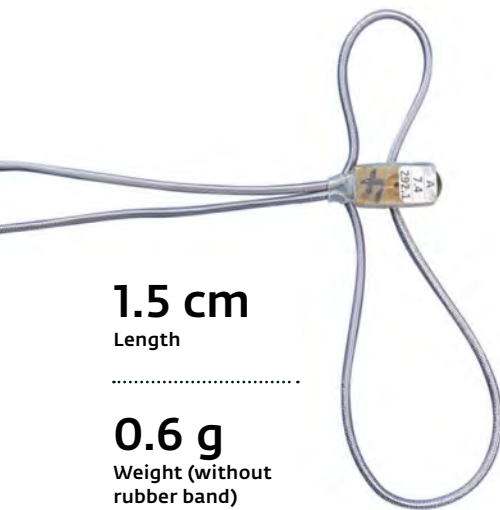
Other birds have an additional miniature transmitter on their heads. It transmits neuronal signals from

songbirds: the young birds first listen and then try to imitate what they hear. They store the sequence of vocal syllables that they have heard in their acoustic memory, which then serves as a template against which to compare their own song.

Usually, the father serves as teacher and lead singer, but there are exceptions: some young birds are known to learn their songs from their siblings, other bird species, and even from non-animal sources. Jürgen Nicolai for example, an ornithologist who arrived at the Max Planck Institute in Seewiesen in 1957, whistled the folk song “Ein Jäger aus Kurpfalz” to a group of bullfinches every day for six months. Not only did the bullfinches learn to whistle the song, they could also continue it without hesitation if the researcher interrupted it at any point.

Ornithologists in Seewiesen are studying how birds learn to sing, focusing primarily on zebra finches. As Gahr explains: “only a few genera learn their vocalizations. In addition to songbirds and humans, these include elephants, seals and whales.” Among the many songbird species that learn their songs, zebra finches are particularly well suited as a model organism, because they are comparatively easy to keep in captivity: they are pure granivores, which makes feeding them in the aviaries easier compared to insectivores. Moreover, finches are sociable and can be kept in larger groups without problems.

Another advantage is that it is easy to breed zebra finches in captivity: all that is needed is a nesting box and some nest building material. The young birds reach sexual maturity after just three months. “Zebra finches,” says



1.5 cm

Length

0.6 g

Weight (without rubber band)

A bug for the back: at the heart of the studies on song learning are the miniature transmitters weighing only 0.6 grams, which are strapped onto the zebra finches like a rucksack using rubber bands.

electrodes implanted in their brains. Vocal and neuronal signals are recorded synchronously.

The electrodes are implanted in such a way that they interface with certain areas of the vocal control system in the bird's brain. During the procedure, the birds are anesthetized and receive painkillers. The birds already interact with the rest of their group in a completely natural manner at the end of the day, as they recover extremely quickly from this procedure.

Neuroscientists usually connect this kind of electrode to a computer via a cable. To prevent the birds from getting tangled up in the wires, they would have to be isolated in cages without perches. Together with engineers, the researchers from Seewiesen have therefore developed wireless radio microphone transmitters as well as small transmitters that transmit brain waves, songs or even the heartbeat. This allows the birds to move completely freely and to communicate among themselves.

FIELD TEST IN THE SAVANNAH WITH RADIO TRANSMITTERS

In the meantime, the relevant technology has been developed to such an extent that it can also be used in the wild. Gahr and his team, for example, have been studying the singing habits of white-browed sparrow weavers in the South African Kalahari savannah, a bird species that lives in groups in which the dominant pair sings in duets with incredible precision. The precise tuning of their vocal syllables aroused the interest of the scientists. They were able to use their miniature transmitters to simultaneously record and analyze the song and the signals of nerve cells in the birds' natural habitat.

The result: when one duet partner starts singing, the nerve cell activity in the brain of the other bird, involved in the duet, changed. This causes a slow down of the song the rhythm so that the partners can take turns at singing. "The individuals' rhythmic duet singing is therefore achieved by means of an acoustic signal from the duet partner," Gahr explains. In this way, both brains synchronize to form a kind of network, acting as a single shared circuit, so to speak. The researchers assume that similar mechanisms may also be responsible for social interactions between humans, thus regulating the coordination of movement in couples dancing.

Gahr and his colleagues have also looked into what happens in the brains of young zebra finches during the learning phase when they imitate their role model. They discovered that a nerve growth factor, the so-called BDNF (brain-derived neurotrophic factor), is formed in the HVC area. Among other things, BDNF influences the formation of the contact points, the so-called synapses, between nerve cells. Therefore, the growth factor in the HVC could influence the differentiation of local circuits.

However, brain activity is not only influenced by hormone-dependent growth factors during learning phases. "The vocal system doesn't develop at all without sex hormones," Gahr explains. For a long time, researchers had been exclusively interested in the male sex hormone testosterone. This was still the prevailing dogma even when Gahr was a doctoral researcher, but he was not willing to accept it. "Testosterone can be converted to estrogen in the brain, which is classically seen as a female sex hormone. That's why I looked into what this estrogen actually does."




During the 1980s, cancer researchers began using antibodies to study the influence of estrogen on tumor formation. Using the same method, Gahr was able to prove the presence of estrogen receptors in the vocal areas of the avian brain for the first time. Both testosterone and estrogen therefore play an important role in the development of bird-song. “So finally, we found that sex hormones regulate the growth factor BDNF in the young zebra finches and facilitate the learning of songs.”

This is why the females of many species can also be encouraged to sing by giving them testosterone. Recent studies on naturally singing female canaries show that this is probably also due to increased testosterone production in the female brain.

It is still unclear why birdsongs are not innate and why the animals have to learn them. Song learning could benefit speciation formation or provide information about the origin of the

singer. Since in many species, song is involved in partner selection and territorial defense, females can select males whose songs differ from what they heard in their youth. Also the owners of neighboring territories can recognize an intruder by the fact that he sings in a different dialect. Vocal learning also aids communication within a bird family and facilitates the development of complex vocal structures, such as duets or group singing. ◀

 www.mpg.de/podcasts/lernen
(in German)

Could they get any smaller? In Seewiesen, scientists (Manfred Gahr, left) are working closely with engineers such as Johann Sagunsky to build even smaller and more powerful transmitters.

SUMMARY

- As with most songbird species of Central Europe, only zebra finch males sing. However, they first have to learn their song.
- This learning process is controlled by the vocal control system in the finch's brain. The sex hormones testosterone and estrogen play a decisive role in this process.