FOCUS

CONNECTION TO THE WORLD

Musical diversity: Fidel Canchi Cuata from the indigenous Chimane people plays a kind of violin. Researcher Nori Jacoby's work in Bolivia included documenting regional musical instruments.

PHOTO: EDUARDO A. UNDURRAGA

SOUNDS DIFFERENT

TEXT: NORA LESSING

Drumming and singing, rhythm and sound – music moves us and brings us together. But what exactly we perceive when a song reaches our ears is something most of us wouldn't be able to articulate. For Israeli researcher Nori Jacoby, this simply won't do: at the Max Planck Institute for Empirical Aesthetics in Frankfurt am Main, he and his team are investigating, among other things, how people around the world perceive rhythms and pitches. In doing so, the researchers are gaining insights into much more than just the perception of music.

PHOTO: JOAQUÍN VALDÉS

Singing for research: the test subject from the Chimane people listens to intervals via headphones and sings what she hears. Cognitive researcher Nori Jacoby (right) controls recording and playback via laptop, with a local translator on hand to assist.

PHOTO: NORI JACOBY / MPI FOR EMPIRICAL AESTHETICS

The first time Nori Jacoby heard about the Tsimané who live in the Bolivian Amazon was in 2016, when he was a postdoctoral researcher in Josh McDermott's lab at the Massachusetts Institute of Technology (MIT). McDermott's lab studied how humans extract information from sounds. "Josh approached me," Nori Jacoby recalls, "and said, 'I'm going to the Amazon with cultural anthropologist Ricardo Godoy to work with the Tsimané. You're interested in music and you love to travel. Would you like to come with us?'"

Within a few weeks, the young scientist had traded the street noise and urban bustle of Boston for the humidity and shrill chirps of the Amazon rainforest. Here, in northeastern Bolivia, the Tsimané live in small communities where they hunt and fish, grow cassava and bananas. Most people here don't have cell phones or access to the Internet. "We did our experiments in small villages where the Tsimané live," Nori Jacoby explains. The experiments involved asking participants to tap out rhythms and to sing certain tones back to the experimenter. "The social aspects of the experiment were not that different from those you would encounter while running tests in New York or Boston," the scientist recalls. "But in terms of auditory perception, we soon realized that the experiences of the Tsimané are completely different from those of people brought up in the Western world."

Understanding what's going on in brain without words

A few years earlier, Nori Jacoby, who is a proficient player of several musical instruments and has worked as a

composer, had already had a similar experience. While on a concert tour in India, he worked closely with a local sound engineer. "This man's approach to sounds and music completely differed from mine – he treated sound in a way that I simply didn't understand." That experience, the researcher says, made a great impression on him – and the memory of it came up again as he worked with the Tsimané in the Amazon. "I asked myself: is it the same anywhere else? Do people all over the world hear the same sounds, but perceive them differently?" To find answers, the scientist conducted experiments in Mali and Uruguay, and began collaborating with researchers around the world. Since 2018, he has been leading a research group at the Max Planck Institute for Empirical Aesthetics in Frankfurt am Main. One of the group's goals is to systematically research the human perception of music and sounds across cultures.

Specifically, Nori Jacoby is concerned with the ways in which people experience musical elements such as rhythms, pitches, and intervals. His research studies how different brains represent such musical elements internally. "What I want to extract from people's minds with my experiments are the mental representations of the building blocks that make up music," the scientist explains. This is an interesting field of study since the musical world represented in the mind is by no means an exact copy of the musical world "out there": the mental representations a person has at their disposal, the things this person can perceive and produce, depend on previous experiences. Moreover, mental representations are not fixed, but change with each new auditory experience. This tricky situation for researchers is exacerbated by the fact that most people have no language to describe what they perceive when they listen. "So, the question I constantly ask myself is: without direct access to the brain, and preferably without words, how can I understand what is happening in a person's mind when they hear something? How can I read people's thoughts?"

Remote research site: the village of Emeya is located on the banks of the Maniqui River in the middle of the Bolivian rainforest. Those who wish to travel there must take a motorized canoe upriver for three days.

The answer the researcher has found is extremely creative: he makes use of humans' ability to imitate. "How do people around the world respond to music? They start singing along, stomp out the rhythm, move to it," says Jacoby. "No words are needed for this, just sound. So we asked subjects to listen to different sounds and imitate what they heard." In one experiment, the researcher played test subjects computer-generated rhythms, asking them to tap the rhythms back to him. What the test subjects didn't know was that they were actually playing a "telephone game" – with themselves. In the "telephone game" also known as "Chinese whispers," one person whispers a complicated word to another, who then whispers the same word as they have understood it, to a third person. Finally, the word, which progressively changes as the game goes on, is spoken aloud. In a similar way, subjects heard a rhythm that they were asked to tap out. A rhythm was then played to them again – an auditory, averaged copy of what they themselves had previously tapped. Over the course of several rounds, the test subjects tapped rhythms, which consistently underwent slight changes. What exactly did Jacoby and his team hope to find out in this way?

Expectation determines perception

"The interesting thing about the telephone game is that you start with an obscure word, but the game usually ends with a banal one," the scientist explains. "People regularly don't pass on the word they actually heard, but a word they think they heard. "With the help of experiments designed according to this scheme, researchers can thus learn something about people's listening expectations, or more precisely, find out which words are sufficiently familiar to test subjects that they expect to hear them – and which words this is less likely to apply to. It was precisely this mechanism that Jacoby and his team took advantage of to find out something about the subjects' expectations of rhythm.

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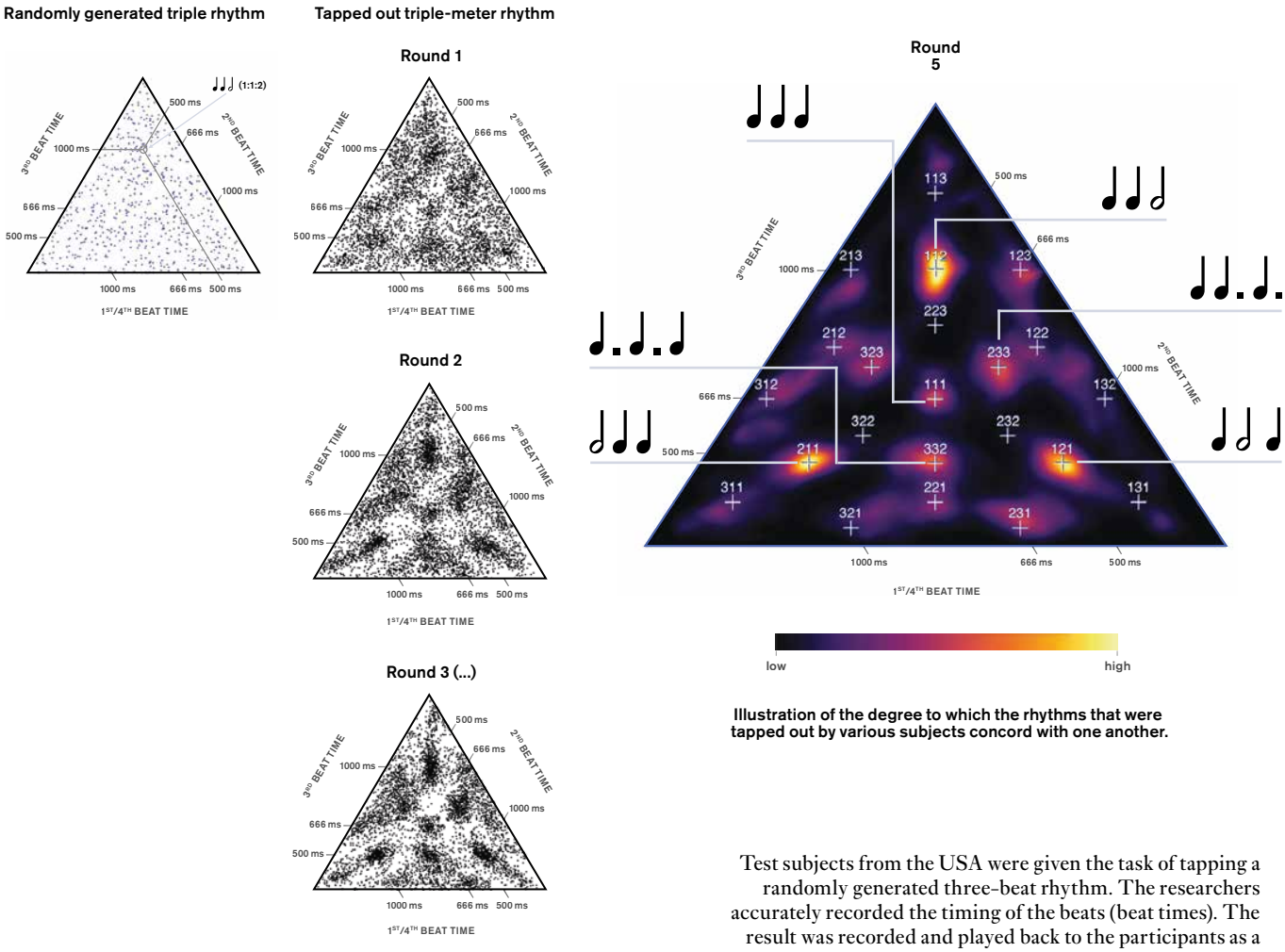

Illustration of the degree to which the rhythms that were tapped out by various subjects concord with one another.

Test subjects from the USA were given the task of tapping a randomly generated three-beat rhythm. The researchers accurately recorded the timing of the beats (beat times). The result was recorded and played back to the participants as a sample. Most of them fell into a familiar rhythm over the course of the five rounds, as shown by the clusters in the black-and-white graphs and the evaluation in the heat map.

They played them a computer-generated, "obscure" starting rhythm and received back "banal" target rhythms: equivalents of the participants' mental representations.

"It is actually like magic: we play a random, computer-generated rhythm, and without them having to explicitly tell us anything about it, what people imitatively tap gradually approaches their musical perceptual categories," Nori Jacoby enthuses. He and his colleagues have repeated the experiment countless times in 15 countries to date, including Korea, Uruguay, and the United States. Heat-map representations of the cumulative results demonstrate that people's tapping responses are highly ordered and follow distinct principles. "When we first saw the distributions, we were really astonished: the mental, musical representations of people with the same cultural background are the same. Many of the test subjects can't say anything about the rhythms they're tapping – and yet these rhythms sit in their heads, determine what they perceive when they hear something, and accordingly, what they tap out in the experiment."

It was not necessarily possible to infer the rhythms the participants would tap from their place of residence and native language. "A lot of our test subjects were students, for example, and although they came from countries as different as Korea and the USA and spoke very different languages, they often ended up tapping very similar rhythms in our experiment." The researchers are not exactly sure why this is the case, but they suspect that similar listening habits indicate similar experiences, meaning that students worldwide are exposed to the same influences and in many cases probably listen to similar music. In contrast to the stu-

GRAPHIC: JACOBY, J. H. MCDERMOTT, INTEGER RATIO PRIORS ON MUSICAL RHYTHM REVEALED CROSS-CULTURALLY BY ITERATED REPRODUCTION, CURRENT BIOLOGY, VOLUME 27, ISSUE 3, 2017, PAGES 359-370.

dents' fairly uniform results, the rhythms tapped by residents of big cities like Bamako in Mali or La Paz in Bolivia were enormously diverse. "Our analyses suggest that socioeconomic factors and the type of education a person has experienced, among other things, influence the rhythms they tap."

The study shows that whether in the Amazon, in Seoul, or in La Paz, people all over the world have a sense of rhythm. Which rhythms they actually perceive, however, varies. There are certain rhythmic structures which even Nori Jacoby, who has had extensive musical training, cannot pick out – the rhythm of the local dance Maraka, for example, which percussionists from Mali immediately recognize. The researcher reports this as just one of numerous examples his experiments have brought to light, revealing the great wealth of listening habits and musical traditions around the world. The fact that rhythms are heard so differently suggests that music perception is highly dependent on cultural imprints. At the same time, however, rhythms and other musical elements are often characterized by simple mathematical relationships. Does this not, in turn, suggest that music perception is universal on a more general level, expressing a kind of mathematical intuition?

Octaves don't sound the same to everyone

"Western thought is indeed deeply influenced by this idea, which can be traced back to Pythagoras," comments Jacoby, explaining how the ancient Greek philosopher found mathematical relationships to be fundamental to the world and thus to the perception of music. "Many physical phenomena, for example, string vibrations, are indeed associated with simple mathematical relationships like integer ratios. It has been widely assumed that the workings of the human mind also reflect Pythagoras' ideas." One prominent example of a physical phenomenon that links integer ratios with a sound that is often perceived to be harmonious is the octave. Many people in the Western world describe the interval as sounding the same, hearing the two notes as if the same note was struck twice, once with a lower and once with a higher sounding frequency. This is reflected in a notation system that uses the same letters – G and G', for example – for notes that lie an octave apart. Physically, the octave is characterized by the higher note vibrating exactly twice as fast as the lower one. Another phenomenon that seems to support Pythagorean ideas: with each note that is struck, the whole-number multiples of its frequency resonate, resulting in the overtone series. So, is the human perception of sound, with all its rhythmic and tonal diversity, ultimately determined by mathematical integer ratios? "If there really were a biological mechanism at work here, it would have manifested all over the world," comments Jacoby.

To test this hypothesis, the researcher designed another experiment based on imitation. He played Tsimané and participants from the United States two high-pitched tones outside their vocal range and asked them to imitate what they heard. "All participants mimicked the interval between the two tones very accurately," the researcher recalls. Yet in terms of the frequency of the notes as they were sung back, there were considerable differences: "When we do the experiment with musicians from the Western world, they sing the same notes to us three or four octaves lower – an expression of octave equivalence." Non-musicians from the US, however, did so only about half the time. In the Amazon, meanwhile, there was no sign of octave equivalence. "The Tsimané also sang the interval between the two notes very precisely. But the first note they sang did not relate to the source, and thus did not show octave equivalence," Jacoby explains. In a follow-up experiment, the researcher found out that the Tsimané also perceived the two tones an octave apart as blended. "However, this did not lead them to consider the two tones as equivalent. They judge the phenomenon differently than musicians from the Western world."

With his research, Nori Jacoby aims to get to the bottom of sound perception. But his results tell us about more than just our listening experience. Rather, human perception in general is under examination here, revealing itself empirically to be the product of an interpretative process that our brains undertake again and again on the basis of previous experiences and current sensory impressions. "What makes this even more exciting is that these processes happen simultaneously in all of us and are tremendously dynamic: on a larger scale, this is the basis of cultural development," Jacoby maintains. For people who place great emphasis on preserving tradition, this may not be the very best news. "Even if I think of myself as a traditional musician and play the same piece over and over again, my brain, and therefore, my perception of that piece, is constantly changing," says the cognitive researcher. For example, he explains, people perceived early bebop as very innovative at the time it emerged, and Elvis Presley's rock 'n' roll as scandalous. "These days, lots of people find both bebop and rock old-fashioned. This shows that our perception is forever in flux – and with it our culture."

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

SUMMARY

Studies with people from many nations demonstrate that, contrary to popular belief, music is not a global language.

How a person perceives musical elements such as rhythms or intervals is shaped, among other things, by their culture and listening habits.

The way the brain processes music is influenced by each new experience and is constantly being altered by these experiences.