

Ina Bornkessel



Everyone's brain functions according to the same blueprint – and yet we speak a wide array of languages. How does the human brain cope with this variety? Which linguistic and functional patterns help it to accomplish this? **INA BORNKESSEL**, head of the independent junior research group neurotypology at the **MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN**

SCIENCES in Leipzig, is searching for answers to these questions. The cornerstone for this research was laid in the childhood of the now 28-year-old – at the other end of the world.

PHOTO: NORBERT MICHALKE

At first glance, the young woman who invites me into her office and serves me coffee and water seems like a typical, very likeable 28-year-old: sunglasses in her blond, pinned-back hair, a stylish summery dress, expertly applied make-up, a winning smile and an open nature. Nor does anything change this positive impression during our discussion – but it quickly becomes clear that Ina Bornkessel is a woman of superlatives. She completed her PhD at the University of Potsdam at the age of just 22 – as the youngest doctoral student in the university's history, and with *summa cum laude*, the highest possible grade.

A few years later, she hit the ground running with her independent junior research group at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig – as the youngest group head in the Max Planck Society. This brought her recognition and attention, and so it happened that, in 2006, Bornkessel was first included in the magazine *BILD DER WISSENSCHAFT*'s "Science's Eleven" – on the occasion of the soccer World Cup and, shortly thereafter, in the ranks of the "100 minds of tomorrow," a joint campaign of the German government and German industry.

Another unusual thing about the Berlin native is where she spent her childhood: Tasmania. At the age of seven, she and her mother moved to Australia's largest island, where she quickly learned English. That was an easy task – the language just came naturally to her at school and at play with the other children. "After just six months, I was correcting my mother, and I soon began to refuse to go to my language classes – they simply weren't any fun," recalls Ina Bornkessel, laughing.

Tasmania is probably also what laid the foundation for her current research interest. "I practically grew up bilingual – though not from the very beginning," says the young researcher. Because of this, both languages somehow simply became second nature to her. Nevertheless, she also constantly mused about the differences. "I questioned very early on why some things are expressed so differently in German than they are in English."

Tasmania will always be her home, declares Bornkessel wistfully. "I fly there at least once a year, also to visit my mother, of course, who still lives there." But also because she can't stand being entirely without Tasmania. Once, she was flying back to Germany from New Zealand and didn't have time for a stopover. "That was a very strange feeling. That will never happen again."

HOME AT THE OTHER END OF THE WORLD

Nevertheless, when she finished school – she was just 17 – she decided to go to Germany to study. Her childhood memories had faded somewhat and she wanted to know what it was like to live here. "No one here can really imagine it," says the scientist, "but just like young Europeans dream of going down under, many Australians want to go to Europe – to travel or even to study and work." The history, universities with a centuries-old tradition, the many different cultures that exist here side by side and yet still retain their own characteristics – that's just fascinating for people from the red continent. And yes, here, again, it was, of course, the languages that attracted Bornkessel. "It's fascinating how so many different languages exist here in such a small area," she says with an excited gleam in her eyes. "You

drive a few kilometers, cross a border that you hardly notice, and suddenly the people speak an entirely different language."

So the passion for languages, and especially for how they work, how they are processed in the brain, has long accompanied Ina Bornkessel. Back in Germany as a 17-year-old, she began studying computational linguistics. "In school, I was interested in both humanities and science, so computational linguistics seemed to be a good choice – a logical and mathematical approach to language," she says. But she quickly noticed that that was not quite right for her. Too application oriented, she decided: "I didn't want to develop language programs for navigation systems and the like – I wanted to understand what goes on in the brain." As a logical consequence, she changed her focus to general linguistics.

Gaining an understanding of how our brain deals with language, how it processes what we hear, is still Bornkessel's primary focus today. Incidentally, the initial spark for her scientific orientation also came from her home at the other end of the world: A visiting Australian professor at the University of Potsdam, where Bornkessel was studying at the time, had given a lecture on the languages of the aboriginal people. "The natives of Australia still speak an incredible number of different languages even today, and they function so very differently than the European languages with which we are familiar. I was curious how such a variety could even come about," recalls the researcher. At this point, she realized that this phenomenon could be understood only by studying as many widely different languages as possible. This is an approach that has long been standard



Putting the final touches on an experiment: Ina Bornkessel and her assistant Katja Brüning prepare a Chinese participant for an EEG. In a soundproof booth, she will then be presented with sentences or dialogs on the screen or hear them through loudspeakers.



PHOTOS: NORBERT MICHALKE (2)



PHOTO: NORBERT MICHALKE

Checking the monitors: On the right, Ina Bornkessel watches a participant's EEG during data acquisition. The left monitor shows the Chinese sentence the participant is reading.

in theoretical linguistics. For Ina Bornkessel, however, the question was also: What happens in the brain? How can our brain, which ultimately follows the same blueprint in all humans, even process this variety?

THE BRAIN WORKS FASTER THAN WE THOUGHT

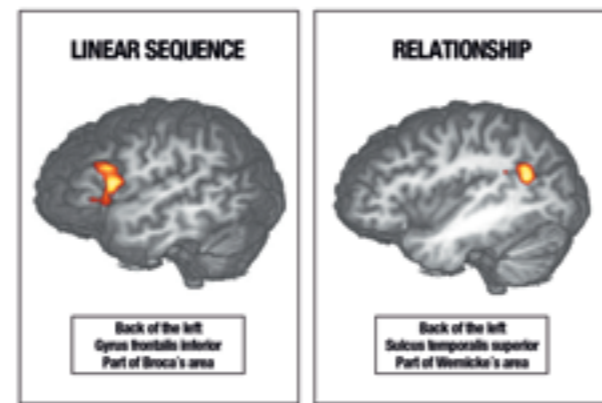
This approach is new. “There are more than 6,000 languages in the world, many of which exhibit vastly different properties,” says the Max Planck researcher. “I am interested in knowing whether there are common structures to which the brain responds – neuronal patterns that are identical for all languages.” Initially, it is the differences that aid in the search for these general principles. English and German, the two languages with which Bornkessel grew up, are good examples. At first glance, they are not that different at all. At least, that is what we Germans think, as we find it relatively easy to learn English. The matter is somewhat more complicated the other way around. German dative constructions, for instance, are quite a challenge for English speakers. Or

the fact that German verbs can occur at the end of a sentence, which, incidentally, is also true for Japanese and Turkish. Under these circumstances, the meaning of a sentence can't be understood – at least from a purely theoretical standpoint – until it has been fully uttered. And that is also what linguists assumed for a long time. In the 1980s, the concept of “head-driven” language processing prevailed. The head is considered to be the verb, which describes the action and thus gives the sentence its meaning. If it occurs at the end, the brain doesn't assemble the content until everything has been said – or so many researchers believed at the time.

“Today, we have come a long way from this concept,” says Bornkessel. Language researchers now assume

that the brain interprets what it hears – even while the speech is still being uttered. “Anything else would be ineffective and would lead to a delayed understanding of speech,” is how the explanation goes. To do this, our brain uses certain structures that it knows and that are repeated again and again – in all languages. Or at least in those that have been studied to date. And the young Max Planck researcher also has experimental proof of this: she watches how the brain reacts to sentences and their small and not-so-small stumbling blocks. To do this, she uses electroencephalography (EEG) and measures her participants' brain activity while they listen to or read various sentences. What is interesting about this is that, as long as nothing unusual happens, brain activity essen-

The brain in action: Part of Broca's area (left) is very sensitive to the linear sequence of the participant roles in a sentence (*The hat was stolen from the gardener yesterday*); Wernicke's area (right) focuses on the relationship between the participant roles (*The pirate stole the princess yesterday*).



PHOTOS FROM: GREWE, T., BORNKESSEL-SCHLESSEWSKY, I., ZYSSET, S., WIESE, R., VON CHAMON, D.Y., & SCHLESSEWSKY, M. (2007). THE ROLE OF THE POSTERIOR SUPERIOR TEMPORAL SULCUS IN THE PROCESSING OF UNMARKED TRANSITIVITY. NEUROIMAGE, 35, 343-352.

tially always stays at the same level – as, for example, with the simple sentence “Peter mag Maria” (Peter likes Maria). Everything is straightforward here, and the standard sequence subject – predicate – object leaves practically no room for misunderstanding.

INCREASED NEURAL ACTIVITY WHEN MARIA ACTS

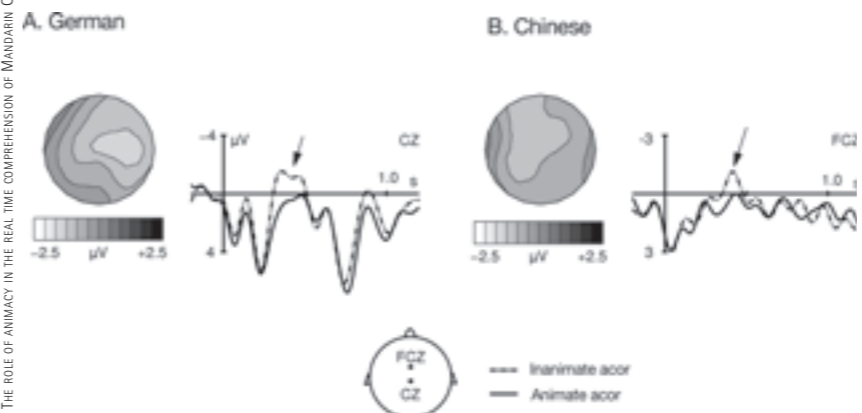
But even when it gets slightly more complicated, such as in “Ich weiß, dass Peter Maria mag” (I know that Peter likes Maria), the EEG shows nothing unusual. However, if the example is “Ich weiß, dass Peter Maria gefällt” (I know that Maria finds Peter appealing), the German brain has to strain a bit. The relationship has been inverted. Whereas, initially, the actor was Peter, in the last sentence, it is suddenly Maria – despite the fact that, at first glance, the structure hasn't changed at all. As soon as the verb is uttered, the brain must therefore rethink the situation, reject the original interpretation and allow a new one. This is work and shows up in the EEG in the form of increased activity.

By comparing unproblematic sentences with others that are, at first glance, similar, but indeed trickier, Bornkessel and her colleagues discover what strategies our brain uses to surmount its difficult task of immediately interpreting what is heard, thus ensuring real-time language comprehension. Her hypothesis is as

follows: In language, there are certain hierarchies that can be used for effective comprehension – features that mark certain words as taking priority over others. “Let us take nouns, for instance. Normally, the rule is that animates take priority over inanimates and thus determine the action,” says the researcher. She cites examples: “Der Gärtner streift den Zweig” (The gardener brushes against the branch) is just as simple as “Klaus fragt sich, welchen Zweig der Gärtner streifte” (Klaus wonders which branch the gardener brushed against). The gardener is the animate entity, so it takes priority over the branch in the hierarchy and is – beyond a doubt – the active party.

But what about the following example: “Klaus fragt sich, welchen Gärtner der Zweig streifte” (Klaus

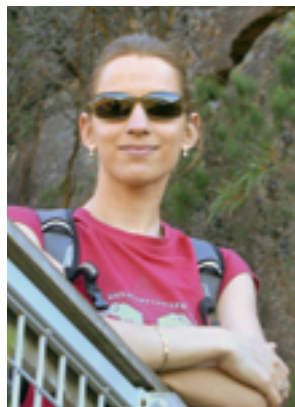
wonders which gardener the branch brushed against)? Here, the relationship has suddenly reversed and the inanimate branch becomes the actor. The brain responds to this with increased activity – around 300 milliseconds after the branch appears in the sentence. Accordingly, within fractions of a second, the brain notices that something is wrong here and that an inanimate and thus non-ideal actor has taken the stage. Now the next hierarchy level comes into play, in which case determines priority of interpretation: “der Mann” (the man – nominative) takes priority over “einen Mann” (a man – accusative), “der Gärtner” (the gardener – nominative) over “welchen Gärtner” (which gardener – accusative) and therefore also “der Zweig” (the branch – nominative) over “welchen



Similar patterns: The diagrams show potential shifts in the electrical activity of the brain for animate (solid line) and inanimate actors (dotted line). Some 300 milliseconds after the presentation onset of the actor, there is an increase in neuronal activity for an inanimate noun (*the stone as compared with the gardener*). Surprisingly, this pattern is very similar in German and Chinese.



Relaxing in nature: Ina Bornkessel went hiking in Freycinet National Park on the east coast of Tasmania in March.



PHOTOS: PRIVATE (2)

Gärtner” (which gardener – accusative). And our brain thus quickly recognizes that the inanimate entity is the actor here.

“We find these or similar patterns in all languages that we’ve studied to date,” says Ina Bornkessel. “This allows us to conclude that these are universal principles for language processing.” Of course we would need to study many further languages to be sure – especially those that are significantly more complicated because they deviate from the very obvious rules. Chinese, for example. Or Fore, which is spoken in the highlands of Papua New Guinea.

Here, the animacy hierarchy is somewhat stricter. If the words “man,” “pig” and “kill” occur in a Fore sentence, then, regardless of their sequence, the action is always initiated by the man. For the speakers of this language, humans always take priority over animals or inanimate objects – even though the pig is, of course, also capable of killing the man. “In German, we can express this alternative state of affairs very simply, but Fore speakers require completely different words and constructions,” explains Bornkessel. She also has a few other such puzzles to solve – and one can see how anxious she is to do just that.

Incidentally, the young neurologist is interested not only in when our brain must shift into a higher gear for language processing, but also in where this takes place in the brain. To do this, she uses functional magnetic resonance imaging (fMRI).

She explains the change in method thus: “With the EEG, we can determine only very generally whether there is more or less activity and when this activity occurs in time. However, this method is too imprecise for the ‘Where?’.”

In the brain, two regions are particularly important for language processing: Broca’s area and Wernicke’s area, both of which are located in the cerebral cortex. Scientists long thought that these two centers play different roles in language production and comprehension. “However, this idea is long outdated, and today we know that both are important for both speaking and understanding,” says Bornkessel. Accordingly, she sees increased activity in both areas in the fMRI when the participants lying in the scanner hear sentences being read to them, or when they read them themselves.

A VARIANT THAT MEANS MORE WORK

Still, there are major differences. Both brain regions appear to engage in different aspects of language comprehension, as the fMRI studies have shown. For example, a portion of Broca’s area is particularly challenged when a sentence does not follow the normal sequence and a noun that is lower on the hierarchy appears first, for instance an inanimate noun before an animate one – such as “Gestern wurde der Hut dem Gärtner gestohlen” (The hat was stolen from the gardener yesterday) instead of simply “Gestern wurde dem Gärtner der Hut gestohlen” (The gardener had his hat stolen yesterday). Both variants are possible, but the first is more unusual and means more work for the brain and especially Broca’s area.

Hierarchy issues activate Wernicke’s area, too. However, this cen-

ter is responsible for the relationship between two participants in an event. It exhibits increased activity when the actor is not higher up in the hierarchy, as in the example sentence “Klaus fragte sich, welcher Zweig den Gärtner streifte,” (Klaus wondered which branch brushed against the gardener), where the inanimate object performs the action. Or even when both nouns are on the same hierarchy level, as in: “Gestern hat der Pirat die Prinzessin geraubt” (The pirate stole the princess yesterday). However, if the sentence were: “Gestern hat der Pirat den Schatz geraubt” (The pirate stole the treasure yesterday) – the actor is animate, the passive object is inanimate – then Wernicke’s area apparently finds nothing unusual about it and there is thus also no increased activity in the fMRI.

Incidentally, these findings were obtained in collaboration with the neurolinguistics research group at the Department of Germanic Linguistics of the University of Marburg – and this is true for much of Bornkessel’s work. This is where Matthias Schlesewsky works, with whom she shares far more than just a common research interest: the two scientists are married and make a good team in their private lives, too. “It’s great to have a partner with whom I can share my passion for neurolinguistics, and with whom I can collaborate so well,” says Bornkessel enthusiastically. But of course she can also switch that off and focus on very different things – such as travel, and not just to Tasmania. The researchers also like to hike, preferably above 2,000 meters. “Up there, I can really clear my head and can’t help but give my projects a rest – the body uses far too much energy at those altitudes,” says Ina Bornkessel. So she recharges her batteries on mountain summits, whether in the northern or southern hemisphere, and then converts this energy back into inspiring ideas for her work. STEFANIE REINBERGER