Look who's talking: most children can say their first words at just one year old, while three-year-olds are already able to conduct conversations. That makes them far more advanced than any animal, or even artificial intelligence.

Speaking out

For us, it appears natural that children should start to speak at some point. Yet learning language is a major feat, which is still not fully understood even today. The Departments led by **Caroline Rowland** at the **Max Planck Institute for Psycholinguistics** in Nijmegen and **Angela Friederici** at the **Max Planck Institute for Human Cognitive and Brain Sciences** in Leipzig are using a wide range of methods to investigate how children learn this complex system of communication with seemingly no effort.

TEXT **TIM SCHRÖDER**

The path to the laboratories where Caroline Rowland works leads through a small park. When you walk along it, you immediately notice that something is different. A baby blue porcelain elf sits in the grass on the edge of the path, and a few steps later you see a pink fairy, about the size of a Barbie doll, then another, then another... until you reach a side entrance.

Once you're inside, this part of the Max Planck Institute for Psycholinguistics also looks different from the rest of the building with its offices and laboratories. In the hallway you see brightly colored stools shaped like mushrooms, which are just the right size for children to sit on comfortably. "And here's our waiting room," says Caroline Rowland as she opens a door onto a small play area with small chairs, cuddly toys, picture books, boxes full of board games and games that test children's skills. Caroline Rowland and her colleagues have arranged everything to make sure that children feel comfortable straight away, since it's they who are the real stars of her research.

She is Professor of Psychology and Director at the Max Planck Institute for Psycholinguistics in Nijmegen in the Netherlands. She wants to find out how children learn their native language – even before they start to become proficient in many other skills. "During their first years of life, most children have no difficulty learning the most complex communication system in the known universe. I want to find out how they manage to do this and why this is the case." To this end, she regularly invites parents and their children to take part in playful experiments. She finds her work with babies and young infants who are just starting to learn their native language fascinating.

Next to the colorful waiting room is one of the laboratory rooms where Caroline Rowland and her team conduct their studies with the children. The contrast couldn't be greater: the room has an austere atmosphere and the walls are bare. Nothing must be allowed to distract the children. In the middle of the room, there is a large monitor with a table and two chairs in front of it. This is where the parents sit with their children. The researchers then show scenes or images on the monitor: a dog chasing a cat or objects such as balls or rubber ducks – things that children are familiar with from their everyday lives. Together with team members Julia Egger, Christina Bergmann and Andrew Jessop, Rowland observes which items attract the children's attention. For this, she uses eyetrackers, which contain infra-red cameras that follow the movements of the pupils and iris and are able to register the direction, and movements, of the children's eyes.

Using this technique, Caroline Rowland, together with her team and colleagues from Liverpool University in

Photo: Michele Constantini/plainpicture

the UK, are able to measure the speed at which a child processes language. This approach is known as the "looking-while-listening" paradigm. A child sits in front of a screen and sees pairs of images, only one of which is mentioned. If, for example, an apple and a car are shown on the screen, they are directed to "look at the apple" by a clear, child-friendly voice.

Using the eyetracker, the scientists can measure how quickly children direct their gaze to the apple. The speed with which children identify the correct picture indicates how quickly they process the language that they hear.

NO PAUSES BETWEEN WORDS

The study aims to solve the biggest puzzle surrounding language development: how is it that some children speak their first words at just eight months, while others only begin to talk when they are two or three years old? And on a very practical level, how is it possible to detect at an early stage whether children are simply rather late developers, or whether they have a language acquisition disorder that requires speech and language therapy early on? The study showed that the speed at which 18-month-old infants process language is indeed a key factor in language development.

Fast language processors have a clear advantage: they are able to learn more from every sentence that they hear, and their vocabulary and even their knowledge of sentence structure grow more rapidly than those of slower processors. What's more, the larger their vocabulary, the faster they can process what they have heard. The project team intends to investigate this phenomenon in greater detail as part of their future research – also with the aim of finding opportunities to help children who struggle with language to learn language more quickly.

For Caroline Rowland, the ability to quickly and accurately process the language that has been heard is crucially important in learning to speak. What newborn babies and young infants first perceive is an unceasing flow of individual sounds and syllables. Adults will recognize this from learning a foreign language: often, the flow of words is almost incomprehensible, and it is only occasionally possible to extract individual, familiar terms and make an attempt to work out the meaning of what is being said. "Usually, when we say a sentence, we leave no pauses between individual words," the scientist explains. "For small children who have to learn the language from scratch, the challenge is therefore to recognize words in this flow of syllables." And not only that: they also need to do this simultaneously with other difficult tasks such as differentiating between different types of words and learning to understand the grammar.

One key question is therefore how children process the linguistic input. In this area, research needs to take into account the fact that in spoken language, the words aren't enunciated evenly. When we speak, we use different accen-

Photo: MPI for Psycholinguistics

Left Playful research: the scientists in Nijmegen perform child-friendly experiments to study which language abilities children have already obtained.

Below Caroline Rowland is the Director of the Language Development Department at the Max Planck Institute for Psycholinguistics.

Photo: MPI for Psycholinguistics

tuations, make pauses, and talk with a certain inflection of speech. We emphasize what we have said with gestures and looks, and we naturally refer to objects and people around us. According to Caroline Rowland, these factors have not yet been taken sufficiently into account by research. In her opinion, this constitutes a complex challenge.

CHILDREN MAKE CLEVER MISTAKES WHEN THEY SPEAK

She herself tackles this challenge using various different methods. In other words, she uses a whole range of approaches: neuroscientific methods, computer models, behavioral experiments and detailed studies of everyday conversations.

To analyze these conversations, Caroline Rowland and her team use large online databases such as CHILDES, in which dialogs by and with children are transcribed into written form from audio or video files. "You can draw a very large number of conclusions from the conversations that children hold," Caroline Rowland explains. Errors typically made by children, for example, provide useful information since they indicate which underlying grammatical patterns the children have already identified in the language. Younger children often make mistakes when forming plural nouns, such as "sheeps" instead of "sheep". For example, a child who says "sheeps" is using the fact that you can add '-s' to words in English to make them plural (as in "dogs"). It just happens that "sheep" is an exception to this pattern.

Among older children, the mistakes change as their language ability grows. A girl's response to being tickled by the father could be to say "Don't giggle me!" This example clearly illustrates the key issue: this isn't an error that involves the girl using words or parts of words in the wrong way. Quite the opposite: the girl is using a pattern that she has frequently heard, and which she can now use in a creative way to express something new, which in

A colorful team: in the Language Development Department, researchers in the fields of developmental and cognition psychology, the neurosciences, linguistics and speech therapy work in close cooperation with experts in computer analysis and simulation.

this case is not quite right according to the rules of the language. Rowland talks of "clever mistakes".

EVEN YOUNG INFANTS FIND PATTERNS IN LANGUAGE

Incidentally, language development researchers advise against correcting children's mistakes when this happens. Children don't consciously learn which language principles they are using. Instead of trying to teach them rules, adults would do better to repeat what the child has just said, but in the correct form ("I won't make you giggle"). In time, the children also learn not to make the "clever mistakes".

One explanation as to why even very young children are able to learn language patterns is what is known as "statistical learning". This describes the ability of the brain to identify general principles in a complex environment, to observe them and to learn from them. This is clearly illustrated by sentences such as: "Look at the baby, darling!" Usually, in everyday language the syllable sequence "ba" and "by" occurs more frequently than the combination of the syllable "the" and the syllable "by". Therefore, a child quickly learns that there is a connection of meaning between "ba" and "by" – the "baby".

This is demonstrated by experiments in which children hear an artificial language. The researchers integrate certain regular elements into this language. In the imaginary sentence, "dalobitaganodalobilimidenatidalobi", for example, which is spoken fluently, the syllables of the sequence "dalobi" occur together in this order multiple times. It has been shown that children learn these regularities very quickly, so much so that they can then easily recognize the term "dalobi" later on when it is spoken on its own. "We have several cameras in the room, which film the faces of the children in order to discover what they have learned by looking at how they react to familiar and unknown sounds,"

Photo: MPI for Psycholinguistics

Caroline Rowland explains. "When the children hear a term such as 'dalobi', with which they are familiar, their level of attention increases significantly and they look up, for example."

COMPUTERS HELP ANALYZE LANGUAGE

Rowland stresses that while this may sound banal, it is actually quite amazing. "Even at just a few months, the brains of human infants are already able to understand complex statistical relationships of this kind – and they are much better at doing so than any animal. Babies can extract complex statistical patterns from spoken sentences within the space of a few minutes. We can train apes to do the same, but it takes hundreds of attempts before they succeed." According to Rowland, if we want to understand why people are capable of developing such a complex communication system as language, it is essential to research how and why infants are so adept at statistical learning.

In her Department, Rebecca Frost, Katja Stärk and Evan Kidd are researching how infants use repetitive patterns in language in order to develop a better understanding of words and grammar. In their research, they don't just analyze conversations but also use behavioral and neurophysiological experimental techniques, such as eye tracking and electroencephalography, or EEG. For this purpose, hoods studded with electrodes are placed onto the babies' and infants' heads to record the weak electrical activity of the brain. In this way, the researchers are discovering how well infants use statistical language learning, and how good they are at it.

Such studies demonstrate that an awareness of language is developed at a very early stage, long before the children start to speak. Evan Kidd, for example, recently published a study according to which infants who later went onto have fast or slow language development reacted differently to language in infancy. Children who start gathering and using their knowledge of words earlier than others, instead of focusing on individual sounds, have an advantage later on when it comes to learning new words.

Another way of studying statistical learning is to analyze everyday conversations from databases. From these, it is possible to determine the language patterns that children are exposed to when they learn the language. Studies have shown, for example, which rules apply when differentiating between types of words. For example, in English, some words occur very frequently in little frames (e.g. the ... is). These frames predict, with a high degree of accuracy, the category of the intervening word (e.g. the intervening word between the and is is likely to be a noun; the cake is..., the apple is..., the universe is...). For example, one study shows that in English, nouns consist of more syllables than verbs do, and that they are more

Take a closer look: in Nijmegen, experiments on the screen are being used to study how rapidly children are able to classify terms. The faster they process words, the easier it will be for them to learn the language later on.

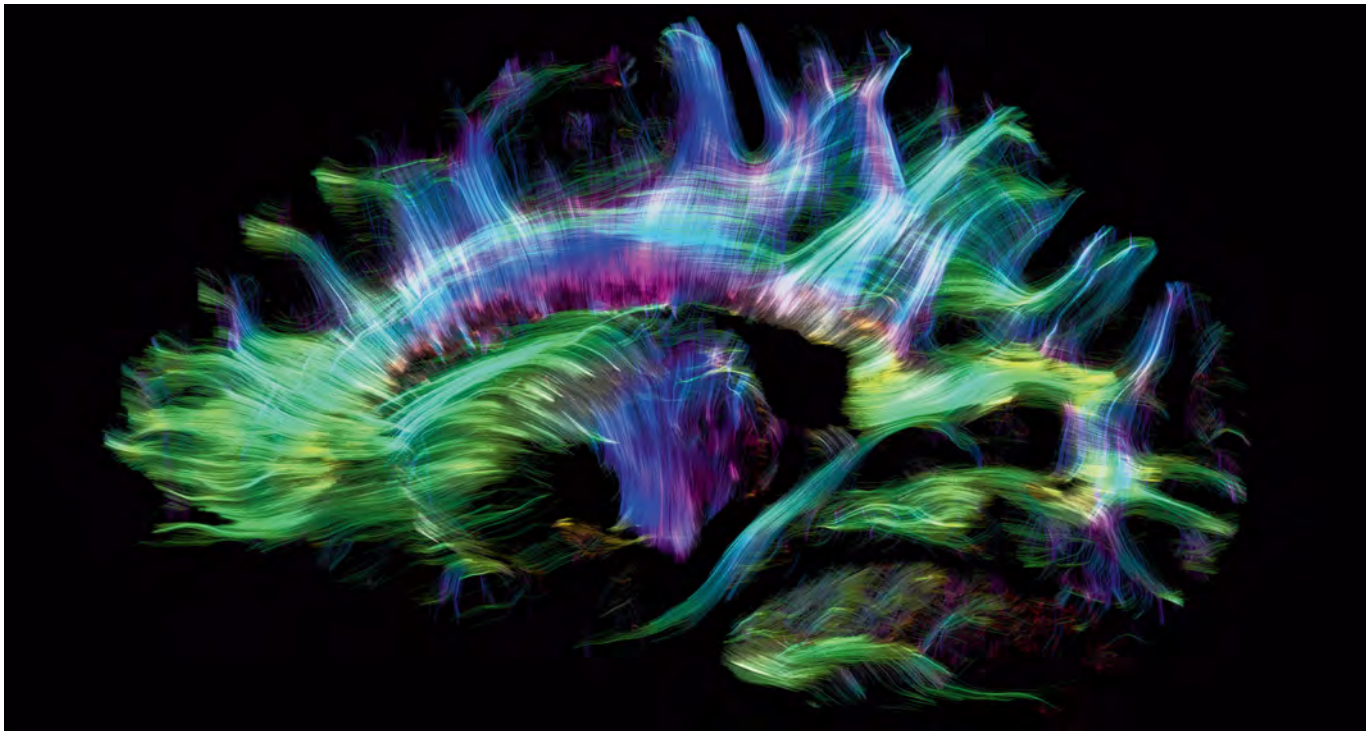
Photo: MPI for Psycholinguistics

commonly stressed on the first syllable than other types of words. Thanks to modern computer technology, researchers in this area have made significant progress in recent years. Automated systems are capable of analyzing thousands of verbal exchanges and statements in a short space of time. In this way, scientists are gaining an increasingly thorough understanding of the complex language input to which language learners are exposed.

ONLY HUMANS CAN CLEVERLY COMBINE WORDS

Computers can also be used to simulate learning mechanisms and in so doing, to examine existing theories of how children learn language. Caroline Rowland together with her project team – Evan Kidd, Raquel Garrido Alhama, Andrew Jessop and a colleague at Nottingham Trent Univesity in the UK – are building computer simulations that test different theories of how children learn language. The idea is to test whether the the computer model learns the language in the same way as children. However, according to Caroline Rowland, artificial intelligence is way behind children in terms of what it can do, for example when it comes to differentiating between various types of words. "Even three-year-olds know that you can't eat adjectives ("I ate the happy"), but models are unable to recognize this fact."

In Rowland's view, the problem is not the fundamental language development models. To a far greater extent, the computer's difficulty arises from the fact that in real conversations, language has added noise, as it were. People restart a sentence, make improvements, and fail to finish what they are saying. For computer models, it is hard to know how to handle this noise. Then there are the dual meanings in natural language, which even extend beyond different word types. Verbs can be the same as nouns ("I like fish.", "John can fish", or adjectives ("That dress doesn't fit you.", "He looks lean and fit.").



The connection makes the difference: the different parts of the brain communicate with each other via a network of fibers. The way in which language understanding develops is also closely linked with a nerve connection of this type.

Photo: Alfred Anwander/ MPI for Human Cognitive and Brain Sciences

"We still have a long way to go," says Caroline Rowland. She hopes that in the coming years, it will be possible to find the solution to many unanswered questions using her portfolio of different methods. During the process, she also takes careful note of the work being conducted by other colleagues, such as Angela Friederici, who is approaching language development from a different angle. The neurophysiologist is a Director at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig. Her work focuses mainly on the development of the brain, which plays a decisive role in language learning.

"In principle, Caroline Rowland and I are approaching the same topic from two different perspectives – language development is our common denominator," says Angela Friederici. "I am also asking what makes us human. Humans are the only living creatures who can logically combine language elements and phrases. No animal is capable of doing that." Dogs, for example, can learn individual words such as "stick" or "sit". However, they can't combine them in the same way as a young infant can.

A CHILDREN'S FESTIVAL AS A RECRUITMENT MEASURE

One of Friederici's most important research tools is functional Magnetic Resonance Imagery (fMRI), which can be used to observe certain processes in the brain from the outside, such as nerve connections and the activity of certain areas of the brain. Using this approach, she has made interesting discoveries, particularly by comparing children and adults. It has been known for a long time that two areas of the brain are particularly linked to language: the Broca area and the Wernicke area. The French surgeon Paul Broca discovered that people whose Broca area is damaged lose the ability to express themselves using correct grammar. In turn, the neurologist Carl Wernicke found that the area later named after him is important for understanding sentences.

Using fMRI, Angela Friederici discovered, among other things, that during the brain maturation process, a nerve connection is formed between two areas that is closely linked to the increasing ability among children to understand language. "Interestingly, animals don't have this connection. That means it probably plays a key role in language development," she explains. This research was only possible because Angela Friederici cooperates with clinics who provided her with image data from medical studies of newborn babies and young infants – naturally with the consent of their parents.

Caroline Rowland is also dependent on parents who are willing to travel to the Institute with their children for the language experiments. After all, these visits last about an hour. However, even the youngest children are able to stay the course, she says. Because everything is done in a playful way, the children are curious about what is happening. Once a year, Caroline Rowland and her colleagues from Radboud University next door organize a big children's festival, called "Kletskoppen", or "chatterboxes". It's a colorful, fun event, with which the researchers aim to fill others with enthusiasm for their work – particularly parents who want to get involved in their studies.

The event is attended by Dutch TV hosts, storytellers and children's authors, the researchers give informal presentations, and the children can play dozens of language games. "We want to make contact with people from different social backgrounds, not just with educated families who are more likely to be interested in research," says Caroline Rowland. The "Kletskoppen" is a door opener, she explains. "If we want to know how language development works, we also have to find out whether there are differences between children from all types of cultural, language and social backgrounds." This is crucial; if we want to understand language acquisition, and eventually develop better programs to help all children learn to talk, we need to discover how everyone learns language. ◀

Angela Friederici, Director at the Max Planck Institute for Human Cognitive and Brain Sciences, is investigating the connection between brain and language development.

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

SUMMARY

- **Even very young children are capable of unconsciously recognizing language patterns and rules such as word relationships, types of words or sentence structure.**
- **For babies, one particular challenge is to be able to pick out individual words from the flow of sounds. However, tests have shown that they are able to identify repeated syllable combinations as words within a very short space of time.**
- **Children who start gathering and using their knowledge of words at an earlier stage than others are at an advantage when it comes to developing language later on.**
- **The development of the brain plays an important role when learning language. A nerve connection between two important areas of the brain, which is not formed until after birth, is closely linked to language understanding among children.**

Photo: fotografa_Berlin/ MPI for Human Cognitive and Brain Sciences