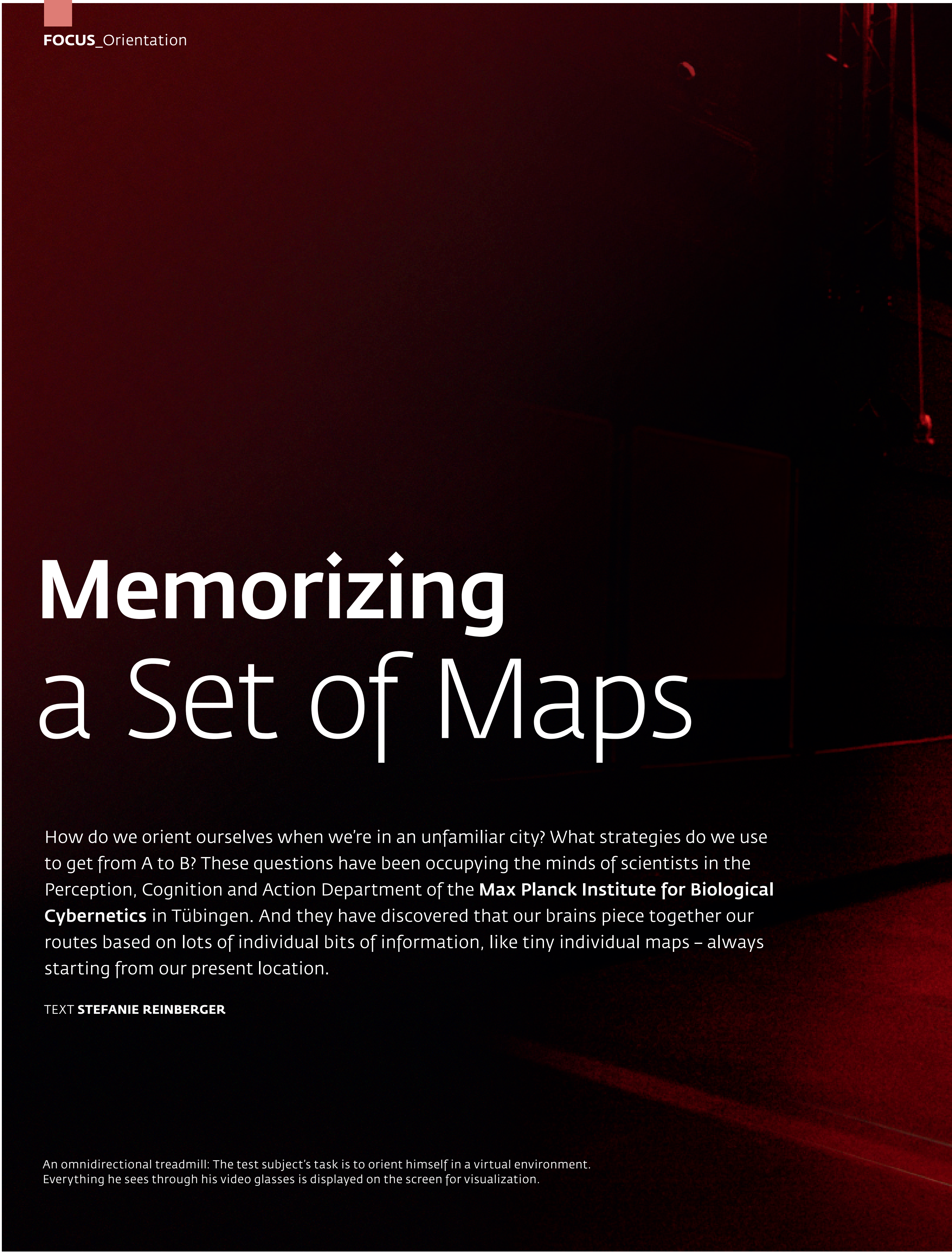
Memorizing a Set of Maps

How do we orient ourselves when we're in an unfamiliar city? What strategies do we use to get from A to B? These questions have been occupying the minds of scientists in the Perception, Cognition and Action Department of the **Max Planck Institute for Biological Cybernetics** in Tübingen. And they have discovered that our brains piece together our routes based on lots of individual bits of information, like tiny individual maps – always starting from our present location.

TEXT **STEFANIE REINBERGER**



An omnidirectional treadmill: The test subject's task is to orient himself in a virtual environment. Everything he sees through his video glasses is displayed on the screen for visualization.

Photo: bopicture – Björn Hänssler

Did you manage to find us alright?” asks Tobias Meilinger as he greets me. A routine everyday question, but one with a deeper meaning for this Tübingen-based scientist. The psychologist is working on a research project at the Max Planck Institute for Biological Cybernetics in Heinrich Bülthoff’s Perception, Cognition and Action Department. Meilinger is interested in how we orient ourselves in space, and what sensory and cognitive skills we need to do this.

As we move from A to B, our brains perform a feat of technical brilliance. Take my brain, for instance, on the day I visited Tübingen: I moved between bed, bathroom and breakfast table on autopilot, and the short distance to the train is a well-trodden route. The stations where I have to change are familiar from previous trips, and even when I finally reach Spemannstraße in Tübingen, I know roughly what direction to take, having visited the area a few years back. I make decisions about which direction to take in no

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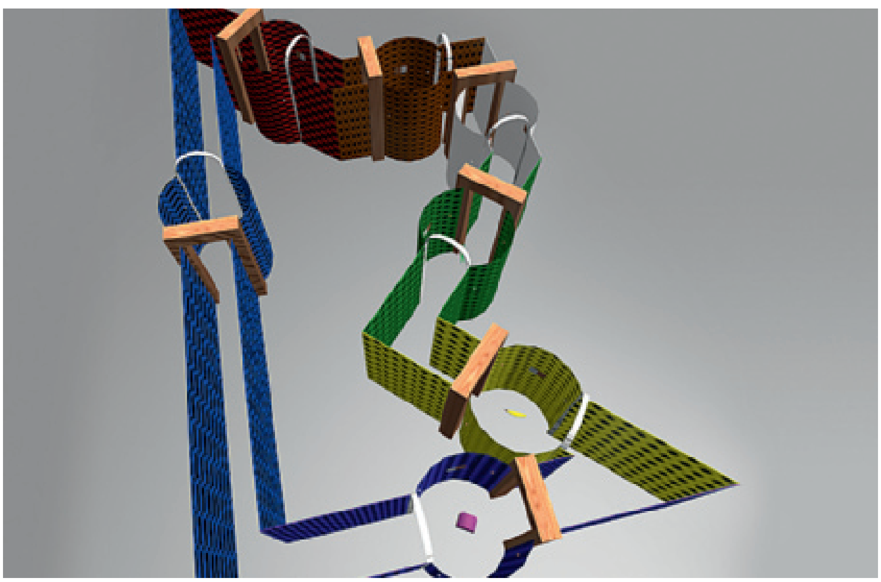
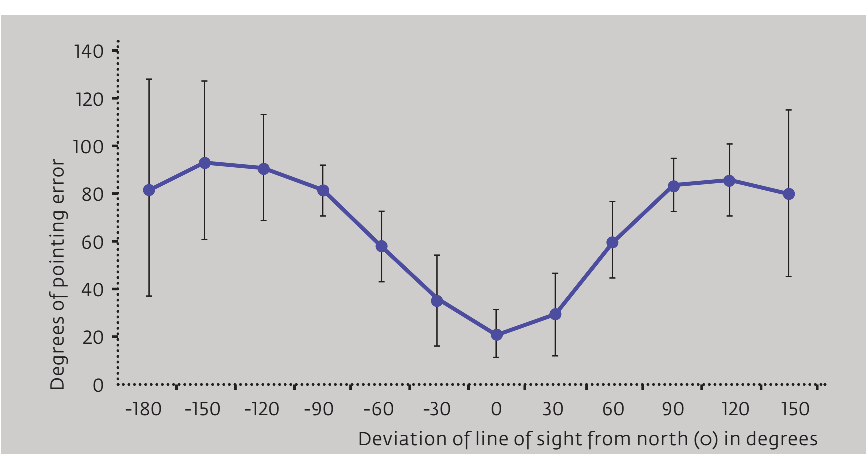




We don't always use the same methods to orient ourselves: Test subjects have to point to a goal in an unfamiliar labyrinth (top). They do this more accurately when they are looking in the direction in which they walked before. When the research team used compass orientation, their success rate fell. But in a town that they know well, the test subjects can easily orient themselves using the points of the compass. The graph (bottom) shows their pointing errors according to the degree by which their line of sight deviates from north (0).

time at all. The information I need to orient myself is stored somewhere in my brain.

NAVIGATION IS A MULTISENSORY PROCESS

A whole range of different details help us recognize a place and choose the right direction when we need to find our way somewhere in a specific environment, such as a building or a city. We use landmarks, such as high mountains or tall towers, to orient ourselves from a distance, but also distinctive roadside features, such as a red house or a bus stop. We also memorize whether we turned right or left coming from a particular street to get to the station.

"In addition to visual perception, our sense of balance plays a key role. But we also notice how much effort a particular route requires – for instance, whether it goes uphill, whether the ground is even or full of potholes and rocks," explains Heinrich Bülthoff. Therefore, we usually manage to follow directions that go something like this: right at the first traffic light, then left at the church and up the hill. Navigation is a multisensory process. Our different sensory organs receive a wide range of impressions, describing a place, a route or an environment. If the bulk of this information is missing, things start to go wrong. During a sandstorm in the desert, for example, everything around us looks the same and we end up going around in circles, as the scientists in Tübingen discovered in 2009. Without sufficient sensory input,

Graphics: MPI for Biological Cybernetics – Tobias Meilinger (2)

Searching for orientation: A test subject wears a safety harness as he walks on the CyberCarpet. The white knobs on his helmet help the computer determine his line of sight.

we lose our sense of direction and our route quickly degenerates into random twists and turns to the right or left. Psychologist Tobias Meilinger is currently focusing on spatial orientation. "I'm interested in how we navigate in completely ordinary everyday situations, for instance when we're walking through an unfamiliar town," he says. How do we orient ourselves? What frames of reference do we use? What impressions help us? Psychophysics can provide the answers to these questions. It is an old scientific discipline dating back to 1860 and describes how the mind generates subjective perceptions from physical stimuli received from our surroundings.

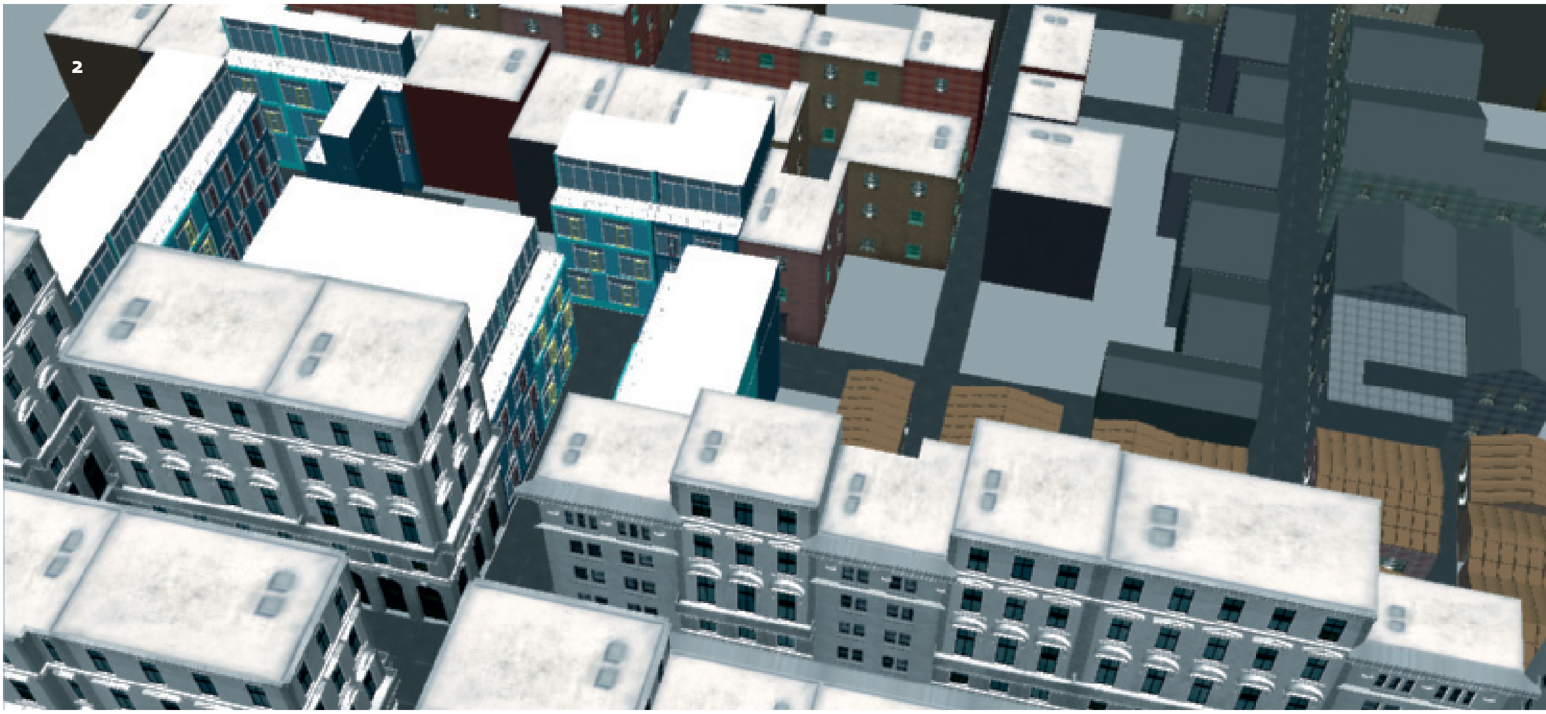
The researchers in Tübingen are studying this with the help of state-of-the-art technology: virtual realities. Wearing video glasses, their test subjects walk through labyrinths, cybercities and computer simulations of real localities. In some experiments, they stroll along on a unique, specially designed treadmill on which they can move not just forward and backward, but also right and left, although in reality they are simply walking in place (MaxPlanckResearch 2/2008, page 50 ff.).

EXPERIMENTS IN VISUAL PERCEPTION

"Working with virtual realities allows us to focus on several sensory responses simultaneously. This means that we can simulate an actual navigation situation very realistically," explains Heinrich Bülthoff. "But unlike a real test lab, we can shut out disrupting influences – additional stimuli that might distract the test subjects from their task." Until now, most spatial orientation experiments worldwide have used a static test setup with so-called vista spaces that can only be perceived from a single viewpoint. Or the test subject uses a joystick to stroll along a route on the screen. These tasks concentrate primarily on visual perception and ignore all the other sensory inputs that we use for navigation.

In the interest of research, Meilinger allows me to try out cyberwalking. He takes me into the test lab, the Cyberneum, and hands me the video glasses. I instantly find myself in a simple computer simulation of a city complete with streets, alleyways and houses of various sizes and colors. I can even make out the vague outlines of a shopping mall. Unfortunately, I'm not allowed to try out the CyberCarpet, as the research scientists have christened their special treadmill. This technological marvel is reserved for real test subjects. I only get to move the joystick and turn in the required direction. No

Photos: Axel Griesch (3)



1 Tobias Meilinger prepares a test subject for an experiment.

2 Routes through an unfamiliar city: A bird's eye view of the labyrinth of virtual streets through which test subjects must find their way.

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matter. That's enough to give me some idea of what Meilinger's work is all about. "Take a look around first and then move forward," the scientist instructs me. "Now along there," he continues, as I look left at the first intersection. He deliberately avoids stock phrases such as "turn right" or "turn left." This is to prevent test subjects from being influenced by his instructions during the experiment, instead of the visual and motor stimuli they receive in the virtual city.

WE TEND TO STORE LOCAL BITS OF INFORMATION

The Max Planck scientist uses his virtual city to investigate how people's brains store a route that they take regularly. The first groundbreaking ideas on this subject were developed in 1971. John O'Keefe and John Dostrovsky of University College London discovered that rats had special cells in their brains – in the hippocampus to be more precise – which fired only when the animal was in a particular spatial position. And wherever the rodents were, at least one of these place cells was active. This discovery formed the basis for the later idea that our brains create cognitive maps that they use to store location information.

Meilinger is reluctant to use the term "map" in this connection. "It implies a map like the ones we're used to seeing in a road atlas," he says. He prefers "reference framework" or "system of coordinates." But whatever you call it, the question the scientist is trying to answer is: Are these global or local systems? In other words, do we all walk around with a giant map in our heads, adding to it and expanding it with each new place we arrive at? Or do we store the information for different environments – each room or each street – separately?

A lot of evidence suggests that we tend to store local bits of information. Meilinger let his test subjects stroll through the virtual city several times – always the same route and always in the same direction – until they had memorized it. Then he teleported them to a specific location along the route and asked them to point in the direction of certain other positions on their walk, such as the starting point or their destination.

Most test subjects managed to accomplish this task faster when they were asked to indicate points that lay ahead of them rather than behind them. Test subjects also found it easier to orient themselves when they were aligned along a street – that is, positioned in such a way that they could have run straight along it. They could point to the required location more accurately in these circumstances than when they were, for example, staring at a wall. In other words, they used local landmarks for orientation rather than global reference points, such as points of the compass.

But this is not always the case, as the Tübingen-based scientists discovered to their great surprise during another experiment. Julia Frankenstein, a former graduate of the department, placed her test subjects in a photorealistic simulation of the old city center of Tübingen. At the time of the experiment, all of the test subjects had lived in the Swabian university town for more than two years, and seven years on average. So they knew it inside out and, unlike the walkers in Meilinger's virtual environment, did not have to memorize the routes from scratch.

KNOWING A CITY LEADS TO A DIFFERENT STRATEGY

Just as in the experiment previously described, Frankenstein teleported her test subjects to certain positions in the town and asked them to point from that position to particular landmarks, such as places of interest. Astonishingly, these Tübingen residents managed this best when they were "beamed" to the aforementioned position in the old town and were facing north, exactly as the location would be shown on a town map. So in this case, the test subjects did not use local frames of reference for orientation – How do I get there? What route do I normally take? – but instead by using a compass point, a global reference point.

Rather than being built along a straight north-south line, the center of Tübingen is a typical "old town" of haphazard winding streets. This suggests that the "north alignment" effect is not restricted to Tübingen, but presumably also occurs elsewhere. The initial data gathered by Frankenstein using volunteers from other places indicates exactly this – people who are familiar with their town tend to use north as a reference point for gaining their bearings. >

Photos: Roswitha Ziegler (top), MPI for Biological Cybernetics – Tobias Meilinger (bottom)

1 | Almost real: The scientists used this photorealistic simulation of Tübingen to test how people orient themselves in their home town.

2 | The experiments show that we locate destinations in a familiar town based on the points of the compass – apparently because we have a map of them (in this case Tübingen town center) in our heads – and that map is aligned to the north.

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The scientists in Bülthoff's team believe this may be because, over time, we not only memorize our experience of different routes, but also the street map of the town itself. And that is always aligned to the north. "Ultimately, this means that the human brain is definitely capable of using different navigation strategies," explains Meilinger. "And if we already know the map of a particular environment, have memorized the layout of a town we often visit for instance, we will refer back to it." When we are new to an area, however, we learn it item by item, and store the information in small, local bits. And then we keep piecing these back together, depending on what we're doing at the time. Meilinger cites an example: "Point toward the cafeteria," he instructs me. I hesitate briefly before pointing in the direction where I think we got our coffee half an hour ago. "Pretty close," the scientist says in praise. "You probably built a mental model in your head of the way there – from your present position and using landmarks you memorized as you went past them."

Further experiments based on the psychologist's virtual city suggest that this is, in fact, the case. When the test subjects were teleported to intersection number four, for example, it was relatively easy for them to point from there to the third, then the second, and finally, the first turnoff, and only after that to their starting point. Things became trickier when they were asked to leave out the intermediate points, and instead to point to their starting position right away and intersections one, two and three only after that. The same applied when they had to point to stops on the training route that, theoretically, still lay ahead of them – in other words, when they were asked to point from the fourth intersection to the fifth or sixth intersection, and so on. Our brains find it easier to map a route starting from our own location than from any other position.

WHAT ROLE DOES OUR SENSE OF BALANCE PLAY?

Meilinger explains the results of the investigation. "This shows that we integrate information about a route incrementally – that is, one step at a time – and starting from our current location. I assume that, wherever we happen to be standing, our brain creates a mental model of our surroundings, or assembles a route made up of different impressions." And this includes the sequence in which we noticed distinctive details, such as whether we saw the red house first, then a hydrant and only then a bus stop at the third intersection. Perhaps this directional thinking also explains why we sometimes choose a different route home than the one we took on the way there.

Visual impressions are certainly extremely important for orientation. But there's more to it than that. Anyone who has strolled for hours through an unfamiliar city can probably remember if a certain street was really long. "We plan to investigate how we process information about distances in our navigation system," says Meilinger, referring to a future research project.

Meanwhile, his boss, Heinrich Bülthoff, is keen to go one step further by adding another dimension. In the Cyberneum, right next to the room in which Meilinger's test subjects stroll through a virtual city, stands a kind of flight simulator, a robot arm with a seat on the end. "We can use this to investigate how pilots orient themselves when flying. They process not only visual information but also information generated by their sense of balance," explains Bülthoff. After all, spatial navigation is a multisensory process. Researching it means incorporating all of our senses, one step at a time. ◂

GLOSSARY

Place cells
Specific neurons in the hippocampus that start to "fire" when an animal is in a specific location corresponding to the relevant environment, the place field of the cell.

Graphics: MPI for Biological Cybernetics – Tobias Meilinger (top), map: 2010 extract from the official map of the university town of Tübingen