How Babies **Get to Grips** with the World

Playing in the name of science: Happy as a sandboy and watched over by his mother, Moritz sees whether he can take the yellow table tennis ball from the koala bear which is being held in front of him by technical assistant Maria Zumbeel. The video camera (in the background) records Moritz' behaviour.

In the first months, babies learn more than they ever do later in their lives. They explore the world and use their senses to cope with a wealth of stimuli and impressions. **GISA ASCHERSLEBEN** *and her research group "Infant Cognition and Action" at the* **MAX PLANCK INSTITUTE FOR PSYCHOLOGICAL RESEARCH** *in Munich are investigating how the basic principles of action control and the understanding of the actions of others develop in the first eighteen months of life. Her central assumption: even young children regulate goal-directed actions by anticipating the effects that these actions produce in the world.*

Moritz* seems to be in a wonderful mood. He peeps cheerfully out from his car seat in which his mother carries the barely nine-month old infant to his various appointments and outings: visits to the doctor, shopping, meetings with his mother's friends, trips to see other children – all the things that a baby experiences. Moritz is completely unaware that there is anything unusual on today's agenda. He is being used for research, by taking part in a study in which scientists are observing the behaviour of healthy, normally developed babies.

*Names changed by the editor

PHOTOS: WOLFGANG FILSER

"We've got an invitation for you!! We'd like your baby to help us!!" Monika Holzmeier was surprised to receive the letter from which a picture of a baby with rosy cheeks and a yellow halo round its head gazed up at her. "Have you ever wondered how babies understand other people's actions and from what age they are able to imitate others? How do babies learn to grasp hold of things and deliberately move them? And how do they recognise for themselves the consequences of their actions?" Monika Holzmeier was unable to give a firm answer to any of these questions, even though she spent a lot of time with Moritz. So it seemed only logical that she should accept the offer made to her by Munich's Max Planck Institute for Psychological Research. "Our research group is looking for scientific answers to these questions. We would be delighted if you and your baby would participate in our studies," read the invitation.

"The Max Planck Institute – straight away I thought that sounded pretty serious", says the mother. "Of course you're glad to help and it's fun as well." So this is how the little world explorer comes to be a guest of the "big" researchers today. Monika Holzmeier sits in the child-friendly waiting room in the institute, which has absolutely no hint of a laboratory atmosphere whatsoever. There is a changing table, toys, and a well-equipped little kitchen area with microwave and bottle warmers – just in case the hungry little mite needs to be fed at any stage. This is where the mother and child are greeted by the scientists who want to get to know Moritz before the start of the observations.

For hundreds of years children were generally regarded as incomplete adults. They were defined by the things that they were unable to do and did not know. Babies were perceived as being passive entities who noticed little of their surroundings during the first three months of life, reacting to their environment only in a reflex-like way. This changed at the beginning of the 20th century when interest was awakened as to how the mind and brain change and develop over the period of a lifetime. Added to this, the systematic observation of babies revealed their incredible capabilities and skills which soon came to characterise the newly termed "capable baby".

In the 1930s the founder of modern developmental psychology, Jean Piaget, observed the development of his own children and meticulously detailed the apparently coincidental behavioural patterns in diaries. This enabled him to recognise that babies possess a certain amount of knowledge from birth on and are also born with a well-developed capacity for learning – a recognition which began to establish itself more and more as research with babies became increasingly popular as a field of scientific focus.

Many studies have shown that babies and young children know and learn a lot more about the world than was thought. Young infants are not just bundles of reflexes, but they observe their environment and fellow beings precisely, make predictions, draw conclusions, and may even be looking for explanations. At the moment, developmental psychologists know more about what children can do at what age than about how they learn this. This is the reason why teams of scientists all over the world are working on theories as to what babies know at each stage of their development, how this knowledge develops, and how they come to learn more.

Do Babies Understand What Other People Do?

There are several institutes and organisations within the Max Planck Society concerned with infant studies. At the Friedrich Miescher Laboratory for biological research groups in Tübingen, for instance, the processes of recognition of faces and objects in babies are being studied. At the Max Planck Institute for Evolutionary Anthropology in Leipzig scientists are researching how social expectations arise during the first year of life, and how imitation and communication skills develop during the first 18 months.

The research group "Infant Cognition and Action" at Munich's Max Planck Institute for Psychological Research, headed by Gisa Aschersleben, is specialising in the cognitive mechanisms of action control in the first two years of life. There are three subject areas: firstly the scientists are researching the cognitive aspects of infants' action control and its development, secondly the development of children's understanding of actions performed by other people, and thirdly, they are interested in how these two aspects are related to each other.

But what is an action? A clear definition of this term is the basis of the group's research work. Aschersleben and her colleagues assume that actions are directed towards goals, and that they differ from simple movements in this respect. Thus, actions consist of two components: the movement and the goal – corresponding to the well-established distinction between means and ends. In order to be able to interpret observed actions as well as to perform goal-directed actions on their own, even young babies must be able to differentiate between a movement and its goal. The baby researchers in Munich feel that developmental psychology literature has paid too little attention to the idea that the effects of an action – i.e. the effect of the action on the infant's environment – are of particular significance for an understanding of that action.

All projects carried out by the Max Planck psychologists in Munich are motivated by the "common coding approach". This approach means that the researchers leave behind the classical idea that the processes of perception and action control each belong to their own operating systems, and that the corresponding sensory and motor information must be processed in isolation. The researchers are more of the opinion that the perceptual processes and processes of action control share a common represention in the cognitive system. The codes of perceived events and actions to be produced - can thus communicate directly without the need for a translation process between the perceptual and motor side.

Actions and perceived stimuli are processed in the same way – namely as events in the environment. If, therefore, actions are controlled and regulated by the cognitive anticipation of their effects, this must apply to adults as well as infants. In detail this means: it should be possible to prove in babies that the effects of movements influence the way in which children control their own actions and how they interpret the actions of others.

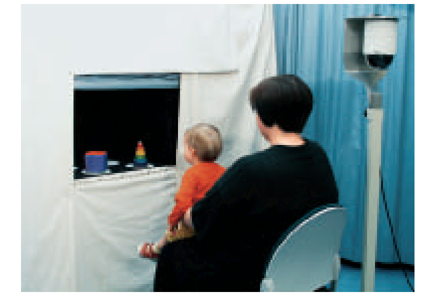
But how can proof of babies' understanding of actions be established? After all, they cannot provide a verbal answer. The advent of video technology made the work of developmental psychologists easier – this is one of the reasons why increasing numbers of scientists worldwide have been turning to infant studies since the 1970s. Using video cameras, it is possible to observe and record the behaviour of babies in firmly controlled conditions. Finally, the video material is analysed frame by frame in order to code and quantify the individual elements of behaviour and the duration of this behaviour. These results are then looked at in relation to the corresponding expectations and hypotheses.

Looking Behaviour Reveals Curiosity and Boredom

The baby researchers in Munich use various established methodological procedures. They make use of children's curiosity and their tendency to imitate actions. In the "preferential looking paradigm", two objects or two actions are shown to the baby at the same time, and the looking times of the baby are analysed. If the infant prefers one of the actions, that is when he looks at one action longer than at the other, this is taken as evidence that he has perceived a difference between the two actions. The "habituation paradigm", on the other hand, is based on the fact that babies begin to get bored if they are shown the same things several times. The infant's interest for a repeated action decreases, and the looking times become shorter because he becomes habituated to the sight. If new actions or objects are introduced, attention increases again and the looking time becomes longer (this is called dishabituation). From this behavioural change it is possible to deduce what characteristics of an action are of particular significance to the infant.

Movement or Aim – Which Is More Interesting?

Using this method, Gisa Aschersleben and Bianca Jovanovic investigated whether infants recognise the purposefulness of actions performed by other people. Their study builds on research by American Amanda Woodward, in which babies repeatedly saw a hand on a small stage grasping for one of two toys. As soon as the babies had habituated to this action, the position of the toys was changed, and the hand grasped one or the other of the toys alternately. It appeared that even at the age of six months, infants dishabituated more strongly – i.e. looked for longer – when the goal object of the activity (the toy) changed, than when the movement itself changed. However, a corresponding pattern of reaction was not evident when the movement looked "non-purposeful",

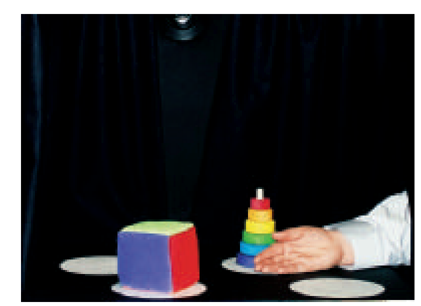


Sitting on his mother's knee, the baby is watching what the arm on

the stage is doing in an unintentional looking movement with the back of the hand.

The eye movements of the children reveal that if the target object, i.e. the toy, is

changed, they look for longer than when the arm moves in a different direction.



The researchers follow the sequence of events on the monitor and record them.

The research group "Infant Cognition and Action" with Gisa Aschersleben (middle).

in the case where the toy was touched by the back of the hand. Woodward concluded from her results that babies are capable of distinguishing between purposeful and non-purposeful actions.

But how do babies make this distinction? Aschersleben's team was keen to find this out. They suspected that the visual pattern for "grasping" and "touching with the back of the hand" differ because the children have different expectations with regard to the possible effects of the actions. Even infants are aware that grasping typically leads to a change of an object's position. Non-purposeful actions, on the other hand, are probably not associated with specific expectations as regards their effects. If a non-purposeful action were, however, to have a visible effect on the object, infants would interpret the action as being purposeful and react similarly as to a grasping action. To test this hypothesis, Aschersleben and Jovanovic showed six month-old babies a hand touching a toy with the back of the hand and then pushing it several centimetres.

As expected, the children behaved in a similar manner under these conditions as they had in the Woodward grasping study: after the habituation period they paid much more attention to the change of the goal toy than to the change in the movement. Goals and effects of actions are therefore particularly important for an early interpretation of what people do. It may be that this specific sensitivity towards effects helps babies to organise the complex plots that they observe in their environment every day into simple and meaningful sequences.

Whether babies transfer things they see other people do to their own activities is investigated with the imitation paradigm which makes use of the baby's imitative instinct; the baby is shown a specific sequence of actions with an object. The baby is then given the object to play with, and the researchers analyse whether she carries out the observed movements more often than a child in the control group to whom the actions have not been demonstrated.

Bear, Ball, Cup – The Means and the End

Moritz is a participant in the control group and is sitting at a table in the observation room on his mother's lap. She is only allowed to hold Moritz by his hips, allowing him to play without interruption. In contrast to the waiting room, this room is decorated in muted colours and simply furnished – nothing must be allowed to distract the child from the movements and objects he is shown. Even the video cameras which record Moritz' behaviour from different angles are barely noticeable. Whilst technical assistant Maria Zumbeel begins demonstrating the movements, everyone in the technical room next door is watching the monitors intently: how will Moritz react?

The little lad is really taken by the koala bear that Maria Zumbeel shows him. A yellow tabletennis ball is attached to the cuddly toy's right arm. The assistant also shows him a cup in which there is a second, identical ball. She shakes the cup and the sound of the rolling ball can be heard. Moritz is really keen to lay hands on the objects immediately, but they are cleared to one side. It is ten minutes later, once Moritz has processed several other tasks, before the bear with the ball and an empty cup are put in front of him. So is he still able to remember what Maria Zumbeel showed him? And will he hit on the idea himself of taking the ball from the bear, putting it in the cup and so constructing a kind of rattle?

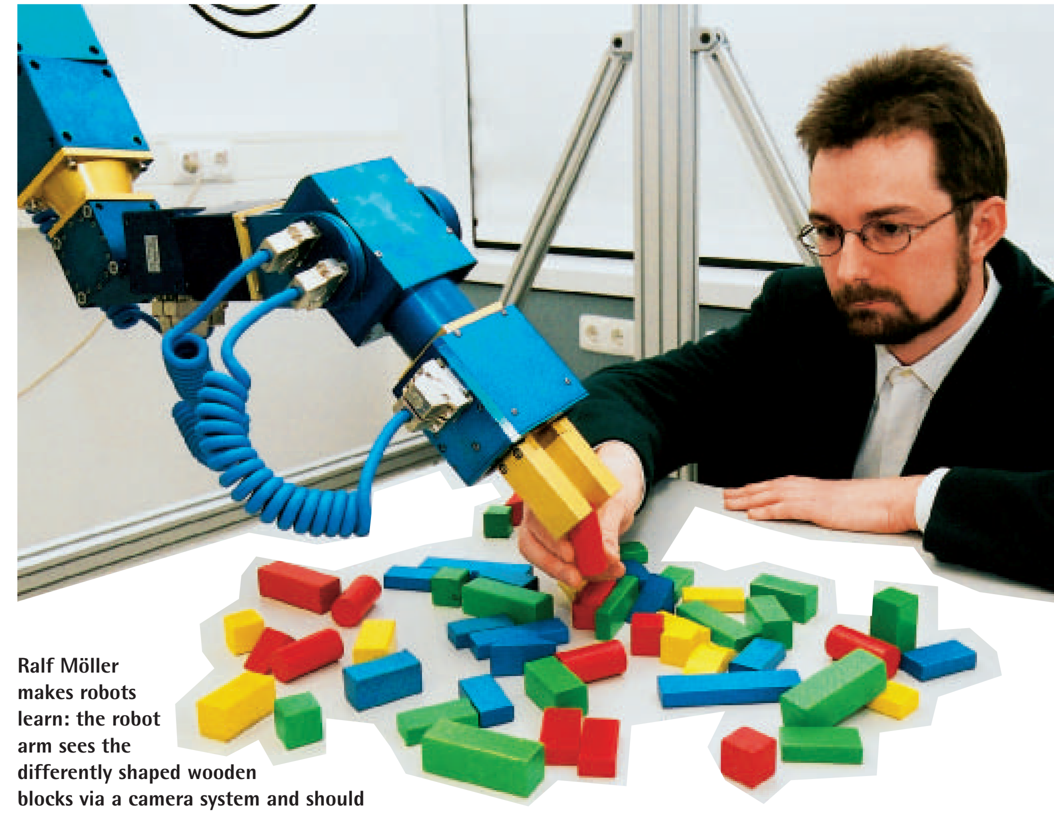
"It's a good job the ball can be washed", says Birgit Elsner who is watching what Moritz is doing on the monitor in the technical room. He does in fact take the ball from the bear, but does not even think about putting it into the cup. He is much more interested in investigating the ball with his hands and mouth. Birgit Elsner is not surprised by this; "Nine month-old babies don't put the ball into the cup after we have demonstrated it to them ten minutes previously", she comments. If the babies are only three months older though, they do throw the ball into the cup after they have been shown. But even at this age, infants do not make the connection between the means ("Put the ball in the cup") and the end ("Shake the ball in the cup to make a noise") unless they have seen the complete action sequence. The fact that one-year-old children imitate action sequences may be taken as evidence that babies first understand other people and in this way learn that people do purposeful things. This knowledge could then be useful to babies to help them understand themselves and their own actions.

Playing for the Scientists Is Tiring Work

By now, Moritz has been "working" in the observation room for almost fifteen minutes and is beginning to get tired. The koala bear, tabletennis ball and Maria Zumbeel's friendly animation are only of limited appeal to him now. He is also starting to complain about the limited field of action on his mother's knee. But this is not an issue, because the research programme is always geared towards the children's willingness to participate. Despite this, Birgit Elsner and her colleagues always reckon on a few observations being unusable because the children show no interest in the studies, are very scared of strangers, or begin to cry. "You have to invite about 30 children in order to obtain 24 usable video recordings", she says.

Fortunately, there are enough interested parents in Munich who accept the Max Planck Institute's invitation. And the fact that parents and children are then more than happy to come back for further studies is not just due to the patterned neck scarves or the certificate with Polaroid photo which the babies are given as a thank you gift for their first involvement in research. It shows rather that the claim that Birgit Elsner has formulated for the working group is being fulfilled: "Fundamental research work with babies does not just require scientific ability. It also thrives on parents and children feeling comfortable with us."

Susanne Beer



Ralf Möller makes robots learn: the robot arm sees the differently shaped wooden blocks via a camera system and should be able to pick them up properly.

Perception and Action – A Unity

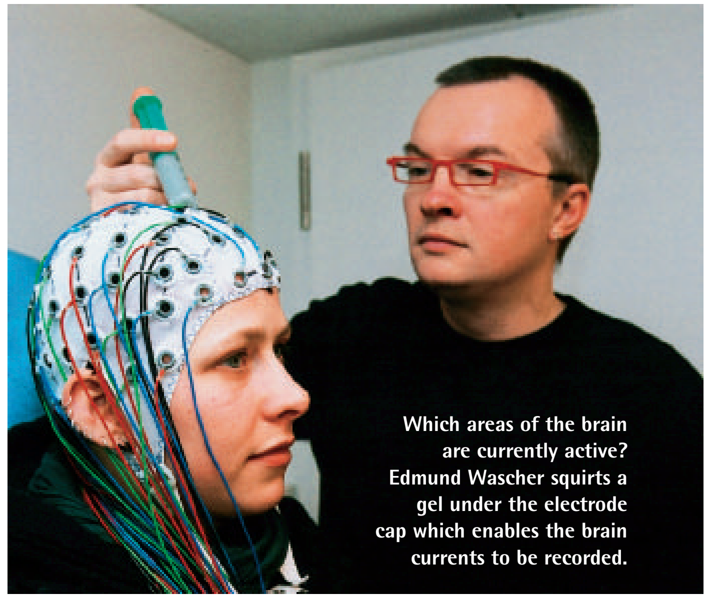
Cognitive psychological research with an action-orientated focus has been at the centre of work undertaken by the Max Planck Institute for Psychological Research since the appointment of Wolfgang Prinz as Director. Its researchers are carrying out studies aimed at a comprehensive analysis of the cognitive basis of action control, not just with babies. The reason for this is that cognitive psychology has, for a long time, largely ignored action processes and restricted itself to people as perceptive, but not active, entities. Now the way in which the processes of perception and action mutually influence each other is to be more closely investigated. By setting up three independent junior research groups, Prinz has now further extended the field of research: the groups are investigating the "Cognitive Psychophysiology of Action", researching "Cognitive Robotics", and looking into "Sensorimotor Coordination".

A Robot as a Model

Usually, human cognition and behaviour is analysed based on the results of experiments, but Ralf Möller's six-strong Cognitive Robotics group is taking the opposite, synthetic approach: it is attempting to formalise models of perception and action selection and translate them into computer simulations which will ultimately "synthesise" behaviour. When observing the behaviour generated by the simulation, one of the main conclusions which can be drawn, on the one hand, is how useful a model is – recognisable by whether it produces appropriate behaviour. On the other hand, it can be compared with the behaviour of human test persons in order to gain further insights into the underlying brain processes. To this end, the members of the group are attempting to reproduce and explain the results of experiments carried out by their “analytically” working colleagues in the institute; this is done by means of artificial neuronal networks – i.e. simulations of processes in the biological nervous system. A characteristic of the synthetic method is that usually only the model of neuronal processes is simulated but not the environment in which perceptions and actions take place. This is something that many groups involved in similar research have started to avoid, as simplifying assumptions as regards the design of the simulated environment have frequently led to erroneous developments in the neuronal models. In the group’s laboratory, there are therefore several “artificial agents”, including a robot arm with six joints which receives visual information about its environment from a moveable stereo camera system. Within reaching distance of the robot arm are various objects, at the moment coloured, differently shaped wooden building blocks. Its perceptive capabilities are ultimately supposed to be revealed by the robot system exhibiting purposeful behaviour – for instance, by grasping objects in the right spot and in a suitable orientation.

The theoretical concepts of the group clearly indicate a turning away from the classical “cognitive paradigm”, which sees perception and the selection of actions as being separate processes. An action-orientated perceptual concept therefore underlies the models, which aim to explain a fundamental understanding of space and shapes: objects are “represented” in the brain not directly by their visual characteristics; rather, their visual characteristics point indirectly to the sensory consequences of handling them – an object is therefore immediately perceived in the context of its associated action. This requires knowledge about the consequences of one’s own actions: the robot arm learns this by interacting with the objects within its reach.

Artificial neural networks create and store the associations between the robot’s movements and the resulting changes in the perceived image. The learned knowledge is then used to predict the consequences of actions in unknown situations. This ultimately leads to the fusion of perception and the selection of action: a visual scene is “grasped” by predicting the consequences of the action; however, at the same time, suitable actions can be chosen based upon the prediction. ●



Which areas of the brain are currently active? Edmund Wascher squirts a gel under the electrode cap which enables the brain currents to be recorded.

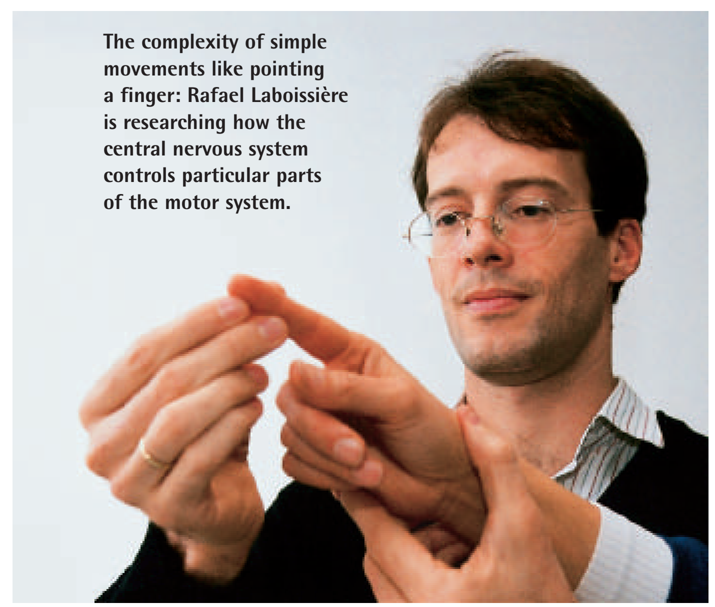
Taking Two Routes through the Brain

Edmund Wascher and his colleagues are investigating the cognitive psychophysiology of perceptual and motor processes. They are hoping, particularly by using EEG (electroencephalography), to find out what happens physiologically in the brain when visual information is translated into manual action. The EEG is used to obtain a better understanding of the mechanism of information processing. The study involves participants solving tasks over a period of several hours, during which time up to 60 electrodes on the scalp measure which areas of the brain are active. Amongst other things, Wascher’s team makes use of the principal of contralaterality: spatial information is always processed in the opposite half of the brain. For instance, if one sees an object on the left, the cortex of the right hemisphere of the brain is more active than that of the left hemisphere. Conversely, if increased brain activity is measured on the right, this is a good indicator that the brain is currently processing a stimulus from the left.

If the activities of both sides are compared, the EEG reveals so-called event-related lateralisations which reflect the processing of spatial information. They also indicate how different areas in one half of the brain interact with each other. Depending upon where an area of increased activity lies, it is possible to tell whether stimulus processing or preparation for motor activity is taking place and thus to track the flow of information from the eye to the hand. One of the group’s primary considerations is that psychological theories have to be also physiologically plausible.

The physiological background of the group’s theoretical concept is the division of the visual system into two paths of information processing: the dorsal and ventral streams. For a long time the general consensus has been that these two pathways are not only physiologically separate but are also responsible for different tasks in stimulus processing. Edmund Wascher is now seeking to prove with greater certainty the assumption that dorsal and ventral processing differ more with regard to their temporal dynamics and less as regards different types of stimuli – if this is the case, the dorsal path would be responsible for fast visuo-motor coordination, whilst the ventral path reflects the slow or cognitively conveyed stimulus processing. The group is now in a position to test this assumption – until now based upon studies of patients – on healthy subjects as well.

In a series of studies, brain activities of participants were studied whilst they solved simple tasks. Depending upon the appearance of a particular stimulus on a monitor, the participants had to press a key with the right or left hand. If the participants received irrelevant information in addition to the actual target stimulus, this information might either speed up the pressing of the key (if the irrelevant information supported the concept) or slow it down (if irrelevant and relevant information contradicted each other). In these experiments, it was shown that only accelerating effects were clearly attributable to activation of the dorsal stream. If, however, in virtually the same arrangement basal fundamental prerequisites were violated (such as, for instance, the participants having to cross their hands permanently), this mechanism was no longer active.



The complexity of simple movements like pointing a finger: Rafael Laboissière is researching how the central nervous system controls particular parts of the motor system.

Although irrelevant information also influenced the action in this case, it was no longer possible to start out from comparable information processing. Wascher and his group now suspect that there must be a string of psychological phenomena that have great similarities with each other on the surface, but are based on different mechanisms and are thus also realised separately in the brain. In order to verify this, the processing of information from the eye to the hand is now being put under the microscope step-by-step. ●

Chewing, Speaking and Pointing

Rafael Laboissière’s junior research group has been set up very recently within the framework of the co-operation agreement between the Max Planck Society and the French CNRS (Centre National de la Recherche Scientifique). It will investigate how the human central nervous system (CNS) copes with the complexity of the motor system. During the course of his research activities in France, he developed a biomechanical model of the vocal apparatus which he intends to use as a springboard for work in the junior research group. What principles does the brain use to generate and coordinate the commands for producing speech or chewing? Is it possible that these commands might be organised in a simple way? To what extent does the CNS have to take into account the complexity of the biomechanical periphery when controlling movements?

Besides the vocal apparatus, Laboissière is also looking at the interaction between hand and finger movements. “What causes people to use either the wrist or sometimes just the fore-finger when pointing? And how does the nervous system learn the degrees of freedom for the arm, hand and finger? Is it of any significance that the hand and finger are of different sizes and hence differ in weight?” asks the scientist. Because although pointing and opening the jaws are simple movements, the brain has to co-ordinate dozens of muscles precisely. And it appears to do this completely effortlessly.

Laboissière also takes into account the Prinz principle of common coding. Perhaps, thinks the researcher, the emergence of a particular degree of freedom of movement may be closely linked with the common representation of the proprioceptive perceptual effects associated with it (perceptions of one’s own body with its muscles, joints, and tendons) and the muscle coordination to achieve this freedom of movement. SUSANNE BEER