Photo: Gesine Born

The nature of **children's curiosity**

Children explore their environment with all their senses, and their curiosity knows no bounds. From a certain age onwards, they never seem to stop bombarding adults with questions. Many people consider this form of active learning to be ideal. Until now, however, almost nothing has been known about the strategies that children use on their own initiative. At the **Max Planck Institute for Human Development** in Berlin, **Azzurra Ruggeri** and her team are developing sophisticated tests in order to understand the way children learn.

TEXT **TINA HEIDBORN**

It's Friday at the Natural History Museum in Berlin. In a closed-off, quiet corner in the area at the back of the museum, a "magic machine", clearly self-made, a cardboard pyramid painted black and with small silver stars stuck on, has been placed on a table. At the front, it has a small, rectangular balcony containing an egg that rattles when it is shaken. If the egg rattle is placed on the balcony, a colored ball on the tip of the pyramid starts to rotate, lighting up and making sounds.

Five-year-old Marta is impressed: "Wow," she says, and yes, she'd like to play this game. While for Marta this is a game, for the team led by the developmental cognitive psychologist Azzurra Ruggeri at the Max Planck Institute for Human Development, this is a sophisticated experiment conducted by her Research Group "iSearch – Information Search, Ecological and Active Learning Research with Children".

According to the researcher, "active learning" does not just refer to children moving a lot while learning. The term "active" also refers to being able to make learning decisions yourself, engaging in *self-directed learning* as it is known in research terms. Azzurra Ruggeri uses the word "ecological" to describe the ability to tune, adapt one's own learning behavior to the specific task's circumstances and requirements to be able to learn in the most effective way possible. Professor Ruggeri's first results suggest that even very young children are able to collect and evaluate information "ecologically," selecting the learning path that promises the greatest success. >

Colorful, but difficult: with the monster game on the tablet, ten and eleven-year-olds are asked to learn the connection between the properties of the monster – friendly, cheeky, funny – and the number of fruits picked, shown on the top right-hand corner of each card.

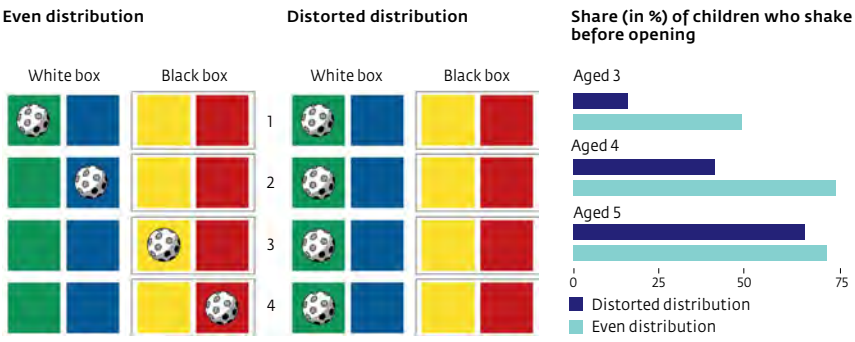
Top Rattles when shaken: the egg (center) is hidden in one of the four colorful round boxes, which are then placed in the two larger black or white boxes. Pre-school children are asked to find out where the egg shaker is hidden by shaking or opening a large box. In this game, when children find the egg shaker, they get to play with the magic machine, which lights up and moves.

Below The egg shaker is either hidden in the green, blue, yellow or red box in a fixed sequence ("uniform condition"), or always in the same box ("skewed condition"). In the final hiding game, 3- to 5-year-olds adapt their searching strategies to the condition they were in: they tend to shake the large box more often in the "uniform condition", where they don't know where the egg could be hidden, as compared to the "skewed condition", where they are more likely to open the box where they learned the egg should be hidden.

Individual sub-aspects of this area of study are now being intensively researched, according to Azzurra Ruggeri. Examples include how children learn by asking questions, to whom they direct these questions, and how much information they obtain from the way in which they ask them. After all, children find out about the world through questioning. According to a study by the University of California, Merced, children aged two to five ask an average 76 to 95 questions per hour when talking to an adult.

The question-asking games that Azzurra Ruggeri and her team use in their research sound playful: why was the Monster Toma late to school? Who lives on Planet Apres? Even toddlers can judge which questions are the most informative and use the answer they receive to solve problems, or to decide to whom they should continue to direct their questions. However, it is particularly challenging to study young children of pre-school age. This is a key task of the "iSearch" Research Group. The purpose of the tasks is to observe how children spontaneously, actively learn. Azzurra Ruggeri describes her work as studying "children's potential for learning." This is the approach used by Jean Piaget, the Swiss biologist and pioneer of cognitive development psychology, who observed the development of his own children and developed his seminal theories on this basis.

The "iSearch" team is developing new kinds of tests in order to achieve its goal. One particular challenge arises from the fact that pre-school children do not have fully developed cognitive abilities or a rich vocabulary. In many of the standard question-asking tests, children generally ask questions that are way less informative than those asked by adults. Questions asked in these tests can be categorized into two types: *hypothesis-scanning questions*, in other words, those that check a single hypothesis or option (for example, "Is Toma late because he woke up late?"), and *constraint-seeking questions*, which tend to narrow down the available options by targeting features shared by several options (for example, "Is Toma



Photos and graphic: MPI for Human Development

Playful challenge: Silvia Martín Lence, a student assistant, explains the rules of another learning game on the tablet to one of the young participants.

late because of something he forgot?") and are usually considered more informative. In general, children up to age seven tend to predominantly ask hypothesis-scanning questions; later, this tendency becomes less prevalent and they grow out of it, until adulthood, when constraint-seeking questions are reliably preferred. However, Azzurra Ruggeri and her team have been able to demonstrate that even very young children can *identify* the most informative questions: if both types of question are presented, even 4- to 5-year-olds select the more general, constraint-seeking type when it is more effective. Their results suggest that by age 4, children are already able to assess the anticipated information gain from the different types of questions, even if they are not able to generate the most informative questions from scratch.

Indeed, to ask good questions from scratch, one has "to first identify features that can be used to ask questions, categorize objects at different levels according to these features, select the category that makes more sense to target, and then succeed in verbalizing the question," Azzurra Ruggeri explains. "This is extremely difficult!" Therefore, when very young children fail to do well in certain question-asking tasks, this does not mean that they are no good at learning. Here, Azzurra Ruggeri quotes her doctoral thesis supervisor, the well-known psychologist Gerd Gigerenzer: a hammer is a good tool if you want to bang a nail into a wall, but it is not a good idea to try to bang a screw into the wall. That is, one needs methods that are suitable and tailored to the problem to be investigated. Is it possible to study the effectiveness of young children's information search in a non-verbal paradigm? This is why the doctoral student Nora Swaboda and the research assistant Eva Kell asked five-year-old Marta to *search for the egg-shaker* in the Natural History Museum in Berlin. She plays the game enthusiastically, although it wasn't really planned: she was there just to visit the museum.

EVEN INFANTS MAKE USE OF PROBABILITIES

The training phase. First, Marta observes Eva, the experimenter, hiding the egg in one of four small, round boxes, each of a different color. Marta watches attentively. The four boxes are inserted into two larger, rectangular boxes – one is white and the other is black. Half of the children, like Marta, are playing the game in the "skewed condition", where Eva always places the egg shaker in the *same* small box, for example into the green box on the outer left-hand side. The other half of the children play the game in the "uniform condition", where the egg is always placed into a different small box. Thus, in the "skewed condition" children should learn that the egg is probably to be found in the green, outermost left-hand box, whereas in the "uniform condition" they should not know where the egg might be. Then Eva demonstrates to Marta that there are two ways of finding out whether a large box contains the egg shaker in one of the two smaller boxes inside: shake the big box or open it. Opening corresponds to a hypothesis-scanning question, whereas shaking is similar to asking a constraint-seeking question. During the test, Eva hides the egg shaker once more, and this time Marta has to close her eyes. Then Eva closes all boxes, and asks Marta to look for the egg shaker. Eva tells her she can open *only* one big box. What is Marta going to do? Because Marta was in the "skewed condition", she should have a strong intuition that the egg shaker is again hidden in the green box – after all, Eva always hid it there! In this sense, she should just go on and open

Photo: Gesine Born

the large box that she knows contains the green small box, and then open the green box. However, if she had been in the "uniform condition" she could not have known where the egg shaker could be hidden, and would have had to shake a large box first, to *hear* which large box makes the rattling sound, indicating that the egg shaker had been hidden in one of the two small boxes it contains. "If you don't know where the egg is, it makes sense to shake one of the large boxes first, so that you don't risk opening the wrong box. However, if you have an idea where the egg might be, because the tester always hid it in the same box, you can immediately open the large box and then the small box you know has it inside: you have a strong intuition about the solution, and you take what you think is a high chance for a quick win," Azzurra Ruggeri explains. Although Marta learned in the "skewed condition" that the egg is always hidden in the green box, she still decides to shake the large box first. It rattles. After hesitating briefly, she opens it, followed by the green round box, to find the egg shaker, which she immediately places onto the magic machine. She watches proudly as the ball on the pyramid lights up and starts to rotate.

Then it's her friend Jonathan's turn. He, too, is five. Eva hides the egg in the small green box – it's the *skewed condition* again. This time during the test, Jonathan decisively opens the correct large box and the green round box inside. Once again, the magic machine starts to move.

The study, now completed, found that 3- to 5-year-olds in the "uniform condition", i.e. when the egg is always hidden into different boxes, tend to shake a large box first, rather than open one, as expected. However, preschoolers in the "skewed condition" are more likely to open the box where the egg has always been hidden during training. According to Azzurra Ruggeri, this is a sign of their ability for ecological learning.

THE CHILDREN MAY BE INFLUENCED UNINTENTIONALLY

If we look at the individual age groups, another result emerges: most of the 3-year-olds immediately open a large box, whereas over half of the 4- and 5-year-olds shake a large box first. Overall, the younger children are, the more they tend to open the boxes rather than shake them. This resonates with the results of the traditional question-asking tasks, where the younger children are, the more they tend to ask hypothesis-scanning questions targeting a single object or hypothesis.

Azzurra Ruggeri says that she loves the challenge related to designing such studies/games. This sounds like logical puzzle work: extremely well thought through in advance and finely nuanced. What game could I develop to investigate this question? If I receive this answer at this point, what options do I then offer children? What patterns of results would I expect, how would I interpret them? When testing children, these highly complex basic research questions and hypotheses have to be packaged in a simple, quick, exciting game. Indeed, children must enjoy participating, and the game cannot last too long. For this reason, every game usually requires an extensive pilot phase, during which the team modifies and improves the details of the task, stimuli and instructions. For example, according to doctoral student Nora

Photo: Gesine Born

Age-appropriate preparation: it is important that children enjoy the games during which their learning behavior is observed. These include the fun-looking drawings of monsters, the special powers of which they can only discover by asking clever questions.

Photo: Gesine Born

Swaboda, the team worked for a long time down to the tiniest detail on how to arrange the training phase of the egg shaker game for children.

Nothing that the research assistant Eva does in the Natural History Museum in Berlin is improvised. Every action is precisely planned in advance. Even the words that the student uses to explain the game to the children have been learned by heart – always the same words, in the same order, with the same emphasis, but without sounding like a robot. Right at the end, Eva reminds the children of the two actions that can be performed to find out if a large box contains the egg shaker – shaking or opening. She alternates saying: "You can shake the box or open it," and in the next test run: "You can *open* the box or shake it." Children might just opt for the last option that she presented.

On this Friday morning, there's no lack of children and parents willing to take part. The idea of going to museums to conduct the tests was brought by Azzurra Ruggeri from the U.S., where she spent two years as a researcher at the University of California, Berkeley. Together with the egg shaker and its magic machine, there is also a tablet at the Natural History Museum in Berlin, with a kind of card game for seven- to ten-year-olds. With this game, the team is studying how children gather information when learning the correlation between the features of a card and its power, so to speak. The tablet initially shows 27 cards, each card displaying a different monster. Each monster has three qualities listed in on the cards, one below the other ("friendly", "cheeky", "funny"). Each property has a value, ranging from 1 to 5, indicating how strong the monster is on that feature. Each monster card also has an additional two-digit number on the top right-hand corner of the card, which is initially hidden. This is the number of fruits that the monster has picked. What is the connection between the qualities of the monster and the number of fruits?

A brief look at the tablet screen filled with the monster cards already shows that while the game is attractive and colorful, it is also quite difficult. The players are confronted with a fairly complex learning environment, a very large amount of fragmented information from which conclusions have to be drawn – a high level of uncertainty.

ONLY A MATHS PROFESSOR WON FULL POINTS

There are two different variants of the game. In the "active" version, the player is allowed to select which cards they want to see: when they click on them, the number of fruits that monster picked gets revealed. In the "passive" version, the monster cards on which the player is allowed to see the number of fruits are selected randomly by the program. During the test, after this learning phase, the children are presented with the feature profile of some new monsters, and are asked to estimate how many fruits that monster has picked. For every correct answer, they are given ten cents, because – unlike for younger children – pocket money is a very good incentive for older ones to play the game at their best.

Can children learn to predict the number of fruits a certain monster picked by looking at the monster's feature profile? Does learning success vary depending on the game variant? What methods do the children use to collect information? Indeed, the scientists observe which cards the children select in the active variant. For example, do they prefer to look up cards on which the monsters have extremely high or extremely low values for one of the three monster qualities, "friendly", "cheeky" and "funny"? This tendency can indeed be observed: many players initially select cards with an extremely high or low value for the property on top of the card (which property that is – funny, cheeky or friendly – is randomized across participants), and then cards where the second property has an extreme value, and finally cards where the property on the bottom is extreme. It is too early to draw conclusions and answer these questions, as the data collection is still ongoing. However, in another project, the group led by Azzurra Ruggeri has already demonstrated that children aged seven and above perform better in a memory game under active learning conditions than in a more passive condition, thus providing proof of the advantages of active learning.

With this tablet game, the maximum amount that can be won is seven euros. Many of the ten and eleven-year-olds

A psychologist with a penchant for logical puzzle work: Max Planck Research Group Leader Azzurra Ruggeri is developing sophisticated but funny games to investigate children's active learning.

go home with around six euros and more. This is not much less than the adults with whom doctoral student Angela Jones previously conducted the test. Among the children, the seven-year-olds whom Angela Jones has also already tested, those who were already in their second year of school often did better than those who were still in their first year. It is likely that the second graders were helped by their more advanced knowledge of maths. "Mathematical skills do play a role here," explains doctoral student Angela Jones, "but so does intuitive learning." The only participant to be rewarded with the full seven euros was a professor of maths.

Onyun, an eleven-year-old from Switzerland, is very happy with his 5.80 euros, which he is putting into his pants pocket. How did he do it? "I guessed and relied on luck" – at least, that's what he says. The evaluation of the data collected from his game session will likely provide a more precise insight.

"I wanted to do something concrete, find a way to get answer to the questions I considered crucial," says psychologist Azzurra Ruggeri. In Italy, she studied philosophy for five years, focusing on logic, philosophy of science and decision theory, until she began to find it too abstract. She was no longer interested in investigating decision theory only from a logical and philosophical perspective. She switched to psychology and came to Germany. She already enjoyed working with children as a scout group leader.

With "iSearch", Ruggeri and her team are now conducting empirically supported basic research. Many of Azzurra Ruggeri's games are conducted in several variants. Ruggeri can also envisage studying learning at earlier and later stages in life. Currently, she is designing an eye tracking study to investigate how babies actively learn by looking at where babies focus their attention. The results contribute to building a more complete, fine-grained picture of children's learning. Her goal is to expand current empirical research, to obtain greater knowledge as to how children learn, and then to put this knowledge into practice. Indeed, she hopes that her findings will later be applied in educational settings – wherever children learn. The basic research that she makes look so playful is later intended to make a contribution towards making it easier and more effective for children to learn, for example in schools, capitalizing on what they can already do from an early age. However, only when there is detailed knowledge of how this complex process works can it be supported purposefully. Although instructional methods inspired by active learning are spreading, the scientific findings that should inform such interventions are still very limited. "There are many myths and assumptions," she says. Currently, Azzurra Ruggeri is also a professor of cognitive and developmetal psychology at the School of Education at the Technical University of Munich. ◂

SUMMARY

- **It is only possible to understand how children actively learn with the help of a large number of observations and tests. To date, only few findings are available.**
- **Pre-school age children can already differentiate between more and less effective given questions. From about age seven and above, they are able to generate more effective questions themselves.**
- **Children from age seven and adults perform better in memory games when they are given active control on the materials to be studied.**
- **One goal of the research is to make learning easier and more effective, capitalizing on what children can do already from an early age.**

Photo: Gesine Born

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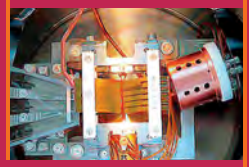

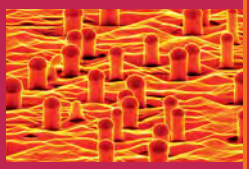

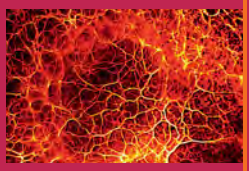

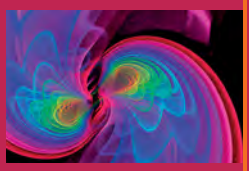

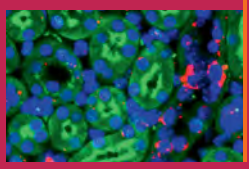

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