Chapter 4. Understanding each other

This chapter describes the research theme 'Understanding each other' in two sections. Section 4.1 provides the substantive preparation on the theme for teachers who want to get started with it. This section deals with content on how we understand each other: Why is it possible that people understand each other and why do robots have so much difficulty with regard to this? And what happens in our brain when we communicate? Additionally, the section also describes how scientists have conducted their research and where more information on the subject can be found.
Section 4.2 describes, on the basis of the seven phases of inquiry-based learning, how this project can be carried out at three levels in the classroom. Our 'Guide inquiry-based learning', in which the general guideline of the seven phases is described, forms the basis for this. We, therefore, recommend the use of the 'Guide inquiry-based learning' as the starting point for the execution of a project in the classroom.

Project team 'Understanding each other'
This chapter is based on a project designed by a project team in which researchers from the Radboud University collaborate with schools and the WKRU. The project team 'Understanding each other' consisted of the following people:

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4.1 How we understand each other

Dr. Arjen Stolk, Miriam de Boer Msc, Dr. Iris van Rooij and Prof. Dr. Ivan Toni

Introduction

Understanding each other – we do that, often through language. Our daily conversations appear to revolve around words and sentences at first, but if you think about it for a moment, it appears that there is more to it than merely formulating grammatically correct messages. Imagine, for instance, you are walking down the street. Someone asks you where they can find the nearest supermarket – how do you react? Your reaction may depend on the foreign accent of the interlocutor or on the fact that she is in a hurry or is travelling by car. All these factors play a role in how you answer: you take into account that she is not familiar with the surrounding area. Or you answer quicker or you provide instructions on how to get there by car. In this way, you probably manage to convey instructions that are tailored to the interlocutor, in a manner that goes well beyond what she said. During your communication, you continuously consider what the interlocutor might already know. She, in turn, takes into account what you already know of her interpretation of your message. By taking into account what you both collectively know, you can even manage to communicate with someone that does not speak the same language. For example, when you want to order a drink during your vacation in a foreign country, you can reasonably assume that a bartender knows that you can drink from a glass, and that he knows you both know that. Given that presumed shared knowledge, you could convey the idea that you're thirsty by pointing to a glass or by pantomiming a drinking motion. Language, therefore, is not necessary to be able to understand each other and is never the only element that plays a role in human communication.
This chapter addresses a fundamental question: how can we understand each other? We explain why this is less straightforward than it might seem at first glance, for instance why robots have difficulty understanding us. We then discuss how we researched these human social skills, using controlled conditions to capture what goes on in our brains when we understand each other. We conclude by elaborating on what these scientific breakthroughs teach us about human communication, and how that knowledge could help us to understand communicative alterations associated with a number of neurological and psychiatric disorders.

The problem of the robot Asimo

We humans are so adept at understanding each other that we often do not see its underlying complexity. However, we could get an impression of those complexities by building a robot capable of understanding us. Mechanically, Asimo is one of the world most sophisticated humanoid robots (see illustration). Asimo can run, climb stairs and even play a game of football. But what Asimo cannot do yet is to understand what people mean. This became evident during a public demonstration (see www.arjenstolk.nl/asimo/wmv) when Asimo asked people to raise their hand if they had a question. At that moment, a man from the audience raised his hand to take a picture of Asimo. Asimo did not realize that the man merely wanted a picture and asked the man what his question was. When the man did not respond, Asimo made-up a question for itself, but it is clear that was a pre-programmed routine to limit damage to the robot's reputation. The important take-home message of this example is that it is not possible to pre-define what counts as a communicative signal. It is obviously possible to re-program Asimo so that he can recognize a camera in a raised hand, and avoid to repeat the same mistake. But how would Asimo deal with a person that extends his arm to ask a questions, but happens to have a camera in his hand? More generally, how would you program Asimo so that it can deal with unpredictable ambiguous situations as they frequently occur in real life?
The problem underlying human communication is that there is no unambiguous relationship between our actions and their meanings. A single act can have many different meanings and the same meaning can be communicated through many different acts. For example, two fingers in the air can have multiple meanings, e.g. "greetings", "peace", "two beers", or "these are the two fingers that I broke during winter sports". For Asimo, this complexity is a great ordeal, yet people can easily understand each other in daily life. Of course, this is partly because we share a common language, but language is not less ambiguous than other non-verbal actions. For instance, when I say "I am going to the bank", do I mean that I am going to withdraw money with my debit card or that I am going fishing? If I know you saw me looking for my debit card, then I probably intended to communicate that I am going to withdraw money. If I know that you know a river nearby is my favourite fishing spot, I can use exactly the same words to convey a completely different meaning. In short, the communicative meaning of our words and sentences are highly dependent on the context of mutually known knowledge across the communicators, irrespectively of whether we use verbal or non-verbal signals. What remains largely unknown, to this day, is how we determine this context, so that we can overcome the ambiguities of everyday communication and understand each other.

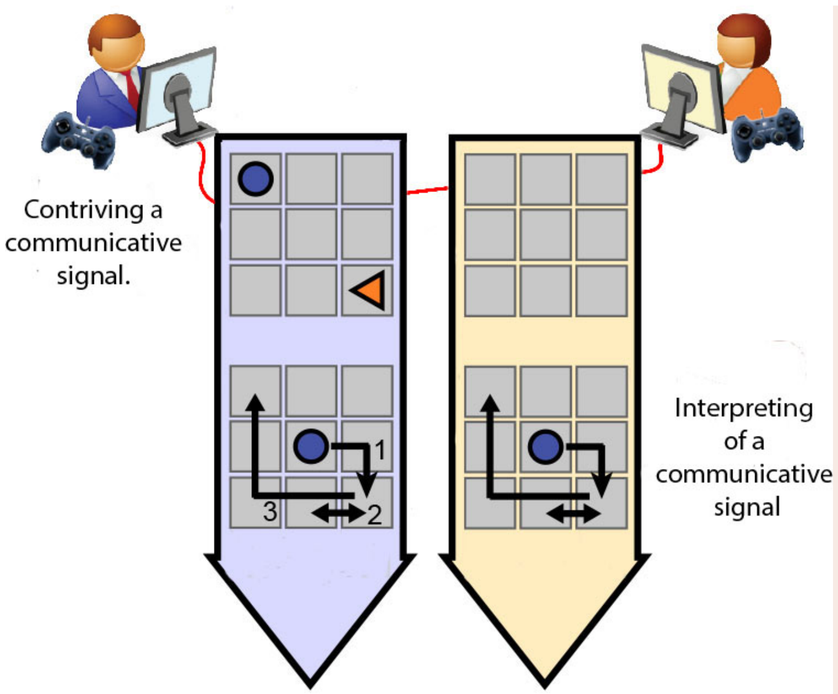
The robot Asimo can do a lot, but he does not understand us.

Communication in the laboratory

In everyday life, language is often used together with various other communicative signals, such as hand gestures, eye and head movements, and body posture, often simultaneously. As researchers, we face the huge problem of studying and recording each of these communicative signals and understand how they work together. And even if we were able to do that, how could we precisely measure the contribution of the social context to those communicative processes? One way to gain control over these complications is to let people communicate with each other using signals we can measure precisely, and in a way they have never done so before. The logic of this approach is that the social context of this new communicative interaction is entirely new, so that we can manipulate it and and observe its influence on the communicators. Therefore, we have invented a novel computer game in which two players have to solve a problem together. The two players do not directly see or hear each other, excluding communication based on words, gestures or any other potential signals with pre-existing shared meanings. Communication takes place through a computer, so that we can

Understanding each other

observe and record every communicative signals. For research purposes, it is very important to know precisely each and every communicative signal. It would be very hard to achieve the same degree of experimental control in everyday situations, where a minuscule eye movement or head nod could be easily overlooked.
In the computer game (a version is available for free as 'Tic Tac Team' in the App Store), pairs need to communicate with one another in ways that they have never done so before. Together they have to establish a target configuration of two pawns without the use of words and without seeing each other. In the picture, you can see how the game is conducted. In this example, there are two players, a man (blue) and a woman (orange). They are sitting in two different rooms behind a computer, so that they cannot see or hear each other. We illustrate step-by-step what happens (see illustration).



Communication in the lab. In this computer game, pairs need to communicate with each other without seeing each other. The only way for them to communicate is via signals (repositioning of pawns) on a digital board game. In this example, the blue player attempts to convey that the orange player needs to end up at the bottom-right position with her orange triangle pointed to the left

Step 1: The players view the screen. The woman sees a blank board with nine compartments, the man sees a board with two pawns. Together they must recreate the configuration seen by the man (target configuration).

They must do it together because the man can only move the blue pawn and the woman can only move the orange pawn. Because the woman doesn't know the target configuration, the man needs to convey the desired position of the woman's orange pawn and the direction it should face, while also repositioning his blue pawn to the correct spot. How this is done is seen in step 2.

Step 2: Here you see the movements made by the man, using the blue pawn. In this step, the woman gets to see exactly what the man sees and also what he does. In this example, the man chooses to first indicate the position of the orange pawn by moving there (1). Then he shows the direction of the triangle by moving from right to left and back (2); he then positions the blue paw in the position that was indicated in step 1 (3).

Step 3: Here you see the movements made by the woman, with the orange pawn. The man can see what she does and can, thus, observe how she interprets his movements. In this case, the woman understand what the man meant: she moved the paw to the place and orientation indicated in step 1 (1).

Step 4: Finally, both players get 'feedback', a green check mark or a red cross, which indicates if the target configuration has been correctly reproduced.

As with human verbal communication, there is no correct pre-determined way of communicating in this game. There are countless ways to move meaningfully across the board, as long as the blue and orange pawns end in their target configuration's position. Despite this complexity, most people understand each other and position their pawns according to the target configuration.
Analysis of participants' behaviour shows that each individual consider what their game-partner might know. For instance, if we do not show to the blue player what the orange player does in step 3, then participants are less successful in accomplishing the target configuration. This means that, on the next turn, the blue player adjusts his movements to what he thinks the orange player has understood. We have seen that when the orange player, in the previous turn, misplaced or misoriented her pawn, then the blue players places more emphasis on the movements marking target position or target orientation, respectively. Both players of a pair are continuously taking each other into consideration and collectively giving meaning to movements that have multiple possible meanings. The role of the social context (what the players collectively think they know) is so important that the same communicative signals may not only have different meanings in different pairs, but also in the same pair. For instance, we saw some pairs make the same movement at a different point in time to communicate a different target configuration. This last observation further emphasizes that in this computer game, just like in everyday situations, relationships between signals and their meanings are flexible and highly dependent on the social context. Just like the word "bank" in the bank-example, communication is only effective when both players collectively agree on the meaning of their actions, using what they both think they know.

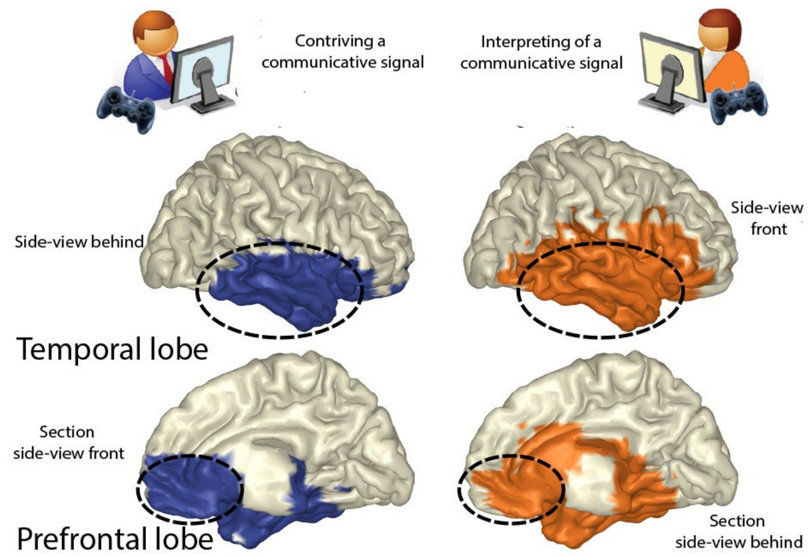
Communicating brains

There is a popular account of how communicative actions convey a meaning to another person. This account relies on the functions attributed to "mirror neurons". Those cells (neurons) are active within the brain of a person that moves, and also when the same person observes another person moving. It has been speculated that these neurons can link the meaning of our own movements to the meaning of another person's movements. This suggestion is beautifully simple, but maybe it is too simplistic as a mechanism explaining how we understand communicative actions. This suggestion assumes that the relationship between movements and meaning is unambiguous. However, we know that this assumption is wrong in most cases of human communication. We have already given examples of situations where we attribute different meanings to the same communicative signal. There must be another explanation for our ability to convey meaning to a different person; one that can explain how we humans continuously succeed in understanding each other during communication despite interacting with different people in a dynamic environment.

We can learn a lot from behavioural research or by reasoning about the mental processes that take place during communication. Such approaches, however, cannot provide a definite answer about how we determine and use the social context during communication, and how our brain does it. Therefore, we measured brain activity in people while they were playing the communicative game described above. We hypothesized that our brain makes use of the social context both when devising a communicative signal (step 1) and when interpreting it (step 2; see preceding illustration). How can we test this hypothesis? If the social context is used in both cases, then one would expect to see similar patterns of brain activity when the communicative signal is being created in the communicator's mind, and when that signal is being interpreted. We also need to make sure that these corresponding brain patterns are specifically related to human communication, e.g. by checking what happens when people solve a similar game that does not require to communicate. Therefore, we asked each pair to also play a control task, whereby they had to devise and interpret pawn movements, but in which they did not need to consider the potential meaning of those pawn movements. During both games, brain activity was measured with a device ('Magnetoencephalography', or MEG) that measures, millisecond by millisecond, the magnetic fields produced by group of neurons in our brain.

From the brain signals of the test subjects, it was found that the right temporal lobe and the ventromedial prefrontal lobe exhibited more brain activity when devising a communicative signal than when devising a non-communicative pawn movement in the control task (see illustration and frame 'Anatomy of the brain' for an explanation of the brain areas). Interestingly, the same brain areas were also more active during the interpretation of the communicative signals, despite something completely different happening on the computer screen, in comparison to the brain activity measured during the pawn movements in the control task. Thus, the right temporal lobe and prefrontal lobe play an important role during communication, both when creating a communicative signal and when interpreting it. These two brain areas are located outside regions where mirror neurons have been found, confirming that the mirror-neuron account does not explain this form of human communication. Actually, studies of the consequences of brain lesions tell us that those two brain areas are necessary for processing conceptual knowledge, that is knowledge gained from insight and abstraction as opposed to factual knowledge. The hypothesis was thus confirmed and qualified: our knowledge of the social context is important both during the creation and the interpretation of a communicative signal. But there's more. These brain areas were found to be active even before the point in time when people started solving a specific communicative problem.

Understanding each other



Brain activity during the creation and interpretation of a communicative signal measured with a MEG scanner

This indicates that that we can communicate quickly and proficiently in everyday life because our brains keep knowledge of the social context on standby, and continuously update it. For example, if you happen to come across the same woman that had asked for directions to the supermarket, your knowledge of your previous encounter would allow you to make sense of statements like "The supermarket was closed…" or "There was a one-way road…" that would be otherwise incomprehensible.

Other experiments using the same communicative game have allowed us to understand better how the right temporal lobe supports human communication. For instance, we have seen that as people get to better understand each other after successive game rounds, this portion of the brain becomes more active, in both members of a communicative pair. This was shown in an experiment in which the brain activity of pairs were simultaneously measured with two fMRI scanners ('functional Magnetic Resonance Imaging', see frame for an explanation of brain research techniques). This same experiment also revealed that the brain activity in the right temporal lobe changes synchronously in those pairs that communicate with each other, but not in pairs that fail to recreate the target configuration. This brain-to-brain synchronization probably occurs because the pairs mutually adapt their knowledge of the social context while communicating. In contrast, when a pair solves problems they have already solved before, the brain activity in the right temporal lobe is no longer synchronous. When solving old problems, people also use their knowledge of the social context, but they can retrieve it independently, it is no longer necessary to simultaneously adjust each other knowledge as when solving a new problem without a pre-existing solution. These findings suggest that during an everyday conversation, interlocutors might simultaneously update their knowledge of the social context. This phenomenon might not happen when the interlocutors already know what each other is going to say and mean, for example in a rehearsed play.

We also learned that people are less adept at using knowledge gained from previous encounters with their partner when we interfere with the functioning of the right temporal lobe (using 'Transcranial Magnetic Stimulation', a technique whereby a short magnetic pulse generates current in the brain). Normally one comes to understand the interlocutor better during the computer game. However, when the right temporal lobe is disturbed, the players do not become quicker at interpreting the communicative signals. If we consider the evidence of those experiments as a whole, it seems clear that the right temporal lobe is important for keeping track and continuously priming knowledge of the constantly changing social context.

We also know a bit more about the role of the ventromedial prefrontal lobe thanks to research on the communicative skills of patients with brain damage to that area. The damage arose as a result of intracranial haemorrhage (see illustration). These patients are still perfectly capable of playing the computer game and they can create novel communicative signals. However, we found out that, when playing the game, they do not take their interlocutor into account. We tested this by telling the patients that were going to play the game with another adult, and with a child. In contrast to test subjects without prefrontal brain damage, these patients communicated in the same way with both players. For instance, although they emphasized the target position when moving their pawn on the board, they did not emphasized it more when they were told they were playing with a child. In contrast, healthy participants and patients with lesions in other parts of the brain still considered who they were told to be playing with. This suggests that the prefrontal lobe is necessary for taking into account information about the interlocutor while making communicative decisions. This insight may explain why people with this type of brain damage may seem socially impaired in their daily life. A famous example is Phineas Gage, a railroad worker who had his frontal lobe impaled by a metal rod and miraculously seemed to have sustained no cognitive damage. In hindsight, however, he did show maladaptive and antisocial behaviour. The ventromedial prefrontal lobe, therefore, probably plays an important role in guiding communicative decisions with knowledge of the social context.

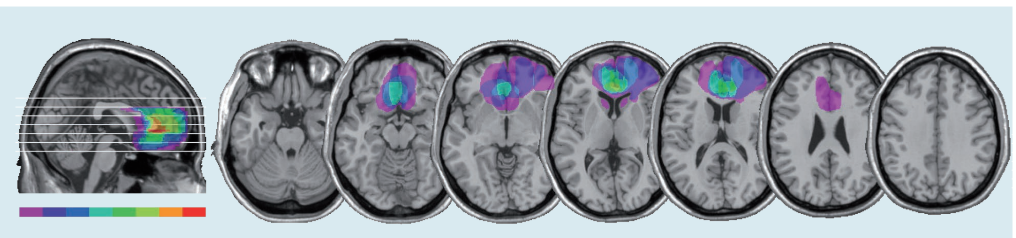


Illustration of brain damage to the prefrontal lobe

Conclusion

The scientific findings described above are among a long series of observations indicating that our communicative skills are not a by-product of our language skills or, as was more recently thought, of our motor skills. They reveal that, during communication, our brains make use of information about the social context – conceptual knowledge which is defined by what both interlocutors think to know. This knowledge is continuously updated and held ready during the creation and interpretation of a communicative signal. This is most likely why, unlike Asimo, we succeed in understanding each other so quickly, despite the extreme complexity of daily communication. These findings provide us with a degree of understanding of the mechanisms supporting our communicative skills.

In addition, it also sets the foundation for understanding the lack of communicative skills, as observed in certain neurological and psychiatric disorders (e.g. autism). This approach can also be used for better understanding the role of social experience on the development of our communicative skills. For instance, we have discovered that 5 year old children already adjust their communicative behaviour to the mental abilities of the person they think they are communicating with. More importantly, the extent of their communicative adjustment was not fixed, but largely predicted by how much time they spent in kindergarten during the first years of their life.

Prof. dr. Ivan Toni

Ivan Toni is professor of motor cognition at the Donders Institute for Brain, Cognition and Behaviour of the Radboud University. His research focuses on the mechanisms that allow us to integrate abstract knowledge into our movements. He examines this integration in the context of instrumental and communicative actions, namely actions that are either intended to alter the physical state of the world (such as filling a glass with water) or to alter the mental state of another person (such as convincing a bartender to fill the glass). Ivan Toni studied biology at the University of Bologna, Italy, and he received a PhD in Neuroscience in 1996. During and after his doctorate, he conducted research in different european research institutes, such as the INSERM in Lyon (France), the Functional Imaging Laboratory in London (England) and the Institut für Medizin in Jülich (Germany). In 2001 he was appointed as head scientist at the Donders Institute for Brain, Cognition and Behaviour, where he has successfully trained many young researchers. The mechanisms that enable us to understand each other continue to intrigue him, and he is exploring further the issues discussed in this chapter.

Inventing a new language without words, and without seeing each other

Message date: 12 August 2014

Being understood is a matter of choosing the correct words, grammatically assembling them together, and supporting the spoken sentence with the correct gestures, right? Wrong. There is another important element: creating and adjusting common ground. Neuroscientist Arjen Stolk devised a clever experiment to test the role of responding to each other's understanding. He will be awarded his doctorate on 2 September at the Radboud University.

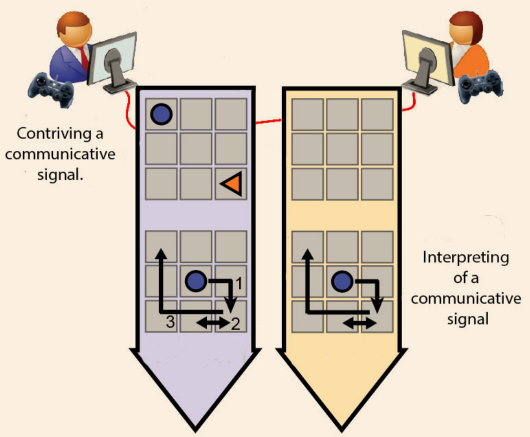
Someone asks you for directions in the city centre. In your answer, you incorporate what think you know about the other person: does he speak with a strange accent or does he seem to be in a hurry, then you might use, for example, different words or shorter sentences. Stolk shows how these processes in the brain work and that you are already capable, at an early age, to adapt to your partner, and that this ability is influenced by your social experiences very early in life.

Consideration of your interlocutor

'When people try to understand each other, their brains are not only focused on the individual communicative actions such as words and gestures. They seem to mainly take into account what they think the other knows when planning, implementing and observing those actions. That knowledge is continuously updated: after receiving feedback about what the other understands, you adjust both your knowledge and the shared knowledge. You constantly adapt to each other.

Ingenious computer task

To research this, Stolk developed a simple, but ingenious computer task. Two test subjects have to collectively recreate a configuration that only one of them sees, without them being able to talk about it. In addition, they cannot see each other. They can only exchange information by moving objects on the screen (see illustration). Subsequently the computer displays whether the configuration made by them is correct or incorrect, and are then given a new target configuration to recreate.



The left subject (in blue) controls the blue object, the right subject (in orange) controls the orange object. Only the blue subject knows the target configuration. Therefore, to solve the game, the left subject must position the blue object on the correct spot, but he also needs to find a way to inform the right subject about the correct spot for the orange object. The right subject only sees the movements that the right subject has made with his object. Based on this information, she can reason where to move her orange object on the screen.

Understanding each other

New language

Different pairs use different movement patterns to communicate about the same configurations. 'Every pair, essentially, devises their own language. And as pairs come to better understand each other, this simple communicative system develops further.' In Stolk's computer task, the solution with the least amount of movements is not necessarily the best. 'There is no general best solution, the only solutions are those that your specific partner understand. The point is to use movements that your game partner can understand.

Overlap in brain activity

Stolk asked subjects to perform the communicative game, simultaneously, in two fMRI scanners. He saw an overlap in brain activity in the right temporal lobe of the brain between the selection of the actions by the left subject and the interpretation of those actions by the right subject. The activity became stronger as the subjects solved more configurations together and came to understand one another better. The activity was also more synchronised in pairs that were simultaneously scanned. This suggests that the knowledge of each other's understanding gets continuously updated during communication.

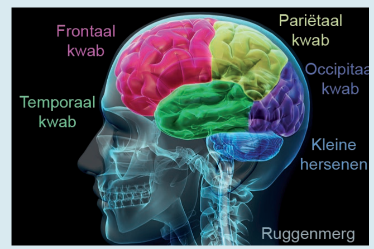
Source: http://www.ru.nl/nieuws-agenda/nieuws/vm/donders/hersenen-cognitie/2014/nieuwe-taal/.

KNOWLEDGE FRAMES

Robot Asimo?

In the year 2000, Asimo (acronym for "Advanced Step in Innovative Mobility") was introduced to the public for the first time by Honda (Japan). Honda anticipates that Asimo can aid people with physically disabilities in the everyday environment and can boost interest of the public for science and technology. Asimo is 130 centimetres tall, weighs 54 kilograms and run up to six kilometres per hour. Honda has found ways to add further intelligence to Asimo. One example is how Asimo, based on visual information and pre-programmed settings, can recognize the postures and gestures of people, and can execute commands based on that information. However, he cannot perform this as well as humans. He is also connected to the internet, which allows him to look up and provide simple facts and tidbits.

Anatomy of the brain



Anatomy of the brain

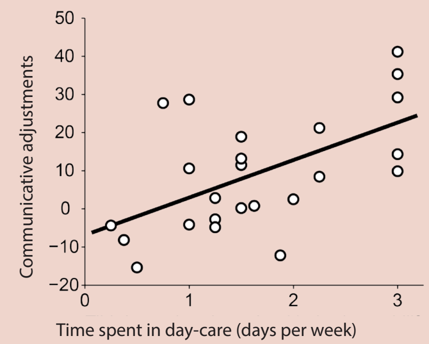
Our brains consist of several parts, including the cerebral cortex and cerebellum. The cerebral cortex is split into two halves (hemispheres). Each half consists of four lobes: the frontal lobe, the temporal lobe, the parietal lobe and the occipital lobe. The outer layer of each lobe is made of neurons, forming the so-called grey-matter of the cortex. The brain is connected to the rest of the body by means of nerves, some of them running in the spinal cord through the spine. Often, a Latin preposition is used to specify the location of a brain area, such as "pre-" (meaning "in front") in "prefrontal lobe".

Brain research

In the past, (functional) brain research in humans focused primarily on linking behavioural deficits to the location of brain damage. Nowadays, brain imaging techniques such as fMRI ('functional Magnetic Resonance Imaging') and EEG ('Electroencephalography') are used to measure brain activity during the execution of a task. The techniques each have their own strengths and weaknesses, which provide different perspectives on the processes of the brain. For example, functional MRI has a relatively high spatial resolution, which allows it to localize activity in the brain, but a relatively low temporal resolution, which implies that it cannot accurately measure when activity occurs. EEG, on the other hand, provides a direct measure of electrical activity generated by brain cells (neurons) and measured using electrodes mounted on the head. EEG has a high temporal resolution. However, the electric signal is greatly disturbed by the skull and scalp, reducing the spatial resolution of EEG. This problem is less severe in the case of MEG ('Magnetoencephalography'), which measure the magnetic consequences of brain activity. MEG provides both a relatively high spatial and temporal resolution. However, the magnetic signal is very weak and can only be detected with special equipment, making MEG considerably expensive. Another common technique is TMS ('Transcranial Magnetic Stimulation'), which involves the generation of current in the brain using a short magnetic pulse. Depending on the brain stimulation protocol, the brain activity can be temporarily disturbed or stimulated, making it possible to determine causal relationships between the stimulated brain area and the function it serves for a particular task.

Research into understanding each other
In phase 3 of inquiry-based learning, students set up research by themselves. To teach them how to proceed in this scientific process, the box below explains how researchers have performed research into the way we understand each other.

Research question	We are usually able of adapting our everyday communication to an interlocutor. How do we do that? Do we simply mimic our interlocutor or do we have built-in skills refined by our social experiences?
Method How do we perform this research?	Since the computer game described earlier in this chapter represents a new form of non-verbal communication, the behaviours displayed during the game could not have been mimicked from previous experiences. This opens the opportunity to test whether subjects inherently take their recipient into account when communicating. By making subjects believe that they are playing the game with two different receivers (for example an adult and a child), it is possible to research whether subjects show differences in their communicative behaviour, driven exclusively by that belief. We also want to know whether social experience influences people's ability to communicatively adjust to their interlocutor. To address this question, we need to test subjects that are old enough to be able to play the game, but young enough to allow us to have a relatively good measurement of their social experiences. For this reason, we have chosen to conduct this experiment with 5 year olds and to record several aspects of their social experiences (how many brothers and sisters each subject has, how often did each subject attend a day-care, etc.)
Results	5 year olds adapted their communicative behaviour to their beliefs about the recipient. The children communicated more emphatically when they thought they were playing with someone younger than themselves (in contrast to someone of their own age). We know that those communicative adjustments were driven only by the children's beliefs because both receivers were, in fact, played by the same person. The crucial finding is that those children had stronger communicative adjustments when they spent more time in day-care during their early years of life (see figure).



Every dot represents a 5 year old that participated in the experiment

What are the implications of these results for society?	These results provide insight into the development of our communication skills. They indicate that we possess a skill that is refined by social experience. Experience acquired at day-care apparently plays a role.
What more do we wish to understand?	This study establishes a link between our communication skills and social experience acquired at day-care. But what specific aspect of a day-care contributes to this? Is it the presence of caretakers that differs from the (biological) parents, is it the interaction with a large group of children, or is it the fact that children there differ in age and change frequently? Follow-up research may shed light into this relationship and find an explanation for how experience acquired at a day-care, and elsewhere, contribute to our communication skills.

Further material about understanding each other:

- Robot Asimo gives a press demonstration in Miraikan science museum in Tokyo: http://www.arjenstolk.nl/asimo.wmv.
- Arjen Stolk's personal website: http://www.arjenstolk.nl (With many popular science articles)
- TicTacTeam: Game designed by the researchers for the iPad and resembles the game explained above: https://www.languageininteraction.nl/tictacteam.html.

4.2 Understanding each other in the classroom!

Project team Understanding each other

In this section we describe how you, as a teacher, can set up a project inquiry-based learning with the theme 'Understanding each other' in the classroom. The descriptions in this section are based on the experiences of Dr. Albert Schweitzer school in Renkum and the Maria school in Boven-Leeuwen. The online appendix, to which different activities refer to, can be found on our website www.wkru.nl/english. Whenever you encounter this symbol ⦿ this is a reference to the website.

Core objectives
In this project, the following core objectives of the Dutch curriculum are addressed:

Oral language education
1. The students learn to acquire information from spoken language. They also learn to structurally present that information, either orally or in writing.
2. The students learn to express themselves in form and content when giving or requesting information, submitting reports, giving explanations, instructing and discussing.
3. The students learn to assess information in discussions and in a conversation that is informative and opinionated in character and learn to respond with arguments.

Written language education
4. The students learn to derive information from informative and instructive texts including schematics, tables and digital sources.
8. The students learn to structure information and opinions when writing a letter, report, a form or a paper. They should pay attention to sentence structure, correct spelling, a legible handwriting, layout, and possibly visual elements and colour.
9. The students develop a sense of enjoyment in reading and writing stories, poems and informative texts intended for them.

Linguistics, including strategies
12. The students acquire an adequate vocabulary and strategies for understanding unfamiliar words. 'Vocabulary' also includes terms that make it possible for students to think and speak about language.

Nature and technology
41. The students learn about the build of plants, animals and humans, and about the form and function of these parts.
45. The students learn to design solutions to technical problems, to execute and evaluate these.

Artistic orientation
54. The students learn to use images, music, language, game and movement to express feelings and experiences, and to communicate.
55. The students learn to reflect on their own work and that of others.

Goals of this project

With this project, the following goals are worked towards:

Cognitive goals
- The students acquire insight into the way people understand each other and how we communicate;
- The students learn that communication consists of more than just grammatically correct messages.

Skill goals
- The students gain experience working with the cycle of inquiry-based learning;
- The students learn, on the basis of examples provided to them, to formulate a research question and to answer it by means of practical research;
- The students learn, on the basis of previous experiences and analysis, to formulate a hypothesis;
- The students learn to process data in tables and graphs;
- The students learn to prepare a presentation based on their own research;
- The students learn to reflect on their own ideas and activities;
- The students learn to draw conclusions from their own research.

Collaboration goals
- The communication between the students while collaborating in groups is strengthened;
- The students learn that it is stimulating to collaborate within a group with the same interest/question;
- The students learn to debate and come to a collective decision;
- The students exchange knowledge with each other.

Affective goals
- The students are introduced to a groundbreaking theme;
- The students work on an inquisitive attitude;
- The students experience fun in doing research. They develop a positive attitude towards research and science;
- The students learn to take responsibility for their own research;
- The students are introduced to literature and visual materials (films, documentaries, series, photographs, etc.) about the subject.

Phase 1. Introduction

During the introduction, the students come into contact with the subject for the first time. The goal is to excite them and invoke curiosity towards the subject.

1 2 3

ACTIVITY 1: **MEETING ASIMO**

Goals
- The students are introduced to the term ‘understanding each other’;
- The students analyse the behaviour of the robot in the film;
- The students are introduced to the question wall;
- The students learn to ask questions about the topic ‘understanding each other’.

Grouping
As a class and in groups of four

Preparation and necessities
- Prepare the film about Asimo on the digiboard;
- Paper

Duration
45 minutes

Introduction
The students watch the film about Asimo. As a class, the students discuss what they saw. What stands out is that Asimo thinks the man with the camera has a question to ask. When no question is asked, Asimo devises a question to which he knows the answer. The conclusion is that what we can do well, namely understanding each other, poses great difficulty for a robot.

Activity
In groups of four, the students determine what they already know about how we understand each other and what questions they still have. They discuss about this and each group writes down what they do and don’t already know about the topic.

Wrapping up
With the entire class, the findings of the students are discussed. The teacher compiles the responses and adds these to the question wall in the classroom.

Tip
It can also be fun for the students to let them post their own notes about what they do and don’t know on the question wall. They could then also add things as the project proceeds.

Online appendix ⦿
- Film about Asimo

Phase 2. Exploring

In the exploration phase, the students explore the topic broadly. They do this by using all kinds of activities that they sometimes perform individually, in groups and sometimes as a class.

1 2 3

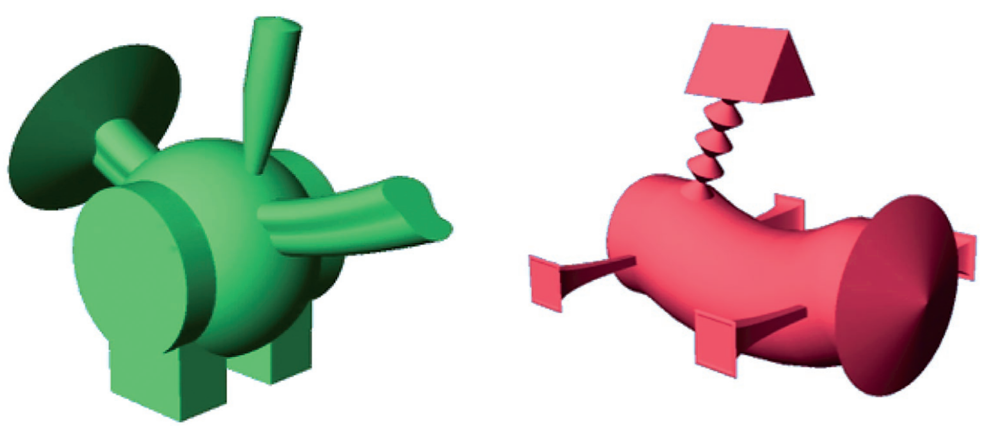
The activities described below are intended to give the students insight into the process of understanding each other. They are layered activities, whereby good instructions and a good debriefing are important.

ACTIVITY 2: **THE FRIBBLE-GAME**

Goals
- The students understand that there are different ways to make something clear;
- The students practice describing what they observe;
- The students understand that shared knowledge and a better understanding of your communication partner makes to easier to understand him or her;
- The students understand that empathy for others can be helpful in the development of mutual understanding.

Grouping
Groups of four

Preparation and necessities ⦿
- For each group, a sheet with numbered fribbles (blue);
- For each group, a set fribbles on cards (red, green, yellow or purple). The groups receive as much of their own colour as possible. Separate cards per fribble are cut. The cards must be approximately the same size;
- Three numbered cards per person. The sheet is cut into six.



Two fribbles

Duration
30 minutes

Introduction
Activity 1 is looked at in retrospect. What did the students see in the film again? And what was the conclusion? Groups of four are made. The groups will soon play the fribble game. This occurs in three phases. For each phase, instructions are provided.

Activity

Phase 1: Understanding each other
Each participant in the group receives two unique fribbles (unnumbered) and a numbered card. They keep this hidden from the rest of the group. In the middle of the group is a sheet of numbered fribbles (blue). The group members take turns to describe their fribbles and thereby, are not allowed to use the numbers on the sheet with blue fribbles. The rest of the group must try to guess which fribble in the middle corresponds with the fribble in the hand of the student who is describing his or her fribble. The players write the name of the person on the card at the number of the fribble they suspect he/she is describing. Once everyone has had a turn, they check if they guessed correctly. If all fribbles have been guessed, a classroom assessment follows. Why is it that the other person understands you, even though the figure that you're holding does not have a formal name?

Phase 2: Understanding each other with prior knowledge
The fribbles are shuffled. The students again receive two fribbles and a numbered card. The game is played again in the same manner. If all is well, determining who has which fribble is easier. Once all the fribbles have been guessed again, another classroom evaluation is conducted. Was this round faster? Why would that be? Perhaps you made agreements on how to refer to the fribbles (for example: the vacuum cleaner with hooks) or you refer to a shared event in the previous round (for example: 'I have the fribble that Tom had recently.') Try to let the students conclude that shared experiences help in the development of mutual understanding.

Phase 3: Dependent on context and listener
Nu worden er nieuwe groepjes van vier gevormd. Twee spelers uit groepje A vormen een groepje met twee spelers uit groepje B. Leerlingen komen dus in een groepje met iemand die het spel al wel samen met ze heeft gespeeld, en twee leerlingen met wie ze het spel nog niet hebben gespeeld. De fribbles worden weer geschud en de leerlingen krijgen opnieuw twee fribbles en een genummerd kaartje. Opnieuw wordt het spel gespeeld.
Er vindt weer een klassikale evaluatie plaats. Was het nou makkelijker om de fribble te raden van je originele groepsgenoot? En waarom zou dit makkelijker zijn? Waarschijnlijk komt naar voren dat met een deel van de groep eerder gemaakte omschrijvingen/afspraken wel kunnen worden gebruikt en met een deel van de groep niet. Er kunnen dus misverstanden ontstaan, omdat spelers uit groep A en B geen gemeenschappelijke kennis delen.

Understanding each other

Wrapping up

The class discusses how the game proceeded. Could the students describe the fribbles adequately? In which phase was the description of the fribbles the best? And why was that? To check whether the goals of the activity were achieved, you can discuss these with the students. For example, do the students understand that empathy for others and shared knowledge can be useful in the development of mutual understanding? And how did they come to realize this?

Tip

A tip for the teacher is to first play the game yourself, for example with the team. It's possible that the game seems complicated; if so, then the difficulty which the students encounter can be better understood.

Online appendix ◉

- Numbered fribbles;
- Coloured fribbles for cards;
- Numbered cards.

ACTIVITY 3: FRIBBLE WITH GESTURES

Goals

- The students learn to develop a hypothesis;
- The students learn to observe critically;
- The students learn to make a statement about the truth of a hypothesis.

Grouping

Groups of four

Preparation and necessities ◉

- For each group, a sheet with numbered fribbles (blue);
- For each group, a set fribbles on cards (red, green, yellow or purple). The groups receive as much of their own colour as possible. Separate cards per fribble are cut. The cards must be approximately the same size;
- A numbered card per student. The sheet is cut into six pieces.

Duration

30 minutes

Introduction

Activity 2 is looked back in retrospect. What did the students do? How was the fribble game played again? What conclusions could be drawn after playing the fribble-game? This time, a variation of the game is played. The students may no longer describe the fribbles, but instead have to portray them. With the class, a prediction is made, a so-called hypothesis, about how this will play out. Will it be easier or more difficult than with words? And wherein will trying to say something with words differ from saying something using gestures? Each group is appointed an observer. This observer assesses if the formulated hypothesis gets accepted or rejected.

A student from the Dr. Albert Schweitzer school portrays a fribble.

Activity

Again groups of four are formed and everyone receives two fribbles. The students all portray their unique fribbles. The rest of the group must try to guess which fribble in the middle corresponds with the fribble in the hand of the person attempting to portray it. The players write the name of the student, who is portraying the fribble, on the card at the number of the fribble that best matches the description of the portrayed fribble. At the end, they check if they guessed correctly.

Wrapping up

The class hypothesis is addressed. What did the observers see? Was the hypothesis correct? How did this variant differ from the variant from Activity 2?

Online appendix ◉

- Numbered fribbles;
- Coloured fribbles for cards;
- Numbered cards

ACTIVITY 4: THE THOUGHT EXPERIMENT WITH ASIMO

Goals

- The students experience that the understanding of words is not something for granted;
- The students practice describing objects as clearly as possible;
- The students get an idea of how computer programs work which directs robots;
- The students can provide different descriptions of the same object.

Grouping

Groups of four

Preparation and necessities ◉

- Two sets of numbered fribbles for each group;
- A dictionary-worksheet for each group.

Duration
90 minutes

Introduction
The film about Asimo, the robot from Activity 1, is watched again. Why is it that we are (usually) capable of understanding other people? Why is it so difficult to build a robot that is also capable of that? In order for a robot to take action, you must tell him exactly what to do in certain situations. This is called programming. You can see a robot program as a kind of dictionary. Such a dictionary describes how the robot should act or what it should say in certain situations. During the press conference, Asimo searches for the situation 'a person raises his hand' in his dictionary. There he finds the definition 'the person wants to ask a question.' But as we have learned earlier, the meaning of a word or action is highly dependent on the situation and the person conveying it; in this case, the person only wanted to take a picture. To resolve this confusion for Asimo about whether someone wants to ask a question or take a picture of him, this situational information would have to be added to Asimo's dictionary.

The information in his dictionary would then look like the following:

Asimo's dictionary
'Someone raises his hand, but is not wielding a camera' = 'This person wants to ask a question'.
'Someone raises his hand while wielding a camera' = 'This person wants to take a picture'.

Let's see whether it is possible to create a dictionary for Asimo, so that he can understand us during the fribble game that we played earlier.

Students of the Dr. Albert Schweitzer school discuss with a researcher, Iris van Rooij, about what this robot can and cannot do

Understanding each other

Activity

Phase 1: Collecting fribble descriptions
We start once again in groups of four. Each group gets a dictionary-worksheet which has eight numbers on it. These eight numbers correspond with the eight fribbles. Each group gets two sheets with numbered fribbles (i.e. one group gets two sets of eight blue numbered fribbles, the other group gets two sets of eight red numbered fribbles, etc.). Collect all the possible ways in which each fribble can be described in the group (gestures can be drawn or described as clearly possible). Then fill in the dictionary-worksheet. Note: make sure the description of the fribble corresponds with the number of the fribble in the worksheet.
Note: make sure the description of the fribble corresponds with the number of the fribble in the worksheet.

Phase 2: Can you ensure that a person can understand you, but Asimo cannot?
Now two students of each group move to a different group. One person plays Asimo the robot, the other person plays Isa the human. The role division is as follows:

- Asimo the robot (this student was previously in group 1) receives the dictionary that group 2 made; he may not see the sheet with the numbered fribbles;
- Isa the human (this student was previously in group 1) gets to see the numbered fribbles belonging to group 2;
- Student from group 2;
- Student from group 2.

Asimo can only understand the other three students based on the dictionary previously made by the others. The other two students must now describe the fribbles to Isa and Asimo in such a way that Isa is capable of guessing the fribble, but Asimo can't. Once Isa or Asimo think they know which fribble is being described, he or she must mention the number.

There is a classroom evaluation: *what did the other students do to ensure that Asimo did not understand them?* The most obvious possibility to make sure that Asimo does not know which fribble is being described is to devise means of communication that are not in the dictionary.

Phase 3: A thicker dictionary for Asimo
Each group now collects the fribble descriptions they used during the game to ensure Asimo could not understand them. After recollecting all the fribble descriptions, a round is played: 'How can you ensure that humans understand you, but Asimo cannot?' Again, two students per group move to another group (not the same group as last time, for example, two students from group 2 now go to group 3). What about now? Can you manage communicating with each other so that Isa can understand you, but Asimo cannot?

Understanding each other

Another classroom evaluation takes place: *what did the other students do to ensure that Asimo could not understand them? Was it more difficult or easier than the previous time? Why? Do you think it is possible to understand each other by collecting all the possible descriptions for the fribbles?* The most obvious possibility is to devise even more means of communication that aren't in Asimo's dictionary and to add them to his dictionary. But if you collected all the possible descriptions for fribbles, then you would end up with an infinitely large dictionary! Just imagine if you had to construct such a dictionary, not just for fribbles, but also for tables, chairs, children, animals and everything around you. And how can you then talk together about situations and things that you have never seen before?

Wrapping up

Divide the class into small groups and try to have the students conduct the following thought-experiment. What building blocks or modules would they put in Asimo to allow him to really understand people? Put this in perspective of the press conference situation that occurred with Asimo. How can Asimo be programmed to understand that the man raising his hand only intended to take a picture of Asimo? If you find this difficult to do in groups, this activity can also be done with the whole class. The students can also receive the assignment to think of more situations where Asimo may not act appropriately.

With the whole class: *Would it be possible to program Asimo with all the possible conceivable situations or will there always be some things that Asimo cannot do? And why is it possible that we humans can do these things?* Scientists aren't too sure themselves. For example, think of empathy, shared collective knowledge and in particular creativity (ability to innovate, devising new solutions, coming up with more descriptions), etc.

Tip

This is an activity with a lot of (conceptual) challenges for the students. It is important to take time for the class discussions, so that students get the time to think about what is happening.

Online appendix ⦿

- Film about Asimo (see appendix activity 1);
- Fribbles for Asimo;
- Dictionary-worksheet.

ACITVITY 5: **CHARADES**

Doelen

- The students practice clearly conveying a word using gestures;
- The students practice depicting certain words without talking, they are limited to gestures only;
- The students practice analysing certain behaviour and can delineate the effective and lesseffective components.

Grouping

As a class

Preparation and necessities

- Think of several Charades' words (a number of words that are difficult to depict);
- Stopwatch.

Duration

30 minutes

Introduction

For the last activity within the exploration phase, the game Charades is played. It is played by having a depicter and four students that attempt to guess what is being depicted. The rest of the group, along with the teacher, are observers. They pay attention to the interaction between the players. Those designated for guessing are called into the classroom one-by-one.

Activity

The depicter receives a word that needs to be depicted in such way that the students can guess it. The depicter is not allowed to talk during this time. The student guessing is allowed to however. The guesser has 1 minute to guess the word that is being depicted. If the guesser succeeds, he or she receives 10 points. If guesser succeeds within 1½ minutes, he or she will receive 5 points. Once the correct word has been guessed, the guesser becomes an observer and observes how another student guesses and can thereby compare strategies. A new guesser enters the class and takes the guesser's vacant spot. The depicter depicts the same word for this guesser too. This is repeated until all four students that were guessing have had their turn.

Students of the Dr. Albert Schweitzer school playing Charades.

Wrapping up

The activity is reflected upon. Who guessed the word the quickest? And why is this? Was this due to the person or the situation? What gestures did the depicter make? Did his or her gestures change in response to the comments of the student? And did he immediately apply this in the next round? Was there a particular gesture that was effective?

Tip

This game is also suitable to be played as a '5-minute game' during the whole project.

Phase 3. Designing research: research question and plan

PHASE 3A. THE RESEARCH PLAN

1 2 3

Subdividing the main theme into subthemes can help students in formulating a question. A single theme without subthemes provides the students sometimes with too little guidance to devise a research question. Moreover, this can lead to the students' questions resembling each other too much. We, therefore, introduced a number of subthemes under this theme:

- Collective framework;
- Forms of communication
- Communicating with robots;
- Brain and communication.

Although the theme of this chapter 'Understanding each other' seems fairly general, a rather specific focus was chosen based on the research of the involved researchers, namely exploring how communication between people works and which process underlies it. Forming a collective framework proves essential to this. This is, by far, the most important subtheme. The other possible subthemes are derived from this: by exploring different forms of communication, it is apparent that the collective framework plays an important role in all these forms. Communicating with robots mainly shows that the formation of a collective framework is an intricate process. Brain research is the way researchers show the importance of the collective framework. It is, therefore, not surprising that the first subtheme was strongly represented in the questions of the students and that we did not find suitable questions from students for all the themes.

At level 1 and 2, the teacher provides each group with one of the research questions below or allows the students to choose one themselves. At level 3, students devise their own research question.

Students of the Dr. Albert Schweitzer school devise a research question.

1 2

Below are five research questions for projects designated at level 1 and 2 (structured and guided inquiry-based learning), whereby each question is accompanied with a brief explanation about the relationship between the question and the theme 'Understanding each other', and under which subtheme the question falls. In this way, students see the connection between what they have explored and what they will research. Teachers can choose to give the entire class the same research question or to give groups different questions. The curiosity and motivation of the students can be promoted by letting groups, for example, choose the question by themselves from a selection of questions, so that they can choose one that is more in line with their interests. The following research questions were devised by students of the schools that participated in this book.

1 *Do you use the same words when you explain something to a toddler and when you explain something to a child from grade 7?* (Subtheme: Collective framework)
Based on knowledge that a collective framework is important in understanding each other, the students conducted research on the flexibility of this framework. To what extent do we adapt our framework when we communicate with different groups, in this case, different age groups?

2 *Does a toddler understand the explanation from a child from grade 4-6 or from another toddler better?* (Subtheme: Collective framework)
Based on knowledge that a collective framework is important in understanding each other, the students conducted research on the mechanism of such a framework within and between age groups. Is the collective framework between toddlers so strong that it also allows them to understand each other better or are older students more capable of explaining something to a toddler based their knowledge of the framework?

3 *Are children from grade 4-6 better understood by toddlers or by 60- to 85-year olds when depicting words?* (Subtheme: Collective framework and forms of communication)
Once again, based on knowledge that a collective framework is important in understanding each other, the students conducted research on the mechanism of such a framework between different age groups. Does the framework of a student fit better with toddlers, who in terms of age are relatively close, or with older people, who may know more gestures?

4 *Which is the better way to depict proverbs, literally or figuratively?* (Subtheme: Forms of communication)
Language does not always have to be taken literally. There are various forms of figurative langu age including proverbs. In order to be able to communicate with proverbs, it is essential that both parties not only know the proverb, but also understand the meaning of it. If this is not the case, miscommunication may arise and as a result, people will misunderstand each other. This research question also matches the theme 'Understanding each other'.

5 *Can children from lower grades or from higher grades recognise emotions better?* (Subtheme: Forms of communication)
Understanding each other does not only occur through spoken language. Body language, facial expressions and intonation all play an important role. We learn to better understand and interpret this form of non-verbal communication as we get older and more experienced. But is there a difference between the way a toddler and a student from grade 4-6 recognises emotions?

Understanding each other

3

At level 3, students devise their own research question. The subthemes and questions above provide an idea of in which direction you can think. Make sure that you do not direct the students too much early on. They are perfectly capable of devising their own question. After all, the questions above were conceived by students.

PHASE 3B. THE RESEARCH PLAN

1

Students of the Dr. Albert Schweitzer school conduct their research.

On the research plan shown here, one of the five questions above has been completed. A completed version for all the five questions can be found online. ⦿ Details of the plan have to be filled in by the students, such as scheduling and role division.

Researchers' names:

1. **What is our research question?**

Do you use the same words when explaining something to a kindergartner and when explaining something to a child in 5th grade?

2. **How does this research question fit the theme of the project?**

Talking and choosing specific vocabulary are part of communication. They deal with the question in what way we do and don't understand each other.

3. **What do we think will be the answer to the research question? And on what grounds do we justify this answer?**
[Researchers call this a 'hypothesis'.]

....

....

....

4. **Which people or what materials are we researching?**

Children from kindergarten and children from 5th grade.

5. **What exactly will we be measuring?**
[Measuring can refer to: the duration or the weight of something.
Measuring can also refer to: asking a group of people the same question and comparing the answers.]

We will measure whether the children from our own class use the same vocabulary when explaining something to a child in 5th grade compared to when explaining something to a child in kindergarten.

6. **In what way will we conduct the measurements?**
[For example through a test, a questionnaire or an interview.]

We will conduct a test. A child from our class will explain a concept to a child from 5th grade and to a kindergartner. We will record what will be said. First we will examine what words will be used during the explanation to the 5th grader. After we will examine what words will be used when explaining the same concept to a kindergartner. We will then compare the explanations for the amount of same words used. Only words that are relevant to the explained concept will be counted (so not 'the' and such).

7. **How often or with how many people do we need to repeat our measurement in order to acquire a confident answer to the question?**

We will have ten children from our class explain a concept to a 5th grader and a kindergarten.

Understanding each other

8. **How will we record the results during the execution of the research?**
[For example: write down short answers, construct a table or keep tally.]

During the explanation, we will record the words used in a table. When a word is used more than once, we will add a mark behind that word. The words used to explain a concept to a 5th grader and to a kindergartner will be recorded in separate tables.

9. **What should remain the same in the research and what should change (fair measurements)?**

Same:
- The concept that will be explained.
- The same children will be used when explaining a concept to a 5th grader and to a kindergartner.
- The children explaining have to be roughly the same age.

Change:
- The age of the child receiving the explanation.

10. **Make a plan: when will you conduct the different research activities?**

Activity:	Location:	Day:	Time:

11. **What help and materials do we need?**

- A concept to explain
- Ten children to explain
- Kindergartners and children from 5th grade
- Two tables and a pen to write down words

12. **From whom do we need permission besides the teacher?**

....

....

13. **Who will do what during the preparation and execution of our research?**

Name:	Tasks:	Will be done by: