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Designing an Interactive Storytelling System for Children Using a Smart Toy

Design of a prototype to investigate the effect of emotional behaviour of a toy on children's storytelling

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Abstract

The society is changing towards a knowledge-based society, demanding a different set of skills than in the past, the so-called 21st century skills. Among the 21st century skills is creativity. Children's creativity can be developed through storytelling activities. Children often tell stories during pretend play activities in which they make use of toys. However, traditional toys do not, or only rarely, respond to children's actions, let alone respond to their storytelling. The aim of this research was to investigate how to incorporate a smart toy in an interactive storytelling system for elementary school children. In addition, it tested the influence of the toy's emotional behaviour on children's storytelling.

The research followed a user-centred design approach including three user studies. Throughout the research a prototype combining a little robot, a tablet application, a play mat, object (blocks) and figures was designed and improved. The robot functioned as the main character in the children's stories. A conceptual framework was created in which the character was approached as an agent. A character can be reactive; only responding to stimuli, or hybrid; combining reactivity with deliberation. This research only focused on the development of a reactive character toy.

The first two studies researched the interaction between the children and the prototype. The final study tested the influence of emotional behaviour of the robot on children's storytelling. Two conditions were compared: condition NE in which the robot did not show any emotions and condition E in which the robot did show emotions.

Results of all studies show that in general children liked the activity and understood the tablet application and the robot emotions. Children collaborated according to different patterns, in the E condition both children tended to be more active than in the NE condition. As the prototype design evolved children's storytelling improved. But, even in the final study storytelling was limited and lacking global coherence. The activity supported barely incorporated pretend play; it better approached a puzzle game.

A quantitative analysis of the results of the final study did not show any influence of the robot's emotions on the quality of the stories told. However, qualitative analysis indicated some differences between the conditions. In the NE condition children only described the robot as being happy, whereas they used multiple emotions in the E condition. In addition, in the E condition children tended to better link emotions to occurring actions. Also, they summarised stories more often from a third person perspective in contrast to summarising the story by solely providing a list of events, indicating they perceived the robot more as an autonomous character. Finally, in the E condition children mainly took the randomness of the robot's emotions for granted. However, the "why-questions" triggered them to come up with reasons to match the random emotions with the story.

Overall, the research indicates the prototype designed can be used as a starting point for an interactive storytelling system. The system has possibilities to be used for instructional scaffolding. In the current setup, the influence of the presence or absence of emotional behaviour is expected to be small compared to the influence of the difference in amount of reactivity of the robot between both conditions. Therefore, it is recommended to improve the prototype by extending the tablet application with a goal reminder, content specific questions from the characters' perspectives and suggestions, and extending the robot behaviour with autonomous driving, speech, object pick-ups and deliberation. Also, the research raised many new issues, such as the link between creativity and storytelling, the type of activity to support: story creation or storytelling and support for the creation of complete stories or creation of solely story fragments. It is recommended to research these issues and, in addition, perform brainstorm sessions with elementary school teachers and parents and caregivers and research gender differences in play. Finally, a new follow-up study with children could test the updated system's support for storytelling, the influence of emotional behaviour (random or according to an emotional model) and the influence of deliberative behaviour.

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Education prepares children for their professional life. The corresponding skills that are important these days are different from the skills that were important in the past. Several models focusing on 21st century skills have been developed to adapt education to the demand of society. One of these models is the KSAVE model. This model includes creativity and innovation as one of the 21st century skills. Creativity can, amongst others, be stimulated via storytelling. Creating stories asks for creative tinkering by the child. Children often perform storytelling during pretend play, in which they make use of toys. However, existing toys do not respond to children's actions. Therefore, this research focuses on the design of a storytelling system using smart toys. This section describes the motivation and research focus in more detail.

Storytelling plays an important role in child development, Still, https://www.flickr.com/photos/milks3/5698148454

Introduction

1.1 Motivation

TOWARDS A KNOWLEDGE-BASED SOCIETY

There largely is a consensus about the fact that our society is changing from an industrial-minded society to an information and knowledge-minded society *(Voogt & Roblin, 2010)*. This changing society influences the professional environments of individuals. The 21st century demands a very different set of skills and competencies than the past, since many children are educated for jobs that do not even exist yet. Several parties have been designing a set of 21st century skills, consisting of core competencies needed in a large range of jobs, related to the knowledge-minded society. Some other parties are not in favour of the 21st skills, they argue not all students will have a knowledge-intensive job later (*Ananiadou & Claro, 2009*). *Ananiadou & Claro (2009)* researched the importance of 21st century skills in several countries. Most of the countries researched see the importance of the 21st century competences and are partly already, indirectly, integrating the skills into the curriculum.

21ST CENTURY SKILLS

Voogt & Roblin (2010) researched the differences and similarities between eight common models focusing on 21st century skills. The goal of the research was to convert the different sets of skills described within the different models to one, common set of skills. The created set of common skills consists of collaboration, communication, ICT and social-cultural skills. In addition, creativity, critical thinking and problem solving are mentioned as essential skills. According to *Voogt & Roblin (2010)* all models specifically mention the importance of ICT skills in the core. *Binkley, Erstad, Herman, Raizen, Ripley, Miller-Ricci & Rumble (2012)* say that especially creativity has increased in importance as a 21st century skill.

Dede (2010) performed a similar research to *Voogt & Roblin (2010)*. He concluded that the frameworks researched consist of skills that are largely consistent in terms of what should be in the curriculum. He only argues each framework emphasises a different skill set. Some of the frameworks focus on the technical skills, whereas others emphasise digital literacy.

Also, *Binkley et al. (2012)* analysed several frameworks, leading to their KSAVE model. This model focuses on three categories: knowledge, skills and attitudes, values and ethics. The model organises these aspects into four themes. The first theme, ways of thinking, consists of creativity and innovation, critical thinking, problem solving and decision making and learning to learn, meta-cognition. The second theme consists of ways of working: communication and collaboration and teamwork. The third theme, tools for working, includes information and ICT literacy. Finally, the last theme, living in the world, focuses on citizenship, life and career and personal and social responsibility. This research uses this KSAVE model by *Binkley et al. (2012)* as a guideline.

Box 1.1 Overview of the aspects of the KSAVE model for 21st century skills by *Binkley et al. (2012)*

The KSAVE Model

WAYS OF THINKING

Creativity & Innovation

This set of knowledge, skills and attitudes consists of thinking creatively, thinking and working creatively with others and implementing innovations.

Critical Thinking, Problem Solving & Decision Making

This set of knowledge, skills and attitudes consists of effective reasoning, systematic thinking, evaluating evidence, solving problems, articulating, creating reasoned judgments and decisions and, finally, attitudinal disposition.

Learning to Learn, Meta-cognition

The last set of knowledge, skills and attitudes of this theme focuses on having knowledge about and understanding of learning methods, the ability to recognise personal strengths and weaknesses, the ability to concentrate and reflect critically and aspects, such as willingness to change and flexibility.

WAYS OF WORKING

Communication

Communication is described in terms of knowledge, skills and attitudes concerning the competency in the mother tongue language and in additional languages.

Collaboration & Teamwork

Collaboration consists of knowledge, skills and attitudes to effectively interact with others, effectively work in divers teams, manage projects, guide and lead others and the ability to be responsible to others.

TOOLS FOR WORKING

Information Literacy

Information literacy consists of the accessibility and evaluation of information, usage and management of information and effective application technology.

ICT Literacy

This set includes the accessibility and evaluation of information and communication technology, but also the analysis and creation of media products, usage and management of information, effective application of technology and application of technology with honesty and integrity.

LIVING IN THE WORLD

Citizenship

Citizenship contains the knowledge of civil rights and policy making processes, but also aspects such as participation in community, a sense of solidarity and willingness to participate in democratic decision making.

Life & Career

The life and career set contains: the ability to adapt to change and being flexible, -managing goals and time, being a self-directed learner, managing projects, working independently, effectively interacting with others, effectively working in divers teams, producing results and being responsible to others.

Personal & Social Responsibility

This last set of skills focuses on knowledge of codes and conducting according to general accepted manners, but also the ability to communicate.

1.2 This Research

RESEARCH FOCUS

Children tend to develop their creativity skills during storytelling activities. Children often tell stories during pretend play in which they make use of toys. However, traditional toys do not, or only rarely, respond to children's actions, let alone the stories they are telling. Incorporation of technology into the toys creates the possibility to interact with the children and provide them with feedback during the storytelling process. *Wang et al. (2015)* describe that interactivity can stimulate creativity. Therefore, this research investigates the development of an interactive storytelling system using a smart toy. The smart toy functions as a character in the stories told. The goal of the system is to create a new way of stimulating children's creativity in home and school contexts.

CHARACTER TOY AS AGENT

The research starts with the creation of a conceptual framework. In the framework a character toy is approached as an agent. Agents can either be reactive: solely responding to stimuli, or hybrid: combining reactive behaviour with deliberation, reasoning about how to act. The different concepts are explained in more detail in 3.2 Components Interactive Storytelling System. This research focuses on the design of a reactive character toy. However, in a later stage the character toy could be extended with deliberation behaviour.

REACTIVE BEHAVIOUR

As shown by the results of a pilot study previous to this research, children expect to receive feedback from a smart character toy, or, in other words: they expect the character to be reactive (*ter Stal, 2017*). In addition, it is expected that reactive behaviour of a character toy can be a source of inspiration for children during the storytelling activity. As an example *Leversund, Krzywinski & Chen (2014)* showed that interactive objects had positive effect on children's imaginations. They observed that dynamic objects that gave feedback in the form of sound or movement where the main important sources for children's inspiration and creativity. A more detailed description of their research can be seen in 3.3 Reactive Behaviour & Storytelling.

EMOTIONAL BEHAVIOUR

Emotional behaviour could be implemented into the toy to stress the character role of the toy in the story. *Saldien, Goris, Vanderborght, Vanderfaeillie & Lefeber (2010)* mention the

importance of emotive expression to make animated characters believable. They also mention that the way characters express themselves conveys apparent beliefs, intents, and desires to the human observer. Another advantage of the implementation of emotional behaviour could be an increase of enjoyability, which could positively affect children's motivation during the storytelling activity. Results of a study by *Bartneck (2003)* show that the presence of emotional expressions significantly increases the enjoyability of the interaction of humans with a robotic character. This research investigates the influence of emotional behaviour of the character toy on children's storytelling.

TARGET GROUP

The target group for this research consists of elementary school children having an age between six and eight. In this age range, children have sufficient skills to tell structured stories, but are also still using toys in their stories. Elementary school teachers interviewed prior to this research confirm that children tell stories this way. Interviewed teachers indicated that only children in lower grades incorporate toys in pretend play activities (*ter Stal, 2017*). A more detailed description of the characteristics of these children can be seen in 1.3 Users.

COLLABORATIVE SETUP

The system to be designed focuses on the support of a collaborative activity. Collaboration can positively influence children's creativity (*Rojas-Drummond, Albarrán & Littleton, 2008; Paulus & Nijstad, 2003; Johnson & Johnson, 1991*). *Sawyer (2003)* even explicitly describes creativity as an emergent process that involves a social group of individuals engaged in complex, unpredictable interactions. Although the research does not focus on stimulation of collaboration, incorporating a collaborative setup might already affect creativity. In addition, a collaborative setup might positively affect the development of other 21st century skills, such as communication and collaboration and teamwork skills.

SUMMARY

Throughout the research a prototype for an interactive storytelling system using a smart toy is developed. In addition, the influence of emotional behaviour of the character toy on children's storytelling is explored. An overview of the research purpose can be seen in Box 1.2.

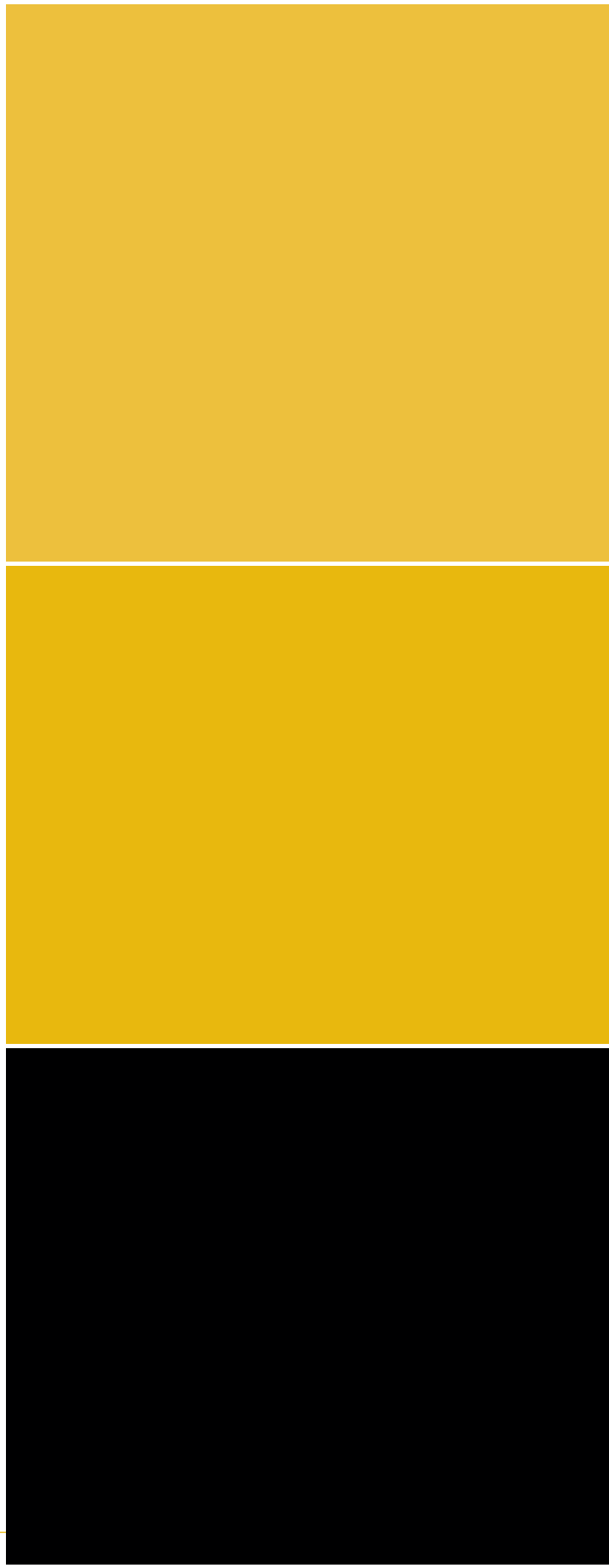
Conditions

The research investigates two conditions. The first condition, in which the character toy responses to stimuli without showing emotional behaviour, is further referred to as **condition NE**. The second condition, in which the character toy responses to stimuli by showing emotional behaviour, is referred to as **condition E**.

Research Question

The research aims at answering the following question:

"What is the effect of emotional behaviour of a character toy on children's storytelling?"



Box 1.2 Overview motivation research

Prepare children for future
By developing their skills needed to integrate into society

21st century skills
Set of important skills

Creativity and innovation
One of the KSAVE 21st century skills

Other KSAVE skills
Included in the themes: ways of thinking, ways of working, tools for working and living in the world

Storytelling
One way of stimulating creativity

Pretend play
Using toys to create stories around

Use of traditional toys
No feedback

Use of smart toys
To provide children with feedback

Condition NE

No emotional behaviour
Responses to stimuli without showing emotional behaviour

Condition E

Emotional behaviour
Responses to stimuli by showing emotional behaviour

1.3 Users

CHILDREN

The first and main target group of the storytelling system consists of elementary school children. These children are still developing, which provides the possibility to improve their 21st century skills. The digital storytelling environment is designed for children to interact with. To be able to adapt the interaction to the children, it is essential the product fits their development stage.

General Child Development

Child development typically consists of three different features, namely: physical development, socio-emotional development and cognitive development *(Markopoulos, Read, MacFarlane & Höysniemi, 2008)*. The physical development of a child mainly corresponds to the increase of physical size and is related with improvement of both gross and fine motor skills. The socio-emotional development deals with the influence of relationships on personal characteristics, such as self-esteem. Finally, cognitive development includes the intellect and language. It focuses on thinking, memory, problem solving and reasoning. Especially cognitive development is essential in digital storytelling. One of the main theories used to described the cognitive development of children is the Piaget's theory. *Markopoulos et al. (2008)* list the five different stages. In addition, they describe key points that have to be taken into account when designing interactive products for children (Table 1.1).

Development Process Storytelling Skills

In the age between three and five children's interpretations of events in a story change. Children's narration changes from one of isolated descriptions towards actions linked by knowledge of goals and causal relationships *(Trabasso, Stein, Rodkin, Munger & Baughn, 1992)*. In the research by *Trabasso et al. (1992)* children did not create their own stories, but narrated a pictorial event-sequence. The results of

STAGE	AGES	KEY POINTS FOR INTERACTIVE PRODUCT DESIGN
Sensorimotor	Birth – 2	
Preconceptual Thought	2 – 4	
Intuitive Thought	4 – 7	Children can use symbols and words and can distinguish reality from fantasy. In the latter part, they can take into account the viewpoint of others.
Concrete Operations	7 – 11	Children can classify things and understand the notion of reversibility and conservation. They can think logically but not abstractly.
Formal Operations	11+	Thinking is about ideas. They can consider various solutions without having to act them out and can deal with hypothetical situations.

Table 1.1 Piagetian stages of development with corresponding key points for interaction created by *Markopoulos et al. (2008)*

the study show that three- and four-year-old children have the ability to make narratives locally coherent, but that they are less skilled in creating the overall story coherence by interconnecting events. In contrast, from the age of five children organise their narrations into goal-action-outcome episodes and, this way, achieve global coherence in their narrations.

Shapiro & Hudson (1991) describe something similar. Their findings suggest that young children are still developing story schema. First graders produce structurally more complex stories containing goals and plots than preschoolers. Also, they use more complex language, past tense, and temporal connectives. These findings suggest that first graders may have a more elaborated story concept.

Like *Shapiro & Hudson, Mandler & Johnson (1977)* suggest young children are still developing story schema; a set of expectations about the internal structure of stories which serves to facilitate both encoding and retrieval. They attach the ability to use a story schema to the adequate effect of accurate recall, the ability to memorise story aspects.

Lynch & van den Broek (2007) examined six- and eight-year-old children's goal inference making processes while they were listening to stories. Their results show that children of both ages regularly make appropriate goal inferences while listening to narratives. In addition, the number of goal inferences can predict children's story recall. Thus, children as young as six are sensitive to the essential role of characters' goals in narrative structure. In addition, their results show children can engage in sophisticated cognitive processing while they listen to narratives to form coherent mental representations of them.

Finally, *Low & Durkin (1998)* researched how children interpret television narratives. Results of their study suggest that event knowledge of younger children allows them to infer narrative structure and causal connections in familiar script-based programmes. Also, the results suggest that, with age, children become more flexible in using their event knowledge in inferring narrative structure and causal connections in less routine television narratives.

Development Process Pretend Play

Pretend play first appears when children are around twelve months old (*White, 2012*). Piaget argued the development process of pretend play follows an inverted U-shape curve: pretend activities emerge during second year of life, increase over the following three or four years, and then decline (as cited in *Fein, 1981*). According to Piaget, play becomes more realistic as thought becomes more logical, and, thus, he predicted a rise and fall in the development of pretend play. Piaget identified two stages within the development of pretend play: solitary symbol activity and socio-dramatic play. These two stages are discussed in the next sections.

Stage 1: Solitary Symbolic Activity

According to Piaget pretend play is initially a solitary symbolic activity. In the beginning pretence is self-referenced: the child feeds itself. The child plays alone and is not interested in or unaware of what others around him or her do. The child talks towards itself. When self-referenced pretence decreases, the child starts talking to dolls. The child is an active agent and a doll is a passive recipient or object of the child's action.

Stage 2: Socio-dramatic Play (Collective Symbolism)

The shift from solitary to social play (collective symbolism) does not take place earlier than the later part of the age of three. This interactive make-believe is called socio-dramatic play. During the ages of three and six, interactive pretend play increases. During development pretend play becomes more and more other-reference, meaning play is directed toward other people and objects. At this stage the child seems to step out of the situation and manipulate "the other" (e.g. the doll) as if it were acting on its own.

The ability to identify an object with another, substituting roles, marks the transition from stage 1 to stage 2 pretence. An example of such a substitution is pretending a physical cup to be a shell. The physical object "cup" is substituted by the abstract object "shell". The ability to substitute roles indicates children are able to see "things as objects of thoughts" instead of "objects of actions". Substitution behaviour continues to improve during early school years, until the age of eight. From this age children do not need a substitute object: they are able to represent the abstract object by gestures alone.

Two aspects of socio-dramatic play receive special attention; meta-communication and role enactment. Meta-communication is defined as the messages that provide info about how another message should be interpreted. Since in pretend play no codified rules exit, meta-communication is needed to maintain and elaborate the flow of play. Examples of meta-communication are communication about the partner's role, such as "Are you going to be the bride?", prospective play plans, such as "Pretend you hate fish" and own plans, such as "I gotta drive to the shopping centre". In pretend play, children use meta-communication to tune their mental representations and layering of these representation over reality (2.4 Pretend Play). Role enactment means behaviour in which the child simulates the identity or characteristics of another person. Older children are more likely to produce integrative role structures.

What can be learned from the developmental research as described in this section is that the development stage of children, mainly determined by their age, influences how children play. Thus, the development stage also affects how children perform in a play-related storytelling activity. In addition, children's developmental stage affects how they perceive technology and how they interact with it. Therefore, the developmental stage should carefully be taken into account when designing a system for children.

TEACHERS

The second target group consists of teachers of elementary schools. In order to influence the children's 21st century skills, it is important the storytelling system can be used in class. To ensure teachers allow children to use the system in class, it is essential the teachers believe in the benefits of the system. Therefore, it is also important to adapt the characteristics of the system to the needs of the teachers.

PARENTS AND CAREGIVERS

In addition to telling stories in a school context, children play and tell stories at home. Thus, the system to be designed can also be used in a home situation. Elementary school parents and caregivers influence how children play at home. To ensure children are able to play with the system designed in a home situation, it is essential parents and caretakers value the possibilities of the system, resulting in them being the third target group.

2

This section describes the definition of storytelling and the definition of a story in particular. In addition, the section provides an overview of narrative elements of a story and ways to assess stories based on these narrative elements. Furthermore, the section describes how storytelling and toys are used in pretend play. The section ends with implications of the definitions for the development of an interactive storytelling system in this research.

Interesting stories are build around a good structure. WillemijnB, https://www.flickr.com/photos/136479298@N02/28134733065

Storytelling

2.1 Storytelling

WHAT IS STORYTELLING?

Different definitions of storytelling exist. In this research the definition by the *National Storytelling Network* is used as a guideline. According to the *National Storytelling Network*, storytelling is defined as: "the interactive art of using words and actions to reveal the elements and images of a story while encouraging the listener's imagination". In this definition, five aspects can be identified. These aspects are used as a guideline throughout the research. The aspects are explained in more detail below.

Storytelling Presents a Story

The most obvious aspect of storytelling is that storytelling always involves the presentation of a story, a narrative. A story contains the characteristics as described before.

Storytelling is Interactive

The second aspect of storytelling is interactivity, meaning a story involves a two-way interaction between a storyteller and one or more listeners. Responses of the listeners can influence the way the story is told.

Storytelling Uses Language

Storytelling always involves language. Language can be used in a spoken or written form.

Storytelling Uses Actions

Use of language not only includes the use of words, but also other actions, such as vocalisation, physical movement and the use of gestures.

Storytelling Encourages Listener's Active Imagination

Listeners are co-creators of a story, since the completed story happens in the mind of the listeners and is, therefore, unique and personal. The listener actively creates vivid, multi-sensory images, actions, characters, and events of the story in his or her mind, based on the teller's performance and on or her own past experiences, beliefs, and understandings.

STORYTELLING & SKILLS

Children often tell stories in their daily life. In education storytelling is often used as a teaching method *(Sugimoto, 2011)*. Therefore, storytelling seems a promising method for developing skills, among which the 21st century skills. *Alves, Lopes, Matos, Velho & Silva (2010)* mention that storytelling allows children to expose their ideas and feelings about things, people and the world. *Decortis & Rizzo (2002)* describe something similar. They say storytelling teaches children to express themselves and make sense of the external world. Much research indicates the value of storytelling in developing children's skills. Storytelling activities are effective for developing children's linguistic and literacy skills (*Fridin, 2014*; *Leversund, Krzywinski & Chen,*

2014; *Sugimoto, 2011*; *Westlund & Breazeal, 2015*), logical thinking skills (*Fridin, 2014*; *Leversund, Krzywinski & Chen, 2014*; *Sugimoto, 2011*), communication skills (*Alborzi, Druin, Montemayor, Platner, Porteous, Sherman, ... & Kruskal, 2000*; *Alves et al., 2010*; *Leversund, Krzywinski & Chen, 2014*; *Sugimoto, 2011*), imagination skills (*Fridin, 2014*; *Sugimoto, 2011*), creativity skills (*Alborzi et al., 2000*; *Alves et al., 2010*; *Fridin, 2014*; *Leversund, Krzywinski & Chen, 2014*) and, finally, collaboration skills (*Alborzi et al., 2000*; *Leversund, Krzywinski & Chen, 2014*). These skills largely overlap with the 21st century skills listed in Box 1.1.

2.2 What is a Story?

The previous section states that storytelling presents a story. But what is a story? It is useful to investigate the definition of a story, also called a narrative. Stories are more than just temporal sequences of events. Different definitions of a story exist. In this research, the definition of *Denning (2004)* is used. *Denning (2004)* defines a story as: "a narrative that links a set of events in some kind of causal sequence". *Tesselaar & Scheringa (2008)* define a story in a similar way: "a reproduction of related events". They emphasise that especially the connection between events and the presence of narrative elements (to be discussed in 2.3 Narrative Elements & Story Assessment) are essential in a story and that these elements give the story its strength. This connection is strengthened in Trabasso's model of story understanding (*Trabasso, Secco & van den Broek, 1982)*. According to this model a coherent story consists of hierarchies of goals, actions and outcomes.

2.3 Narrative Elements & Story Assessment

Several frameworks exist that address the quality of stories based on narrative elements. For example, *Petersen (2014)* provides a story grammar scoring scheme to assess the quality of a story retold by children. The scoring scheme identifies the following story grammar elements: the character, the setting, a problem, one or multiple feeling - plan - attempt - consequence sequences and finally an ending and end feeling. Children can either receive one or two points depending on how detailed they describe the elements. An example of a story read to the children of which they are asked to retell it can be seen in Box 2.1. The different story grammar elements are indicated with icons. The story grammar scoring scheme fitting this story can be seen in Table 2.1. Although the story grammar scoring scheme was created for the retell of a story, it nicely lists the story grammar elements that can be present in the story. In addition, the example story clearly shows how these story grammar elements can be implemented in a story.

The design of this story grammar scoring scheme largely corresponds with the Index of Narrative Complexity (INC) created by *Petersen, Gillam & Gillam (2008)*. However, the INC is not specifically created for the retell of stories. In addition, the scoring instructions are clearly specified to be applied for every story. The INC integrates existing research and conceptual approaches related to the assessment of macro-structural and micro-structural aspects of oral narratives. The INC scoring system includes categories for rating the complexity of characters, the setting, initiating events, internal responses, plans, action/attempts, complications, consequences, narrator evaluations, formulaic markers, temporal markers, and causal adverbial clauses.

This research takes the INC as a guideline for the design of story grammar support of the prototype. A list of the different story elements considered, including an explanation and scoring structure can be seen in Table A1 in A1 Index of Narrative Complexity.

On Thursday, **Louis** was playing **outside**. He was having fun with his puppy. When Louis gently tossed a ball, **the puppy limped**. Louis, who loved his pet, felt **sad** because **the puppy couldn't walk**. He **decided to read about treating hurt paws**. Louis **read a big book on helping animals**. Then he **wrapped the puppy's paw with a bandage**. He put it on so that it would feel better. But **his puppy instantly chewed it off**. Louis was **frustrated**. **He couldn't remedy the problem**. So then Louis **decided to get help**. **He visited an animal doctor**, a kind- hearted woman. **Louis said, "Please help. My puppy can't walk."** The **vet inspected the paw. She said, "I see a tiny, jagged thorn that is stuck in its paw."** She carefully **removed the thorn**. After **his puppy was better**, Louis was **excited** because **he could finally play with the small, healthy pet**.

Box 2.1 An example of a story to be told to children by *Petersen (2014)*. The children are asked to retell the story and their stories are then scored according to the scheme in Table A1 in A1 Index of Narrative Complexity. The icons correspond to the story grammar elements as listed in Table A1.

STORY GRAMMAR ELEMENT	2 POINTS	1 POINT
Character	Louis / any name	A boy / the boy
Setting	Playing outside	Playing / outside
Problem	Puppy was hurt / had sore paw	It couldn't play
Feeling	Sad / mad / upset	Didn't like it / cried
Plan	Decided to read how to fix paws	Decided to do it
Attempt	Read how to fix it / wrapped paw	Read about it
Consequence / Same problem	Dog chewed off bandage / couldn't fix the paw	Didn't work / couldn't do it
Emotion-2	Sad / mad / frustrated	Didn't like it / cried
Plan-2	Decided to see the vet	Decided to get help
Attempt-2	Went to vet / told vet dog is hurt	Talked to vet
Consequence	Found thorn in paw / removed the thorn	Fixed it
Ending	Dog got better / he played with the dog	All better
End feeling	Happy / relieved	Liked it / smiled

Table 2.1 Story grammar scoring scheme by *Petersen (2014)*. Example of how to give scores for the retell of the story in Box 2.1.

2.4 Pretend Play

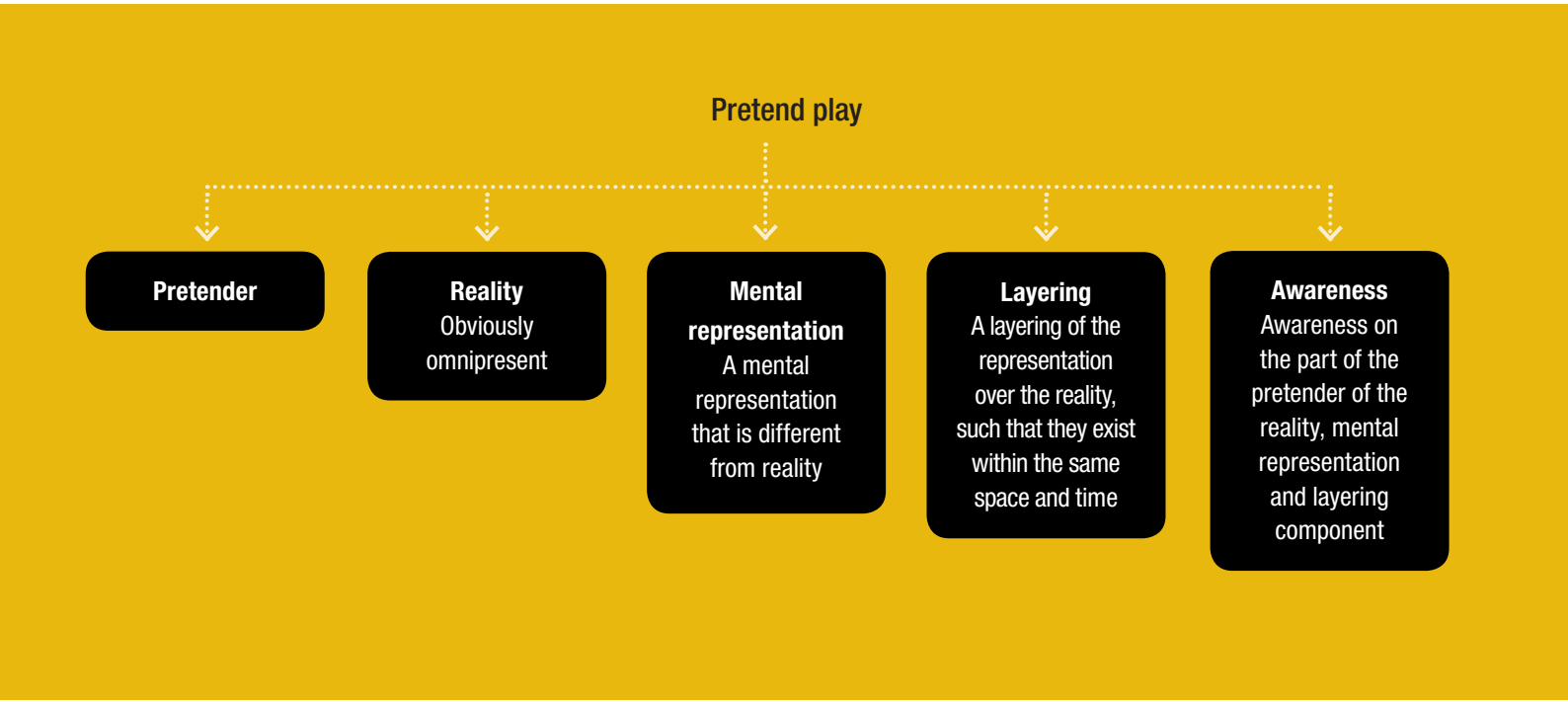
An activity in which children perform storytelling is pretend play. Pretend play, also referred to as imaginative play, make-believe play, fantasy play or dramatic play, is a hallmark activity in early childhood (*White, 2012)*. In addition, Levin & Turgeon state pretence is seen as a vehicle which permits children to vent feelings that cannot be expressed in real life (*as cited by Fein, 1981*).

WHAT IS PRETEND PLAY?

As described by *Lillard (1993)* pretend play can be seen as an intersection of two broader concepts: play and pretence. There exist no single definition of play, *Lillard (1993)* defines play as: "any activity that is engaged in for the purpose of fun, rather than survival". In addition, she mentions that pretence involves "stretching one 'reality' over another, or holding 'one thing in front of another in order to protect or conceal or disguise it'. *White (2012)* defines pretence in a similar way: she states pretending involves the creation of alternate realities for the real world. *Fein (1981)* describes pretence as a theoretical construct defined as behaviour in a simulative non-literal or , "as-if" mode. *Lillard (1993)* combines the concepts of play and pretence to define pretend play: "the projecting of a supposed situation onto an actual one, in the spirit of fun rather than for survival". Or, described in less technical terms: children that playing pretend are playing 'as if' something or someone is real; they create a situation in which more is going on that what is literally happening. In addition to the definition of pretend play, *Lillard (1993)* describes five features that could be considered necessary to identify pretend play (see table Box 2.2).

STORYTELLING IN PRETEND PLAY

The five aspects of storytelling as described in 2.1 Storytelling, can all be present in pretend play, although they not necessarily have to be present. The "as-if" layer of pretend play, in which more is going on than what literally is happening, provides an opportunity to tell stories. Children often involve language in pretend play by talking aloud. Also, they can use actions, such as vocalisation, physical movement or gestures in addition to words. Howev-



Box 2.2 Five features of pretend play as described by *Lillard (1993)*

er, the playing not necessarily includes listeners, and is, therefore, not necessarily interactive.

PRETEND PLAY & SKILLS

As described by *White (2012)*, pretend play influences the cognitive and social and emotional development of children. *Fein (1981)* describes relationships between pretend play and skills in similar domains.

White (2012) identifies three main cognitive benefits, namely the development of creativity, language and literacy and executive functions. *Fisher* describes pretend play mainly affects divergent thinking, a key component of creativity *(as cited in White, 2012)*. *Fein (1981)* also provides some references that show a positive link with creativity. In addition, pretend play provides children with the opportunity to practice their use of language. They jointly develop narrative abilities, since they have to communicate with others *(White, 2012)*. Some evidence exist that the vocabulary of children in kindergarten is positively related to the amount of time the children spent talking with others during pretend play sessions at the age of three *(Moreton as cited in White, 2012)*. Lastly, pretend play could influence children's executive functions: their cognitive abilities behind conscious self-control of thought, action and emotion *(White 2012)*.

Pretend play also comes with social emotional benefits. *White (2012)* describes a set of social emotional skills trained by pretend play. First of all, he describes children learn to navigate interpersonal interactions, since they learn to negotiate and cooperate. Also, according to him children develop their problem solving and conflict resolution skills due to the interactive characteristic of pretend play. In addition, children's social understanding improves, since the children develop an understanding of themselves and others: they develop the ability to create mental states (theory of mind). Furthermore, children learn about realities and expectations of culture and how to act in society. Lastly, *White (2012)* mentions children learn to cope and regulate their emotions, since they can master negative feelings in a risk free context.

Thus, what can be seen from this research is that pretend play is powerful tool for learning. In addition to the advantages of storytelling in general as described above, combining the two has potential to be a powerful tool for the development of children's 21st century skills.

2.5 Use of Toys in Pretend Play

Traditional toys, such as puppets and dolls, encourage children's storytelling in the form of pretend play *(Vaucelle & Jehan, 2002)*. The *Cambridge Dictionary (2017)* defines a toy as: "an object for children to play with". Thus, according to this definition, any object can become a toy as long as a child starts playing with it.

As described by *Kara, Aydin & Cagiltay (2014)* interaction with toys plays a crucial role in child development. Also *Vaucelle & Ishii (2008)* provide evidence for toys serving a fundamental function in the development of children. An activity in which children use toys is storytelling.

But, what role do toys have in children's pretend play storytelling? *Alves et al. (2010)* state toys allow children to connect the tangible world with their imagination. Furthermore, *Vaucelle & Ishii (2008)* describe toys can be used to externalise and elaborate a child's mental constructions. Children create their own symbolic meaning by investing toys with their images and feelings. The symbolic meaning of the objects is a result of the children's interplay with it. Also, children build story worlds around objects, take an interest in manipulating objects and imbue them with personalities. (*Budd, Madej, Stephens-Wells, de Jong, Katzur & Mulligan, 2007).* By adding these personalities, objects become story characters. With these character toys

children create interrelationships and plots, meaning they expose their social knowledge: knowing about human beings and social relationships In addition, children explore the visual and narrative perspectives of the character toys (*Budd et al,. 2007*).

TOYS & SKILLS

Toys can trigger children's exploration and their internal fantasy, their imagination (*Kara, Aydin & Cagiltay, 2014; Ribeiro, Iurgel & Ferreira, 2011; Wang, Tao, Liu, Wang, Yao & Ying, 2015*). Toys can inspire children's creativity (*Alves et al., 2010*; *Kara, Aydin & Cagiltay, 2014; Wang et al., 2015*). In addition, by playing with toys children train communication (*Alves et al., 2010*) and linguistic skills *(Kara, Aydin & Cagiltay, 2014).*

SMART TOYS

Nowadays, toys developed are sometimes being integrated with technology. These toys are, for example, referred to as smart toys, intelligent toys, animated toys, high-tech toys, interactive toys and robotic toys. In this research the toys are referred to as smart toys. In today's world, smart toys are in high demand among young children (*Kara, Aydin & Cagiltay, 2014*).

However, there exist a gap between traditional toys and smart toys. Some toys have a low threshold, because they are cuddly and fluffy, whereas others are technologically advanced. Only few are both at the same time *(Fontijn & Mendels, 2005)*.

Kara, Aydin and Cagiltay (2014) describe that a smart toy is an effective tool for engaging children in technology and storytelling. However, many of these toys focus on entertainment. The passive consumption of entertaining tools might prevent children from creating their own solutions, developing new ideas and seeking new styles in their play *(Kara, Aydin & Cagiltay, 2014*). *Cao, Lindley, Helmes & Sellen (2010)* describe similar disadvantages. According to them technology for children tends to entertain, rather than to serve as a source of inspiration for child-initiated creativity. Furthermore, *Vaucelle & Jehan (2002)* state that the majority of technological toys today does not provide space for children to tell their own stories, but rather tends to tell stories to them.

Therefore, as described by *Kara, Aydin & Cagiltay (2014)* new technologies should take an open-ended approach (multiple opportunities for manipulation and forms of play) to encourage children to use their creativity skills. First of all, open-ended features of toys foster children's creativity and imagination. Secondly, open-ended design features support not only children's motivation, but also their exploration of physical and virtual objects. Using an open-ended approach provides children with the opportunity to produce imaginative and dynamic stories (*Kara, Aydin and Cagiltay, 2014*). In addition, *Wang et al. (2015)* describe that interactive operation can help children to stimulate creativity. The broad term interactivity has many definitions. In this research we take two characteristics of interactivity. Interactivity is contains two characteristics: there must be at least two participants (human or non-human) and some technology allowing for mediated information exchanges between users through a channel *(Kiousis, 2012)*.

When designing an interactive storytelling environment with tangible toys, it is thus useful to take an open-ended approach and include interactive operation.

2.6 Discussion

The section above showed how the use of multiple narrative elements can lead to coherent stories. This research focuses on the development of an interactive storytelling system. On the one hand, the system to be developed could support children in telling a coherent story by forcing them to include narrative elements. On the other hand, structuring the story too much in advance limits the children's freedom in telling their own story. Therefore, the system could also enable, but not force, children to tell coherent stories. This approach would result in them telling emergent narratives *(Aylett, 1999)*. In emergent narratives children have a lot of freedom to shape the story they take part in. This approach is in line with the open-ended approach as suggested by *Kara, Aydin & Cagiltay (2014)* in 2.5 Use of Toys in Pretend Play. However, using this approach the stories told may not have much coherence. The trade-off between narrative structure and player freedom is called the narrative paradox *(Louchart & Aylett, 2003)*. It is opted to develop a system that does not constrain the children's freedom too much, since eventually the goal of the system is to stimulate creativity. Such as development approach prevents the system from becoming a passive entertaining tool.

3

To be able to design a system for interactive storytelling, a conceptual framework is created which is used as a guideline throughout the research. The framework contains three categories of components that can be identified in an interactive story. Also, the framework contains categories of components that can be identified in an interactive storytelling system. The framework connects the story component categories with the system component categories. Then, a connection between the framework and storytelling is created. The section ends with a discussion.

A conceptual framework is used as the fundamental to build design decision onto, Astris1, https://commons.wikimedia.org/wiki/File:Lorimerlite_framework.jpg

Framework

3.1 Components Interactive Story

The three different story component categories identified are: **1. the story world, 2. objects and 3. characters**. The categories and their relationships with the system component categories can be seen in Box 3.1. Below, the categories are explained in more detail.

THE STORY WORLD

The first component category, the story world is defined as: **the imaginative location where actions of characters take place**. Thus, the story world is only "present" in the children's heads. The location where the story takes place in the real world can influence the story world. In the real world actions might take place on a floor or table top where children play. Also, the story world can be affected by, for example, a background projection or physical background map.

OBJECTS

The second story component category consists of objects. A story can contain multiple objects. An object is defined as: **a tangible, inanimate thing that cannot perform actions, used in a story**. Although objects cannot perform actions they can be used in the actions of characters (e.g. a character may eat a carrot, an object).Objects can specifically be designed for storytelling. Also, they can be already existing objects that are used in a story.

CHARACTERS

The final category consists of characters. Children can use multiple characters in their story. Different from objects, characters are animated, lively objects that are able to perform actions. Therefore, a character is defined as: **an animated, lively object that can perform actions, used in a story**. An action is defined as: **a character's process of doing something**. As explained before, objects cannot perform actions, but characters can use objects in their actions. Characters do not necessarily have to be persons. Characters can specifically be designed for storytelling, but can also be existing objects that are animated by children.

3.2 Components Interactive Storytelling System

The different story components can be translated into system components. The storytelling components can be linked to three system component categories, consisting of: static components, dynamic components and agent components. The agent component category is divided into two subcategories, namely the reactive component category and the hybrid component category. Below, the different components are clarified.

STATIC COMPONENT

A component is categorised as a static component if: **the features of the component do not change over time, they are fixed**.

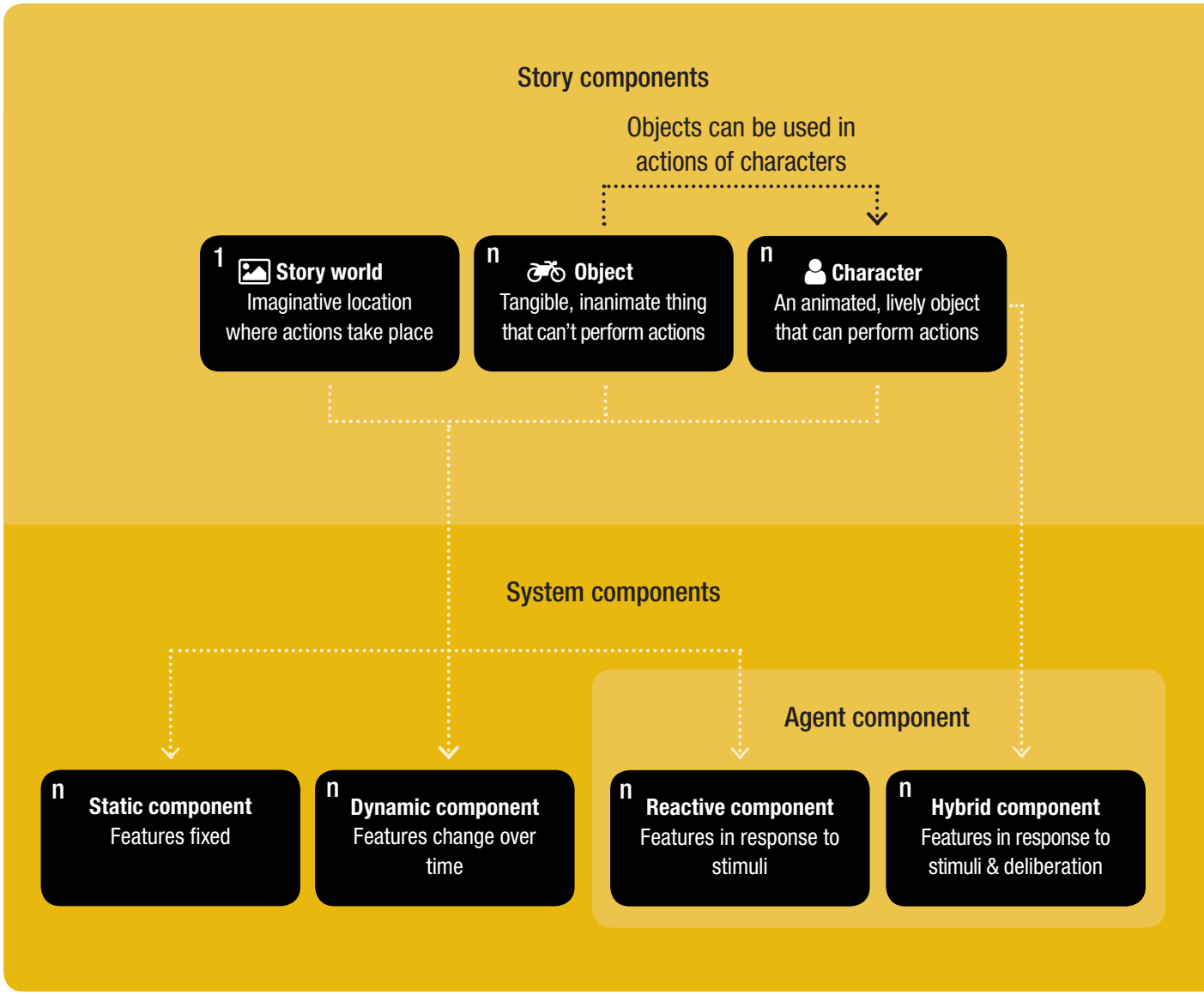
DYNAMIC COMPONENT

The second category contains the dynamic components. Different from a static component, a dynamic component is defined as: **a component of which the features are not fixed, but change over time**.

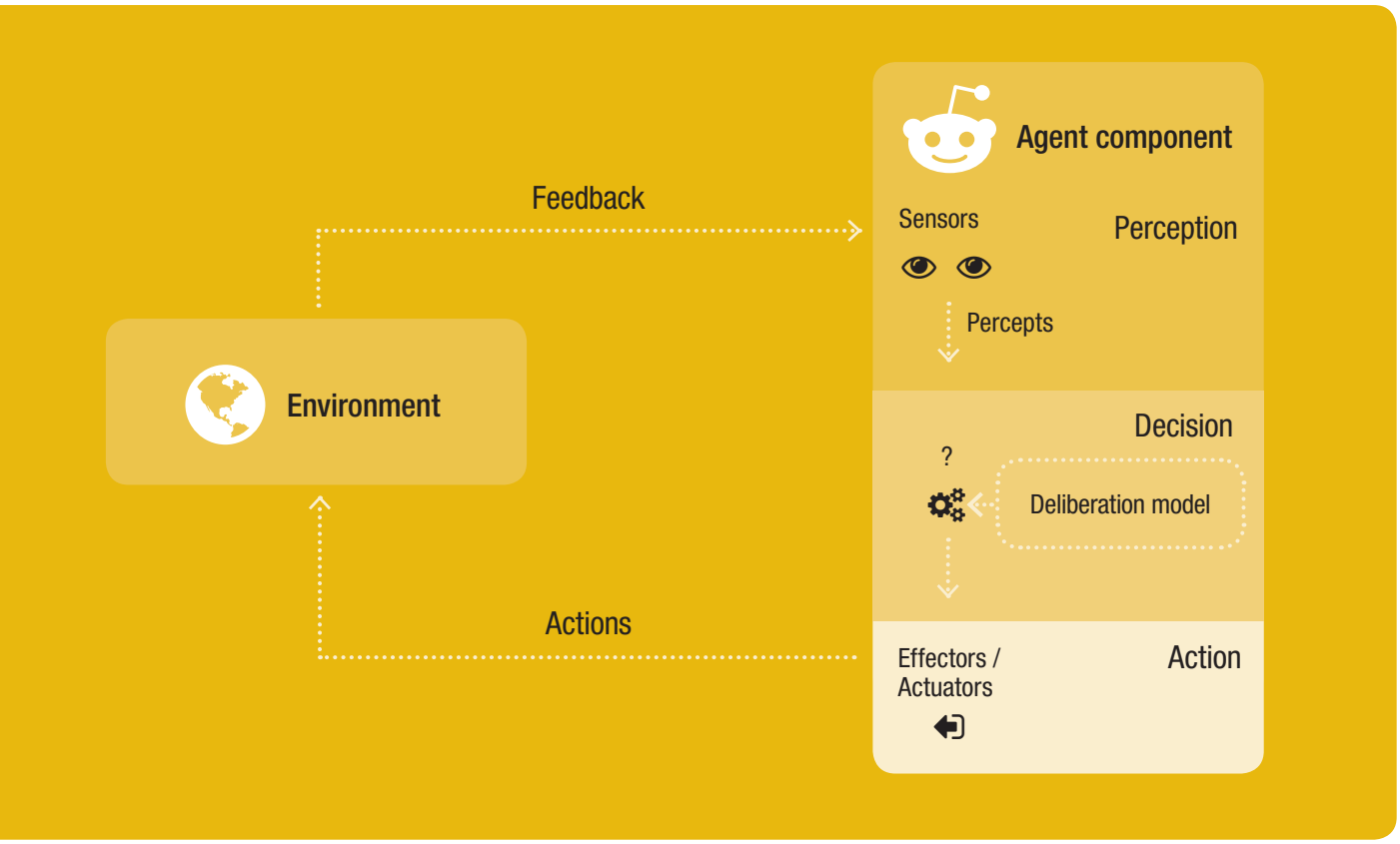
AGENT COMPONENT

The final category contains agent components. Of the three system component categories, components in this category approach human-like behaviour the most.

Different definitions of an agent exist, according to *Wooldridge (2009)* an agent is defined as: **"a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meets its delegated objectives"**. An abstract view of an agent situated in an environment can be seen in Box 3.2. An agent takes sensory input from the environment, and produces, as output, actions that affect it. Thus, according to Wooldridge's definition, an agent is autonomous. But what is autonomy? The *Cambridge Dictionary (2017)* describes autonomy as "the ability to make your own decisions without being controlled by anyone else". *Wooldridge (2009)* emphasises autonomy is a spectrum,



Box 3.1 Three story component categories are identified. The first category is the story world. Only one story world is present in a story. The story world is the imaginative location where actions of characters take place. In addition, a story can include multiple objects and characters. In this research objects are defined as tangible, inanimate things that cannot perform actions, whereas characters are animated, lively objects that can perform actions. However, characters might use objects in their actions. The story component categories can be linked to three system component categories. The first system component category contains static components of which features are fixed, whereas the second category contains dynamic components of which features change over time. The third category consists of agent components. Agents perform autonomous actions and can either be reactive or hybrid. The features of reactive agents only change by responding to stimuli, whereas for hybrid agents the features also change based on deliberation. The story world, objects and characters can be a static, dynamic or reactive component. However, only a character can function as a hybrid component. A character is the only animated component, which implies only a character component is able to "reason consciously" and is able to be deliberative.-



Box 3.2 An agent in its environment as described by *Wooldridge (2009)*. An agent takes sensory input from the environment, and produces, as output, actions that affect it. The interaction is usually an ongoing, non-terminating one. Only a hybrid agent contains a deliberation model during the decision process, a reactive agent simply reacts to a stimulus.

with on the one end full freedom to act according to own beliefs, goals and actions, and, on the other end, simply acting according to what it is told. Different agent types can be distinguished. Some research distinguishes reactive agents and deliberative agents (*Stone, 1997*), deliberative agents are also referred to as autonomous active agents (*Ricci & Santi, 2012*), proactive agents (*Padgham & Winikoff, 2005*) and goal-directed agents (*Franklin & Graesser, 1997*). In this research, the distinction described by *Wooldrige (2009)* is used. *Wooldrige (2009)* defines two type of agents: reactive agents and hybrid agents: agents which are both reactive and deliberative. *Arkin (1995)* describes a similar distinction. The agent types are described in more detail below.

Reactive Component

The first agent subcategory consists of reactive agents, defined as: "**an agent that simply reacts to an environment, without reasoning about it**" (*Wooldridge, 2009)*. Reactive agents link perception directly to actions. Thus, a reactive agent describes the relation between two components: a stimulus (the perception) and a response (the action).

Hybrid Component

The second agent subcategory consists of hybrid components, hybrid agents. Like reactive agents, hybrid agents react to the environment. However, hybrid agents do not simply react to a stimulus, they also reason about it. Hybrid agents are deliberative: **they decide what states of affairs to achieve** *Wooldridge (2009)*.

RELATIONS STORYTELLING & SYSTEM COMPONENTS

The story world can either be classified as a static component (e.g. contain a printed background map), a dynamic component (e.g. contain a dynamic background projection), or a reactive component (e.g. contain a dynamic background projection that reacts to the user, characters or objects). Objects and characters can also be static components (e.g. a regular dolls), dynamic components (e.g. doll with dynamic appearance.) or reactive agents (e.g. smart toys). However, only a character can function as a hybrid component. A character is the only animated component, which implies only a character component is able to "reason consciously" and is able to act deliberatively.

3.3 Reactive Behaviour & Storytelling

As shown by the results of a pilot study previous to this research, children expect to receive feedback from a smart character toy, or, in other words: they expect the character to be reactive (*ter Stal, 2017*). In addition, it is expected that reactive behaviour of a character toy can be a source of inspiration for children during the storytelling activity. As an example *Leversund, Krzywinski & Chen (2014)* showed that interactive objects had positive effect on children's imaginations. They observed that dynamic objects that gave feedback in the form of sound or movement were the main important sources for children's inspiration and creativity. The research evaluated the RoboTale, a tangible multi-touch tabletop application, in supporting children's collaborative storytelling. Children showed great interest in interactive weather objects. The weather objects provided children with feedback by using a combination of sound and visual effects. These objects became the centre of their attention and were used very frequently. *Leversund et al. (2014)* observed that the weather objects had positive effects on the children's imaginations. Therefore, the weather objects had great influence on the content of the stories.

3.4 Deliberative Behaviour & Storytelling

It is expected that deliberative behaviour of a character toy is a source of inspiration during a storytelling activity, but also helps children with story structuring. Extending character toys with deliberative behaviour, allows them to initiate ideas. Children might be inspired by the toys' ideas and based on these ideas adapt their story. This way, the toys could influence the children's creativity.

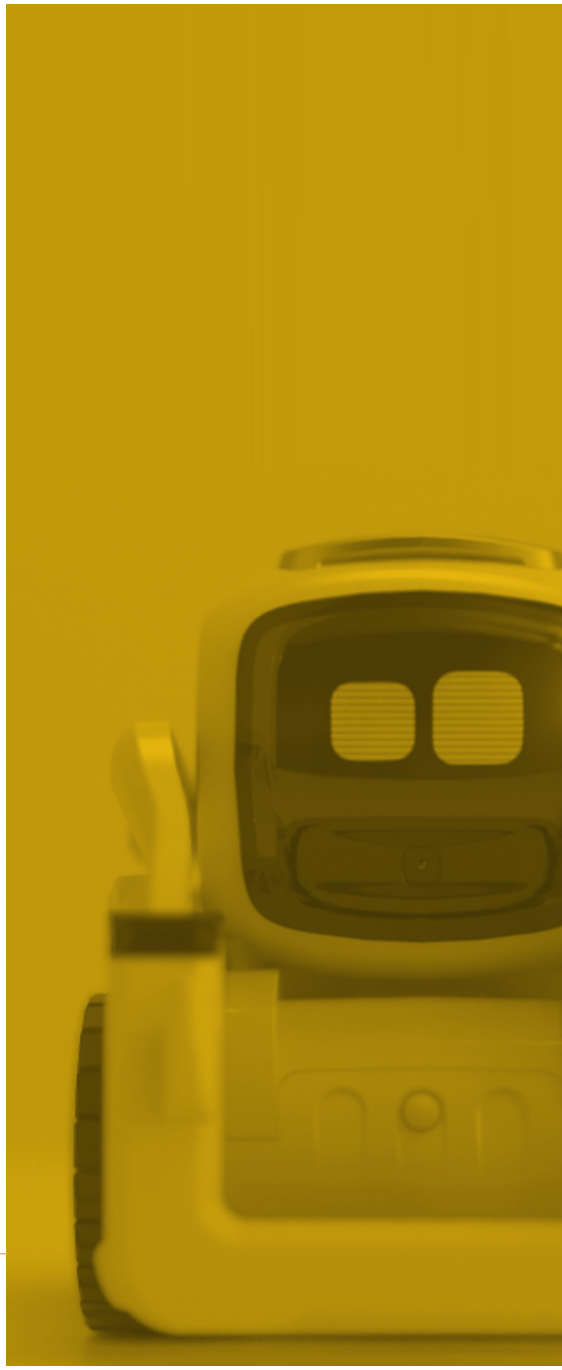
In addition, deliberative toys could provide suggestions concerning the structure of the story. The toy could use a similar strategy as adults. Thereby, the characters take over the teacher role of supporting the children. Feedback and help can be tailored towards the individual child, increasing the educational effectiveness *(Lieberman, 2006).* Adults typically provide children with encouragement and guidance around the creation of the story structure Questions such as "and then what did the boy do?", "was scared?" or "how did they find their way out of the forest?" help children to understand basic elements of character and plot development (*Cherry, 1977; Hough, Nurss & Wood, 1987, as cited in Steiner & Moher, 1992*). Elementary school teachers help children in a similar way, known by interviews and brainstorm sessions with teachers in a study prior to this research. The teachers indicated it would be great if technology can help children in structuring their stories (*ter Stal, 2017*). Encouragement and guidance can be integrated into a deliberative character toy to help the children with story structuring.

3.5 Discussion

This research focuses on the implementation of reactivity into the character toy, deliberation can be implemented in a later stage. In order to implement reactivity into a character toy technological possibilities have been investigated. The character toy should be able to pick up stimuli from the environment to be able to react. Two matrices have been created. The first matrix shows how various stimuli can be sensed with technology (see Table A2 in A2 Technical Solutions Reactivity) and the second matrix shows how technology can be used to react in various ways (see Table A3 in A2 Technical Solutions Reactivity). It is important that the technology integrated into the character toy can measure multiple stimuli and can react in various ways as described in these matrices. Decisions for the technology used are explained in 5.2 Main Character.

4

In this chapter relevant related work is described. The section starts with a small description of traditional toys. Secondly, some examples of commercial and interactive toys for elementary school kids are presented. Thirdly, related research projects that specifically focus on the use of interactive toys for storytelling are described. Per project is listed how reactivity and, if present, deliberation are implemented. The chapter ends with a discussion section.



Investigating related work, such as the Cozmo robot, provides insight in how reactivity and deliberation can be implemented in interactive toys for storytelling, The Verge, http://www.theverge.com/2016/6/27/12007772/anki-cozmo-robot-ai-toy-wall-e-pixar

Related Work

4.1 Traditional Toys

Many existing toys for elementary school children are just static, although of some of the toys the posture can be changed by allowing children to rotate, for example, the arms, the legs or the head of the toy. An example of toys of which the posture can be changed are character toys designed by Playmobil, as can be seen in Figure 4.2. In addition, sometimes the appearance of toys can be changed by providing children with separate clothes or accessories that can be combined with the toy, such as the ones designed for the Barbie dolls (Figure 4.1) and delivered with Playmobil characters (Figure 4.2). This section does not describe all traditional toys, since this is out of the scope of the project. The most important notice is that many of the traditional toys have similar characteristics as described before.

When playing with traditional toys children have to adapt aspects, such as the appearance and posture of the toys, to fit with the story they are creating. In addition, the toys are not interactive, meaning children also have to adapt aspects, such as the behaviour and emotions of the toys. Thus, traditional toys provide a different way to play than interactive toys. Therefore, the rest of the chapter focuses on commercial interactive toys and research on the use of interactive toys.

Figure 4.1 The Barbie fashion beauty package. The package allows children to design their own clothes by adding stickers onto special Barbie clothes. This way, children can adapt the appearance of their dolls to fit with their story, Barbie, http://play.barbie.com

Figure 4.2 The Playmobil flower shop. Children can change the posture of the character toys by rotating their heads, arms and legs. Also, characters come with accessories, such as flowers that can be "clicked" into the characters' hands, Playmobil, http://www.playmobil.nl

4.1 Commercial Interactive Toys

This section provides an overview of commercial interactive toys. Most of the toys react to a limited set of commands. When using the toys in a story, the toys' responses are independent of the story that is created by the child. The section is not meant to be an inexhaustible list of all available toys, but is created to provide an overview of the variety in characteristics of the toys. In addition to the projects described below, more examples of interactive toys exist, such as CHiP, a robot dog by WowWee, the robot dog by Bandai and the Penbo, a robot penguin designed by Bossa Nova Robotics. However, these toys are not discussed in detail, since they have characteristic that are similar to the ones described.

AIBO

AIBO, designed by Sony, is one of the early commercial robotic pets (Figure 4.3). Although the toy is no longer on the market, the toy is highly related to this research; AIBO is a self-learning toy that shows, both, reactive and deliberative behaviour. The user can instruct AIBO what do via speech commands. AIBO reacts to several predefined speech commands, such as "Sit", "Go for it" and "Don't do that". In addition, AIBO reacts to physical instruction cards (recognised by AIBO's camera). The cards can be used to instruct AIBO to perform actions, such as dancing, walking or turning. Finally, AIBO responds to touch and is able to recognise and avoid objects and to recognise faces. AIBO comes with a special ball. AIBO likes playing with the ball: when the ball is thrown, AIBO fetches it. When the user does not play with AIBO and the ball for a certain period, AIBO starts looking for the ball. AIBO reflects a wide range of emotions via its LED-illuminated face of which the colour can be changed. In addition, it can adapt its posture by moving its limbs, tail and head. An emotional model calculates AIBO's emotion based on interaction with the environment and the user. For example, AIBO becomes more happy when it sees its ball or recognises the owner's face. AIBO becomes a truly unique individual by sharing memories with the owner. In the beginning, the owner is registered with a name and photograph. The user can train AIBO by praising and encouraging it (e.g. using the speech command "Go for it") when AIBO performs an action (e.g. plays with the ball). When encouraged, AIBO will try harder and this way improve its performance. When scaffolding it ("Don't do that") AIBO might lose interest in performing the action (in this case, in playing with the ball). Thus, the toy is self-learning when it comes to actions. In addition, the toy establishes a relationship with the owner. As an example: when AIBO falls down and the owner helps AIBO to get up, AIBO reacts nicely to the user in a later stage. If the owner does not help AIBO, it become rebellious towards the owner. A summary of the characteristics of the AIBO can be seen in Box 4.1

Figure 4.3 The Sony Aibo, Sony, http://www.sony-aibo.com/aibo-models/sony-aibo-ers-7

Box 4.1 Characteristics Aibo

Aibo

Reactivity

STIMULUS	RESPONSE
Speech command	*Change face animation, sound, posture, movements*
Instruction card	*Change face animation, sound, posture, movements*
Touch	*Change face animation, sound, posture, movements*
Recognition face	*Change face animation, sound, posture, movements*
Recognition object	*Moves around object*
Recognition ball	*Plays with ball: change face animation, sound, posture, movements*
Not close to ball for certain period of time	*Moves around to search for ball*

Deliberation

ASPECT	IMPLEMENTATION
Emotion	*Emotional model based on interaction with user and environment*
Self-learning on performance and interest actions	*Change of performance on and interest in actions by encouragement and scaffold by user*
Builds relationship with owner	*Establishes a relationship with owner based on interaction (e.g. frequencies of petting, help, encouragement and scaffold)*

Figure 4.4 The KidiFluffies dog, a soft, interactive toy, designed for children in the age from four to ten, VTech, http://www.vtechnl.com/kidifluffies-hond.html

KIDIFLUFFIES

VTech designed the KidiFluffies dog. The technology-integrated stuffed animal is positioned as a child's friend (Figure 4.4). The toy can talk to the child and react on touch (sensed by touch sensors in the head and body), speech (sensed by a microphone) and movement (sensed by an accelerometer). Based on these stimuli, the facial expression of the toy and its speech change. The toy can be personalised by recording a child's voice and recalling the speech with a voice with a different pitch. The toy comes with a set of build-in stimuli-response pairs, such as: sleeping when being cradled, laughing when being tickled and actions such as singing a song. A summary of the characteristics of the KidiFluffies dog can be seen in Box 4.2.

KidiFluffies

Reactivity

STIMULUS	RESPONSE
Voice	*Change sound, face animation*
Loud sound	*Change sound, face animation*
Being shook	*Change sound, face animation (too often: dizzy)*
Being cradled	*Change sound, animation (doing a nap)*
Being tickled	*Change sound (laughing), face animation*
Being stroked	*Change sound, face animation*
Being thrown in the air	*Change sound (too often: "Stop!"), face animation*
Being held upside down	*Change sound, face animation*

Deliberation

ASPECT	IMPLEMENTATION
None	*n.a.*

Box 4.2 Characteristics KidiFluffies

Cozmo

Reactivity

STIMULUS	RESPONSE
Specific face	*Change face animation, sound, posture, movements*
Sound	*Change face animation, sound, posture, movements*
Touch	*Change face animation, sound, posture, movements*
Position (close to a certain object)	*Change face animation, sound, posture, movements*

Deliberation

ASPECT	IMPLEMENTATION
Emotion	*Emotional model based on interaction with user and environment*
Builds relationships	*Recognises person based on face, adapts emotion and actions based on experiences with this person*
Self-learning on performance and interest actions	*Change of performance on and interest in actions based on daily activities performed*
Amount of actions that can be performed	*The more the user plays with Cozmo, the more actions are "unlocked"*

Box 4.3 Characteristics Cozmo

Figure 4.5 The Cozmo robot interacting with an interactive power cube, Anki, https://anki.com/en-us/cozmo/life-with-cozmo

Figure 4.6 Cozmo: an interactive consumer robot, Anki, https://anki.com/en-us/cozmo/product-details

COZMO

The Cozmo robot, designed by Anki, is a smart consumer robot that establishes an own personality (Figure 4.6). The robot is self-learning and builds a relationship with a single human by using face recognition and the processing of events. Based on this relationship the robot adapts its future actions. Cozmo learns: it explores and adapts behaviour, but also portrays emotions by changing its face animation, sound, posture and movements. The bot comes with three interactive power cubes which can be used to play games with users as can be seen in Figure 4.5. A summary of the characteristics of the Cozmo can be seen in Box 4.3.

KIDIDOGGY

The KidiDoggy, also designed by VTech, is a robotic toy (Figure 4.7). Children can move and rotate the dog using "the bone joystick" as can be seen in Figure 4.8. In addition, they can change the posture of the dog; the dog can either stand or sit. When pulling the hypnotism cord on the joystick (see Figure 4.8), the robot will listen to preprogrammed speech commands, such as "transform", "sit" or "dance". Then, the posture of the dog and the face animation change. Via the "transform" command the dog can be transformed into twenty funny characters. A summary of the characteristics of the KidiDoggy can be seen in Box 4.5.

KidiDoggy

Reactivity

STIMULUS	RESPONSE
Touch chin	*Change face animation (happy)*
Button press joystick	*Change movement, rotation or posture*
Pull cord joystick	*Change face animation (hypnotism)*
In hypnotism mode, speech: "transform" or "become animal"	*Speech: "change into what?"*
Defined speech commando	*Change face animation, sound and posture*

Deliberation

ASPECT	IMPLEMENTATION
None	*n.a.*

Box 4.4 Characteristics KidiDoggy

Box 4.5 Characteristics Teksta

Teksta

Reactivity

STIMULUS	RESPONSE
Touch	*Change face animation, sound, posture, movements*
Defined hand gesture	*Change face animation, sound, posture, movements*
Voice	*Change face animation, sound, posture, movements*
Light	*Change face animation, sound, posture, movements*
Time: night	*Change face animation, sound, posture, movements (sleeping)*
No interaction for a certain period of time	*Change face animation, sound, posture, movements (crying)*

Deliberation

ASPECT	IMPLEMENTATION
Self-learning on performance actions	*Increase performance toy on executing predefined tasks (sit, stand, walk, back-flip) when interacting with the toy more often*

Figure 4.7 The KidiDoggy, a robotic, interactive toy, designed for children in the age from four to eleven, VTech, http://www.vtechnl.com/kididoggy.html

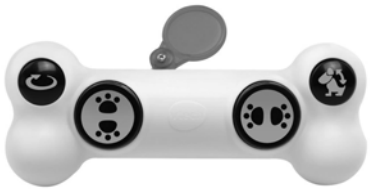


Figure 4.8 The KidiDoggy joystick, with on top the hypnotism cord to active the robot's listening mode, Bart Smit, http://www.bartsmit.com/nl/bsnl/speelgoed/gadgets-1/vtech-kididoggy

Figure 4.9 The Teksta puppy, Intertoys, http://www.intertoys.nl/schoolspullen/educatief-speelgoed/robots/teksta-robot-puppy-blauw

TEKSTA

The Teksta robot, designed by ToyQuest, is a robotic puppy that reacts to touch and hand gestures (Figure 4.9). Also, the dog responds to a predefined set of speech commands. The toy can be instructed to sit, stand, walk or make a back-flip by the touch, hand gestures and speech commands. The more the child trains the toy to perform these actions, the better it will perform. The dog's head, ears and tail can move according to its emotion. In addition, the sound it produces and its facial animation changes. The dog's emotion depends on how the child takes care of the toy: how often the toy is fed and petted and how often the child talks to and plays with the toy. A model determines the emotional state of the toy based on the frequencies of these events. If the toy is happy its ears move, its eyes flash, its tail wags and it walks happily. If the toy is unhappy, it will cry and moan, its ears go down and its eyes display a sad pattern. In between these two end states several other states exist. A summary of the characteristics of the Teksta can be seen in Box 4.5.

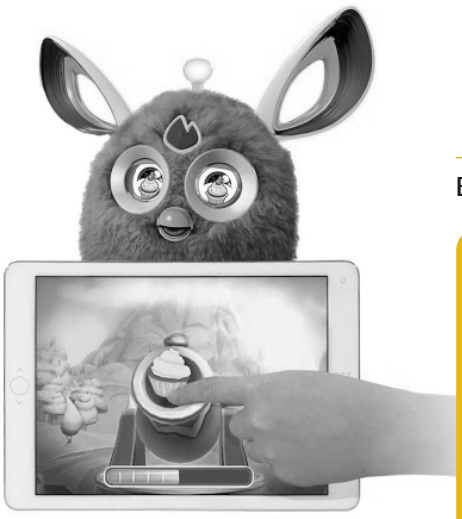


Figure 4.10 The Furby connected to the virtual application. The user feeds the Furby with a virtual cupcake. The physical Furby reacts by showing an image of the cupcake in its eyes. AMP, https://www.google.nl/amp/furby-connect-world.android.informer.com/amp

FURBY CONNECT

The Furby Connect, developed by Hasbro, uses a tangible Furby as an input and output medium for a virtual world provided by a tablet application (Figure 4.10). The Furby is connected to the application via Blue-tooth.

On the one hand, Furby reacts to the physical world when being pet, tickled, shook or turned upside-down. To portray Furby's emotions, the eyes can display over 150 animations. In addition, its body, ears, mouth and antenna can move and the Furby can speak. Furby can pronounce a predefined set of words and sentences. The tablet application can be used to extend the set of predefined words and sentences. Also, the Furby can sing preloaded songs. The set of songs can also be updated via the tablet. Lastly, the Furby can be set to sleep by placing the included sleeping mask onto its head.

On the other hand, Furby reacts to the virtual world. The antenna of the Furby lights up when something new can be discovered in the app. The actions of the Furby are synced with the virtual world. The Furby can, for example, be used as an output medium that portrays the behaviour of a Furby in the virtual world. Also, the application can be used to feed the physical Furby. The physical Furby reacts happily and the food selected is shown in the eyes of the Furby (Figure 4.10). On the other hand, the behaviour of the Furby in the physical world can be used as input for the virtual world. The more the child takes care of the Furby (e.g. by tickling, petting or hugging it in the real world, or by feeding, healing or cleaning it in the virtual world), the more friendly it becomes. The Furby uses an emotional model that contains a set of emotions. The value of the emotions is increased or decreased based on actions performed (or not performed) by the user.

If two Furbies are connected to the tablet application they can communicate: they greet each other, talk to each other, sing songs together and dance together. A summary of the characteristics of the Furby Connect can be seen in Box 4.6.

Box 4.6 Characteristics Furby

Furby

Reactivity

STIMULUS	RESPONSE
Being pet	*Change face animation, sound, posture, movements*
Being tickled	*Change face animation, sound, posture, movements*
Being shook	*Change face animation, sound, posture, movements*
Being turned upside down	*Change face animation, sound, posture, movements*
New element in virtual application	*Antenna lights up*
Sleeping mask placed	*Change sound, posture, movements (sleeping)*
Input virtual world	*Sync face animation, sound, posture, movements based on action in virtual world*
Multiple Furbies connected	*Speak to each other, sing songs together, dance together*

Deliberation

ASPECT	IMPLEMENTATION
Emotion	*Emotional model based on interaction with user and virtual world*

4.1 Research Toys for Storytelling

DollTalk

Reactivity

STIMULUS	RESPONSE
Doll removed from platform & speech detected	*Record sound*
Doll attached to platform	*Stop recording sound*
Motion doll	*Speech linked to doll*
No motion doll	*Speech labelled as voice-over*

Deliberation

ASPECT	IMPLEMENTATION
None	*n.a.*

Box 4.7 Characteristics DollTalk

Box 4.8 Characteristics StoryMat

StoryMat

Reactivity

STIMULUS	RESPONSE
Squeezing toy	*Record coordinates toy, record sound*
Releasing toy	*Save coordinates and sound*
Position toy similar to position of a toy in a previous story	*Project previous story, recall recorded sound*

Deliberation

ASPECT	IMPLEMENTATION
None	*n.a.*

DOLLTALK

The DollTalk is a computational toy which is created to enhance children's creativity during pretend play. The project implements an approach for sensing which doll "is speaking" by using the gestures of the dolls. The doll, developed by *Vaucelle & Jehan (2002)*, consists of a platform with two dolls attached (Figure 4.11). The platform contains speakers, microphones and a processing unit, whereas the dolls are integrated with accelerometers. When removing a doll from the platform, audio recording starts. The recording stops when placing the doll back onto the platform. On the platform a virtual peer, in the shape of an alien, is present. The alien functions as a virtual guide to help the children in the storytelling process. The alien asks the children to tell it about earth, and to dress up the dolls in a way earthlings are dressed. When the children talk, their speech is recorded. The sentences are cut up and indexed according to the motion of the doll. When the accelerometer of a doll measures motion when a child speaks, the speech becomes the voice of this doll. When no accelerometer data is measured, the speech is categorised as a neutral voice over. Finally, the speech can be played back. The system changes the pitch of the children's voice to create different sounding voices per doll. A summary of the characteristics of the DollTalk can be seen in Box 4.7.

Figure 4.11 DollTalk platform consisting of a virtual alien and two tangible characters, *Vaucelle & Jehan (2002)*

STORYMAT

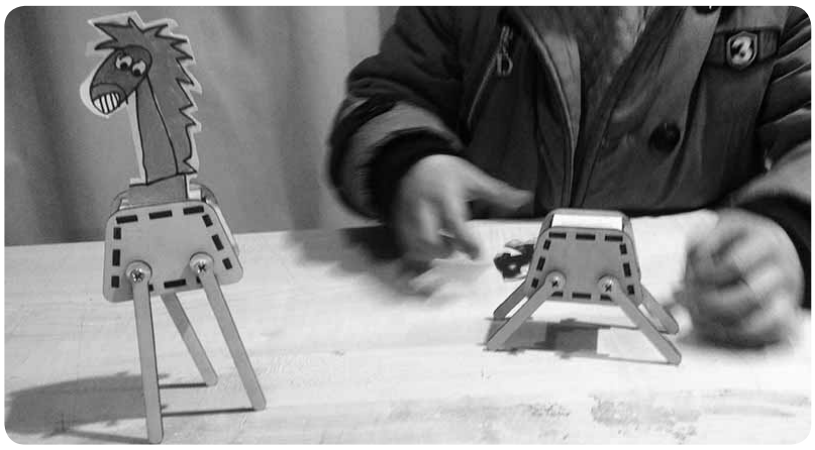
The StoryMat, developed by *Ryokai & Cassell (1999)*, is an interactive play map that records and recalls children's storytelling activities. Story evoking objects are sewn onto the physical play map. In addition, speakers are place beneath the map (Figure 4.12). The map is combined with sensor-integrated stuffed animals and a beamer. Inside the stuffed animals a wireless mouse is placed. When squeezing the animal (alias pressing the mouse button), the coordinates of the stuffed animal are recorded, even as the sound. When releasing the animal, the data is saved. When a new story makes use of similar coordinates as a previous story, the previous story is recalled. The beamer then projects the stuffed animal of the previous story onto the map. The projection of the stuffed animal changes according to the path taken. In addition, the recorded sound is replayed. This way, children can be inspired and create co-productions by building stories upon each other's work. A summary of the characteristics of the StoryMat can be seen in Box 4.8.

Figure 4.12 The StoryMat combines a physical map with sensor-integrated stuffed animals. Squeezing a stuffed animal triggers the recording of the movements of the animal and the sound created. Using similar coordinates as in a previous story triggers the beamer to show the previous story as a projection, *MIT Media Lab*, https://www.media.mit.edu/gnl/projects/storymat

CARTOON

The cartoon project, by *Wang, Tao, Liu, Wang, Yao & Ying (2015)*, focuses on designing interactive toys to be used in role playing stories. The interactive toys enhance the children's imagination and creativity. The cartoon prototype consists of a main body with some hardware inside and movable limbs attached. The hardware can detect and record the track of the movements of the limbs. Children can draw the top of the characters on paper, cut them out and attach them to the main body (Figure 4.13). Then, they can start making stories with the interactive toys. They can reset, record and play back the movements of the toys to make their stories more tangible and to share their stories with others. A summary of the characteristics of Cartoon can be seen in Box 4.9.

Figure 4.13 A child creates a story using a Cartoon main body with movable limbs and a drawn character on top, *Wang et al. (2015)*.



Cartoon

Reactivity

STIMULUS	RESPONSE
Press record button	*Record movements limbs*
Press play button	*Recall movements limbs*
Press reset button	*Clear movements limbs*

Deliberation

ASPECT	IMPLEMENTATION
None	n.a.

Box 4.9 Characteristics Cartoon

Figure 4.14 The StoryToy farm scene with stuffed animals, *Fontijn & Mendels (2005)*

Box 4.10 Characteristics StoryToy

StoryToy

Reactivity

STIMULUS	RESPONSE
Motion toy	*Toy produces sound (showing an emotion or desire)*
Correct toy picked up (in story play mode)	*Storyline continues*
No motion of any toy for a certain period of time	*Toy portrays a desire*

Deliberation

ASPECT	IMPLEMENTATION
Toys can talk to each other	*According to states toys*
Toys portray emotions and desires	*Pre-programmed, randomly*

STORYTOY

The StoryToy, a storytelling system developed by *Fontijn & Mendels* (2005), consists of an audio recording engine. Children can play with a farm scene made out of cloth and stuffed animals functioning as the characters (Figure 4.14). The farm animals contain motion sensors that can wirelessly transmit manipulation of characters to the engine. In addition, the animals can provide auditive feedback. The farm animals can have conversations with each other based on their states. The tool allows for types of play having different levels of complexity, namely: free play, reactive play and story play. In the "free play mode", the children use the animals as traditional toys, meaning all activity has to come from the child. In the "reactive play mode", the animals support children in playing by providing feedback when being picked up or by showing emotions and desires not related to the story. The "story play mode" allows for linear and branched stories, determining whether or not the child can control the direction of the story. In linear stories a storyline explicitly ends with mentioning an animal that needs to be picked up. If the child performs the correct action, a sound is played and the story continues with the next story line. Branched stories make use of decision models. The models determine the plot, for example, based on the order in which animals are picked up. A summary of the characteristics of the StoryToy can be seen in Box 4.10.

Figure 4.15 Movements of the action figures above the paper map are tracked and translated into an animation on the screen, *Ribeiro, Iurgel & Ferreira (2011)*

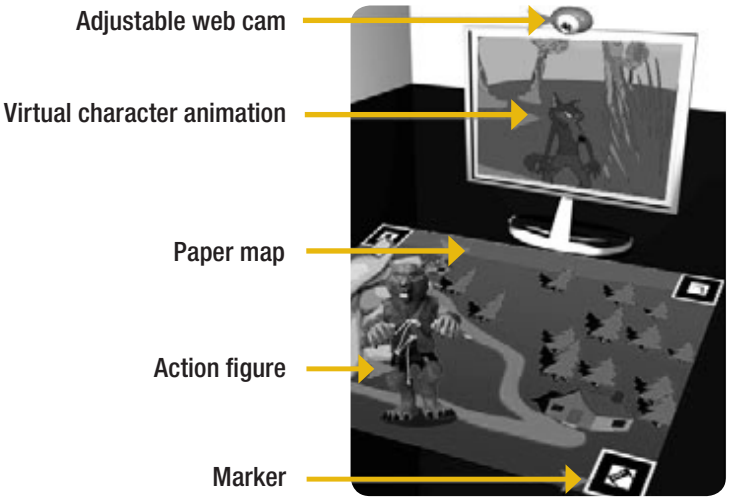


Figure 4.16 An example of an animation shown on the screen, *Ribeiro, Iurgel & Ferreira (2011)*

VOODOO

Ribeiro, Iurgel & Ferreira (2011) created the Voodoo. The system combines playing with tangible dolls with the creation of a movie. The environment consists of a screen on which an animation is played and a paper map with the story context (Figure 4.15). Children animate the virtual characters on the screen by moving tangible action figures. The stories are based on the well-known story Little Red Riding Hood. The actions children take with the action figures will be influenced by the associations they have with the existing story, these associations are used by the system. Based on movement patterns of the characters in the existing story, the system translates the movements of the action figures into the movements of the virtual characters. *Ribeiro et al. (2011)* describe an example of such patterns in the story of Hulk. Using the Hulk setting, information can be extracted from the character Bruce Banner and its relationship with other characters and with the story environment. When angry, Bruce Banner is transformed into a wild and powerful creature, and this transformation is more likely to happen when General Ross is nearby. In addition, Bruce Banner will show an affectionate behaviour when he is close to Betty Ross, but the transformation into Hulk can again occur when he is enclosed in a prison. Thus, the interpretation of the movements of the action figure can take a schemes of a story into consideration The system interprets the movements of the action figures by incorporating computer vision. Tracking is based on the detection of markers printed on the paper map. The markers correspond to a story location, such as the house. The system determines which action figures are used by the child and the position of the action figures above the map. Based on the relationships between figures at specific area on the map, an animation is played on the screen (Figure 4.16). A summary of the characteristics of the Voodoo can be seen in Box 4.11.

Box 4.11 Characteristics Voodoo

Voodoo

Reactivity

STIMULUS	RESPONSE
Action figures used	*Different type of animation*
Position action figures above map	*Different type of animation*
Distance and relationship between action figures on the map	*Different type of animation*

Deliberation

ASPECT	IMPLEMENTATION
Actions virtual characters	*According to movement patterns existing story*

4.2 Discussion

Traditional toys are mainly static toys. However, of some of the toys children can change the posture or change the appearance by using clothes and accessories. The use of traditional toys in storytelling infers children themselves have to adapt the toys' features, such as the appearance and posture, to fit with the story told. In addition, the toys do not respond to children, they are not interactive. The absence of interactivity means children have to be more creative. They have to take care of changing features, such as the emotions and behaviours of the toys.

Therefore, the rest of the chapter focused on commercial toys that do include this interactivity. The chapter provided an overview of the variety in characteristics of the available toys. Interactive toys show reactive behaviour. Much of this reactivity is only in response to the user. For example, some projects use face recognition to determine which user is in front of the toy or sense if the toy is picked up by using accelerometer data. In addition, some of the toys show deliberative behaviour. These toys include models to determine, for example, the emotion of the toy based on what events are happening. However, not all commercial toys include deliberation and also the amount of deliberation differs.
The last part of the chapter described relevant research focusing on the use of interactive toys specifically for storytelling. The research projects mostly combine the toys with other interactive components, such as an interactive background. The toys of projects focusing on storytelling itself are often less reactive than the commercial toys. However, different from the commercial interactive toys, these projects do not only include reactive behaviour in response to the user, but also in response to the story components: the story world, characters and objects. Like the commercial interactive toys, deliberation is implemented only limitedly.

What can be learned from investigating related work is that the opportunity exists to create a storytelling system using tangible, interactive toys that are responsive to the user, but also respond to the story components: the story world, objects and characters. Existing toys either only respond to the user, without specifically responding to the story told, or are not responsive themselves, but part of a larger storytelling system that does provide the user with responses on the story told. In addition, the opportunity exists to include toys with deliberation. This way, the actions of the toys might better fit with the story being told.

SUMMARY RELATED WORK

- Traditional toys are static
- Children have to adapt features of traditional toys to fit the toys with the story they are creating
- Many commercial interactive toys show only reactive behaviour towards the user
- Not many commercial interactive toys show deliberative behaviour
- Interactive toys used in storytelling research are less reactive, but often part of a larger system that is reactive
- Interactive toys used in storytelling research show reactive and deliberative behaviour in response to users, but sometimes also in response to the story world, objects and characters

OPPORTUNITY RESEARCH

- Design of a storytelling system using tangible toys that show reactive and deliberate behaviour in response to the user, but also in response the story world, objects and characters

5

This section describes the system components and arguments for selecting them. First of all, the story theme is described. Then, the decisions for the main character, the other characters, the objects and the story world are explained. The section ends with a schematic overview of the technical implementation of the different system components and how they are combined into one system.

The system combines a robot with a play mat, Playmobil and a tablet

System Design

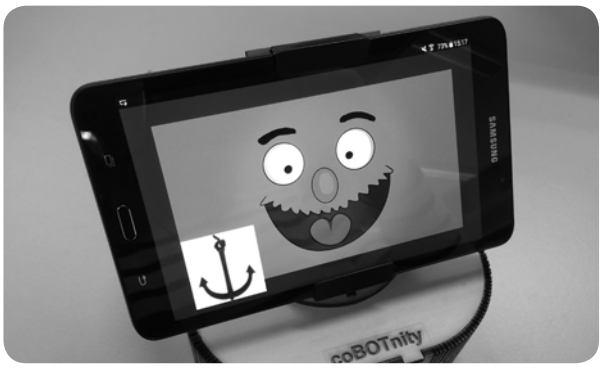


Figure 5.1 The surfacebot tablet displays a character and the virtual image selected with the control tablet. Also, it can be used to change the character

5.1 Story Theme

To guide the children in creating a story, the characters, objects and locations fit within a certain theme. This way, the storytelling task is a bit more delimited. The space theme is selected to fit both interests of girls and boys.

5.2 Main Character

This section describes the selection criteria for the technology to be used for the main character toy. The selected technology is then described in more detail.

SELECTION CRITERIA

3.5 Discussion already provides an overview of the selection criteria for the technology to be used in a character toy when it comes to implementation of reactivity. The selected technology should be able to **sense the occurrences of several stimuli** and should have **the possibility to implement varying responses**. In addition to the selection criteria described 3.5 Discussion the technology should **allow children to imagine the technology to be a character**. In this research the technology of the main character only functions as a tool to explore the effect of different robot behaviours. Thus, the technology of the character solely functions as a tool to implement these behaviours, designing the technology itself is out of the scope of the project. Therefore, a technology which, compared to other technologies, allows to **implement own-designed behaviour patterns** in a relatively easy way, is searched for. The last selection criterion is the price; the technology should be **affordable by schools and parents**.

Figure 5.2 With the control tablet images can be selected to be used as story assets (left image), in addition, the tablet can be used to navigate the surfacebot in space (right image) by moving it [up and down arrow], rotating it clockwise and counter-clockwise [left and right arrow] and stopping it [central circle].

ELIMINATION SURFACEBOT

Recap Surfacebot Setup

In the previous of this research a setup using a surfacebot was used (*ter Stal, 2017*). A surfacebot is a technological device consisting of a programmable, wheeled robotic base with a tablet on top (see Figure 5.1). The tablet displays a character, which can be changed by swiping on the tablet. In the setup, the surfacebot was combined with a control tablet (Figure 5.2).

Firstly, the control tablet could be used to navigate the surfacebot. The robot's base allowed the surfacebot to rotate and drive around. Secondly, the tablet could be used to select images to be used as story assets. When selecting an image, the same image appeared on the surfacebot tablet.

Elimination Reasoning

Although the surfacebot technology is affordable and children see the technology as a character (*ter Stal, 2017*), the technology is eliminated for this research. As explained, the essential aspect of the research is the evaluation of the influence of the different behavioural patterns. The current surfacebot setup does not yet sufficiently support the implementation and evaluation of different behavioural patterns. The main reason the technology is eliminated is the absence of sensors that are already optimised to detect the various stimuli in Table A2. In addition, responses can only be shown via a change in tablet content. This medium is sufficient to provide a variety of responses, but implementation of elements such as facial expressions and robot speech were not yet extensively developed. Although the setup can be adapted to extend the detection of stimuli and the ways to respond, this is out of the scope of the project. The goal of the research is not to design the technology itself; technology only functions as a tool. Therefore, technologies that do include several sensors and have multiple options to respond are preferred.

ELIMINATION OTHER TECHNOLOGIES

Several technologies combing multiple sensors and ways to respond exist. However, these systems are often too expensive. On the contrary, affordable technologies have limited features. These technologies have to be combined in order to create a system containing both sensing and responsiveness. Thus, a trade-off between the price and features of the technology has to be made. Another important reason for technologies being eliminated is the closed nature of the system. For many systems it is not possible to use the technology's features to program own-designed behaviours. However, implementation of own-designed behavioural patterns is essential in this project.

Figure 5.3 Cozmo can recognise, roll and stack its blocks. The blocks can light up in different colours, GadgetKing, http://www.gadgetking.com/2016/10/19/cozmo-a-robot-with-attitude

Figure 5.4 The Cozmo robot is used as a character in the story, Anki, https://anki.com/en-us/cozmo/product-details

FEATURES COZMO

- Ability to drive & rotate
- Ability to change posture (due to in height-adjustable arms)
- Ability to lift objects
- Ability to use back lights
- Ability to create speech (via text-to-speech)
- Ability to create sound
- Ability to use facial animation
- Ability to use facial text
- Ability to recognise faces and objects (due to a camera with computer vision)

Box 5.1 Features of the Cozmo robot

SELECTED TECHNOLOGY: THE COZMO ROBOT

Based on the criteria as explained, a technology was selected. In this research the Cozmo robot (Figure 5.4), designed by Anki, is used as a main character.

The robot comes with three specially-designed blocks which can be recognised by the robot via markers. The robot is able to roll the blocks over and is able to stack them as can be seen in Figure 5.3. The robot comes with sufficient features, such as the possibility to change its speech and facial expressions, which can be used to create different behaviours. A summary of Cozmo's features can be seen in Box 5.1. Cozmo can be used in a commercial and developer mode, both accessible via a mobile application (Figure 5.5). The robot has advantages over other technologies, seen in Box 5.2. First of all, the robot costs only 180 dollars, which s the technology affordable for schools and parents. Another advantage of the Cozmo robot is its physical size: the robot is quite small which fits well with the character function. However, the largest advantage is that the technology is open source. A SDK and clear API are available, which, in combination with the varying features of the robot, allows for designing robot behaviours which nicely fit with the two research conditions. Since the Cozmo is a commercial product many basic functionalities, such as movement, communication with the tablet application and interaction with the specially-designed blocks, are already handled. In addition, the robot is robust, reducing technical problems during user tests.

Figure 5.5 The commercial Cozmo application. The user can interact with Cozmo and unlock new functionalities, Anki, https://anki.com/en-us/cozmo/life-with-cozmo

ADVANTAGES COZMO

- Relatively cheap: $180,-
- Sufficient features
- Open source
- Many basics already handled: movement, communication, interaction with specially-designed blocks
- Perfect character size
- Robust device

Box 5.2 Advantages Cozmo

TABLET INTERFACE

In addition to via its behaviour, Cozmo communicates with the children via a tablet application. The tablet application was self-made and, thus, specifically designed for this prototype. Reasons to include a tablet application for the system have to do with Cozmo's speech. The Cozmo Python library comes with a text-to-speech (TTS) feature. However, this TTS functionality is only optimised for general words. In addition, the TTS module is based on the English language. This is quite inconvenient, since the system is tested with young, Dutch kids, which do not understand English. Therefore, the tablet interacts as a medium between Cozmo and the children. Also, the tablet can play sounds that can be used to create a Dutch robotic voice. This is potentially useful, because children in the age of six to eight might have difficulties in understanding written language displayed on the tablet. Reading the text aloud for them could resolve this issue. The children will be told that the robot cannot speak yet, and, therefore, communicates with them via the tablet.

5.3 Implementation System Components

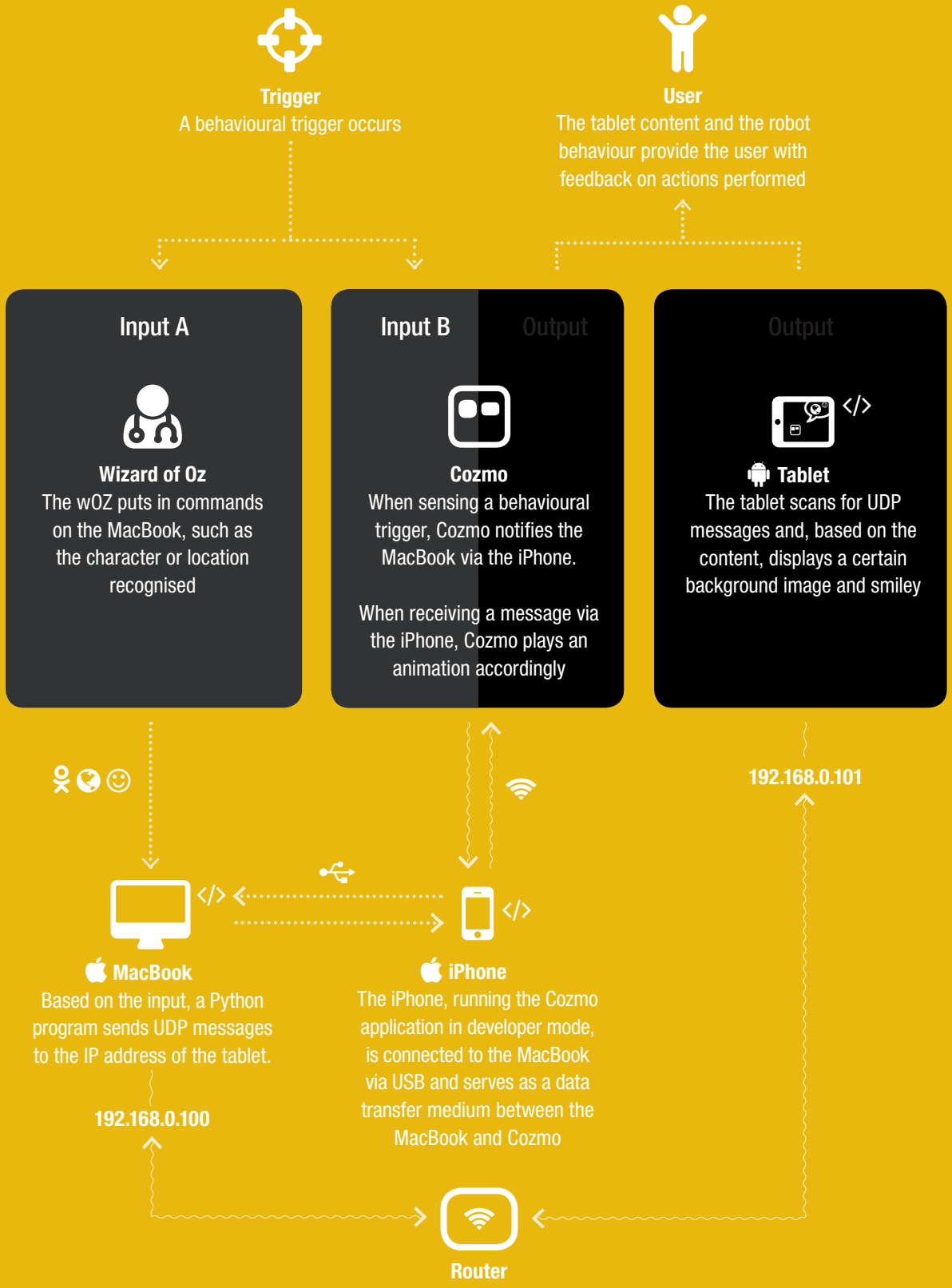
Box 5.3 shows a schematic overview of the implementation of the different system components.

PROCESSING DATA

A MacBook running a Python program receives input, either from Cozmo's sensors or via the Wizard of Oz (wOZ) implementation. The wOZ is a person that takes over the role of the robot in sensing the environment for behavioural triggers. The program processes the input and based on the input sends a message to both the robot and the tablet, which change the robot behaviour and tablet content accordingly.

ROBOT BEHAVIOUR

The robot behaviour is programmed using existing animations provided by the Cozmo Python library.



Box 5.3 System components

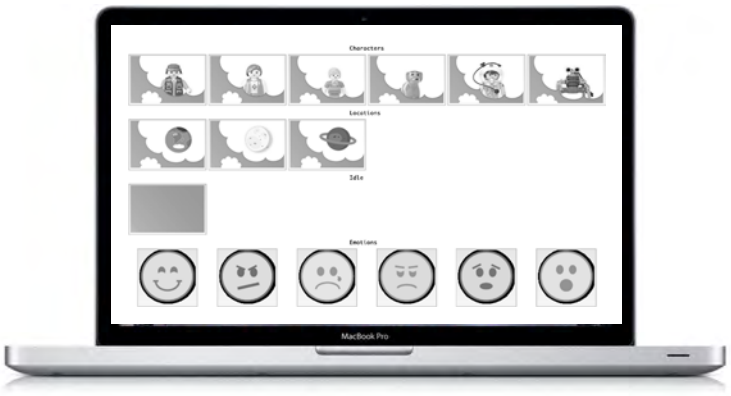


Figure 5.6 The GUI created for controlling the background images and smilies shown on the tablet. When selecting a button in GUI, an UDP message is sent from the MacBook to the tablet. Based on the content of the background and smiley on the tablet are changed.

TABLET APPLICATION

The tablet application is programmed in Android Studio (Java) and uploaded to the tablet (a Samsung Galaxy Tab A, Android 5.1) as a native application. The application checks for incoming User Datagram Protocol (UDP) messages and changes the content of the tablet accordingly. The images shown on the tablet were made with Adobe Photoshop and Adobe Illustrator.

COMMUNICATION MACBOOK & ROBOT

An iPhone running the commercial Cozmo application in developer mode is connected to the MacBook via USB. The message from the MacBook to the robot travels via the connected iPhone as medium. The iPhone is connected to Cozmo's private WiFi, which allows the phone to forward the messages from the MacBook to the robot.

COMMUNICATION MACBOOK & TABLET

The MacBook and tablet are connected to a router and both have a fixed IP address. Therefore, the MacBook can use the WiFi to send an UDP message to the IP address of the tablet. Using a stand-alone router creates a mobile system, and in addition, prevents the system from being dependent on an external internet connection.

INPUT

The system checks for the occurrence of behavioural triggers. This can be done in two ways: the robot can sense the environment itself or a wOZ can provide the system with input.

A) Wizard of Oz

The wOZ approach was only used during the pilot study. The approach is created by two Python programs running on the MacBook simultaneously.

Robot Behaviour Program

The first Python program includes the Cozmo library which takes care of the robot behaviour. When running this program, the MacBook communicates with the robot with the iPhone as a medium. This program also includes key press handling. The robot's emotions are linked to a certain key. The program constantly checks for keyboard input and sends a message to the robot to play a certain animation based on the emotion linked to the key press.

Tablet Content Program

The second Python program provides the wOZ with a graphical user interface (GUI) created with the Python TkInter library. When the wOZ notices a behavioural trigger, he or she selects a button on the GUI. The buttons allows the wOZ to select the background image and smiley to be shown on the tablet (see Figure 5.6). When selecting a button, an UDP message is sent to the tablet. If a background image is selected via the GUI a message with the structure 'b, NAME' is sent, if a smiley is selected a message with the structure 'e, NAME' is sent. The tablet application changes the background image and smiley presented based on the key, either a 'b' or an 'e', and the corresponding name of the message.

B) Sensors Robot

Instead of using input provided by the wOZ, input can be created by using the robot's sensors to pick up triggers from the environment. First, the robot receives an UDP message containing the object to look for. The robot constantly checks for this trigger. When a trigger is detected, the robot notifies the MacBook by sending a confirmation message via the iPhone to the Python program notifying the MacBook that it sensed the requested object.

OUTPUT

The user is provided with feedback on its actions via both the content of the tablet and the behaviour of the robot.

6

A well-designed pilot study can guide the research in the right direction, Martindale, https://www.flickr.com/photos/enidmartindale/4078048277

A pilot study was performed to explore how children interact with the prototype and what aspects of the prototype could be improved to strengthen the purpose of the project: using a small robot to influence children's storytelling. This section describes the goals of the pilot study in more detail and describes the sampling method, the measurements, consisting of observations and interviews, the procedure and the prototype. Then, the results of the pilot study are presented. The section ends with a general discussion and a list of suggested improvements.

Pilot Study

Figure 6.1 Playmobil figures as characters

Figure 6.2 In addition to the Playmobil dolls, children could play around with a Playmobil shed

6.1 The Prototype

WIZARD OF OZ

The prototype used in the pilot study was designed in line with the design as described in 5.3 Implementation System Components. The robot was controlled using the Wizard of Oz approach (wOZ), meaning the robot did not sense the environment for behavioural triggers, but a person sensed the environment instead. The amount of robot behavioural triggers and amount of corresponding robot behaviours were limited to four and six respectively, since the person controlling the wOZ should be able to react to the triggers.

CHARACTERS

In order to tell a rich story multiple characters can be useful. Therefore, the prototype is extended with figures. For practical reasons existing Playmobil figures are used. These figures are largely available and, besides, they are robust and match the size of the robot. In addition to some general figures, figures that nicely fit the space theme were found. The selected figures can be seen in Figure 6.1.

OBJECTS

In addition to the characters, children could also use a shed in their story (Figure 6.2). Like the characters, the shelter was an existing Playmobil toy. Children were allowed to change the position of the shed. The shed is large enough for the robot to fit in.

LOCATIONS

To support the children's creation of a story world, they are provided with a play mat. The play mat, created in Adobe Illustrator, is printed on A0 and can be placed onto a table. The play mat supports the space theme, since it contains an earth, moon and a planet positioned in space. The design of the play mat can be seen in Figure 6.3.

Figure 6.3 The play mat supports the space theme. On the play mat a large moon, planet and the earth positioned in space are present. The mat is printed on A0 and placed onto a table to support the creation of a story world.

THE ROBOT

The robot reacted to the triggers listed in Table 6.1. A trigger resulted in the robot showing different behaviour and the tablet interface communicating a message. Two triggers were already handled by the robot, the other triggers were handled by the wOZ. Depending on the character in front of the robot, or the location of the robot, the robot showed a different emotion. The emotions implemented were the six basic emotions as described by *Batty & Taylor (2003):* happiness, anger, sadness, disgust, fear and surprise. The emotions linked to the characters and locations can be seen in Table 6.2. Each emotion was linked to at least one character or location. The emotion per character or location was fixed in order to make the situation controllable for the wOZ; however, no rationale behind the link between the emotion and the character or emotion was present. A description of the robot behaviour per emotions, consisting of a facial animation, movement and sound, can be seen in Table 6.3.

THE TABLET

As an example, the tablet can show how Cozmo feels about a certain character by displaying Cozmo with a thought bubble including an image of the character and a smiley according to its emotion, see Box 6.1.

1. *Idle screen.* Displayed when no trigger is detected.

2. *Thought screen.* A thought bubble including an image of the character (in this case the astronaut) or location and a smiley portraying Cozmo's emotion (in this case surprise) is displayed.

Box 6.1 The tablet screens. The tablet continuously changes between showing the idle screen and the thought screen. When no trigger is detected, the tablet shows the idle screen. When a character is placed in front of the robot or the robot is placed at a certain location, the thought screen is displayed for a fixed period of time.

	TRIGGER	HANDLED BY	BEHAVIOUR ROBOT	TABLET IMAGE
	Idle	Cozmo	Idle animation as described in Table 6.3.	Idle Cozmo
	Robot is picked up	Cozmo	Pick up animation as described in Table 6.3.	Idle Cozmo
	Robot sees a character	wOZ	Emotion differs per character as described in Table 6.2. Animation according to this emotion as described in Table 6.3.	Cozmo thought bubble with the character and emotion as described in Table 6.2.
	Robot at location	wOZ	Emotion differs per location as described in Table 6.2. Animation according to this emotion as described in Table 6.3.	Cozmo thought bubble with the location and emotion as described in Table 6.2.

Table 6.1 Triggers and corresponding robot behaviour

CHARACTER							LOCATION			
EMOTION							EMOTION			

Table 6.2 Robot emotions when seeing a character or being at a certain location

SITUATION	FACIAL ANIMATION	MOVEMENT	SOUND
Idle	Blinking and moving eyes	• Periods of silence alternated with periods of humming	No
Pick up	Animation, according to either 	Movement, according to either 	Sound, according to either 
	Small, moon-shaped eyes	• Arms up • Rotates 360 degrees	Gibberish speech, sounding like: • "Hahaha" • "Hihi" • "Yeah"
	Small, straight eyes, rotated downwards	• Arms down • Head slowly rotating downwards • Moves a few centimetres backwards	Gibberish speech, sounding like: • "Oh" • "Ouwaa Ouwaa"
	Small, straight eyes, rotated inwards	• Moves arms up and down very fast in a continuous movement • Moves head up and down very fast in a continuous movement • Rotates a few degrees	Gibberish speech, sounding like: • "Hmm" • "Grrr"
	Large, wide open eyes	• Arms down • Moves a few centimetres backwards	Gibberish speech, sounding like: • "Woooh" • "Wauw"
	Small, straight eyes, rotated inwards	• Slightly shivering body	Gibberish speech, sounding like: • "Grrr" • "Naaa"
	Small eyes, rotated downwards	• Shivering body • Shivering head, rotated downwards • Arms down	Gibberish speech, sounding like: • "Brrrr"

Table 6.3 Robot behaviour consisting of its facial animation, movement and sound per situation.

6.2 Goals

The pilot study focused on exploring two aspects of the project, namely the storytelling task and the robot behaviour. The questions to be answered by the pilot study are listed below.

THE STORYTELLING TASK

- **Do children understand they have to tell a story?**
  Rationale: when children do not understand they have to tell a story, they probably will not tell a story. In that case, the differences in storytelling between the two research conditions cannot be researched.
- **Do children manage to tell a story?**
  Rationale: children might understand they have to tell a story, but that does not imply they will. If children do not tell a story, the differences in storytelling between the two research conditions can still not be researched.

THE ROBOT BEHAVIOUR

- **Do children understand the meaning of the robot behaviour?**
  Rationale: in order to research the differences of the influence of the robot between the two research conditions, it is essential children understand what the robot is communicating.
- **Do the children understand what the robot is communicating via the tablet?**
  Rationale: in order to research the differences of the influence of the robot between the two research conditions, it is essential children understand what the robot is communicating.

6.3 Procedure

Due to practical reasons, only one of the two conditions was tested. The study focused on condition E, the condition including robot emotions, since the behaviour of this condition also contains the behaviour of condition NE, the condition without the robot emotions. This way, the understanding of the children of the behaviours in both conditions could still be explored. An ethical approval from the University was acquired for the study. In addition, children participating in the study had permission of their tutors/parents to participate and to be recorded for research purposes.

THE SETUP

The pilot study took place at the day care facility at the University of Twente. The study was performed in a separate room. In the middle of the room a table was positioned with some chairs around it. The play mat was placed onto the table. Another table was placed perpendicular to the table with the play mat to be used for the wOZ computer. This way, children were not able to look at the computer screen, minimising the risk of them recognising the wOZ principle. To allow the children to choose which Playmobil figures to use in their story, the figures were placed next to the play mat. Cozmo was placed onto its adapter, just next to the play mat, but the tablet was placed onto it. Children were playing in groups of two created by the employees of the day care. Children not participating in the study were playing somewhere else. When a group finished playing, the employees were asked for a new group of children. An overview of the setup can be seen in Figure 6.4.

INTRODUCTION

When entering, children were asked to sit down on one of the chairs. Then, the video recording was started. The researcher took place behind the wOZ computer. The children were shortly introduced to the robot and they were informed about the storytelling task as described in Box 6.2.

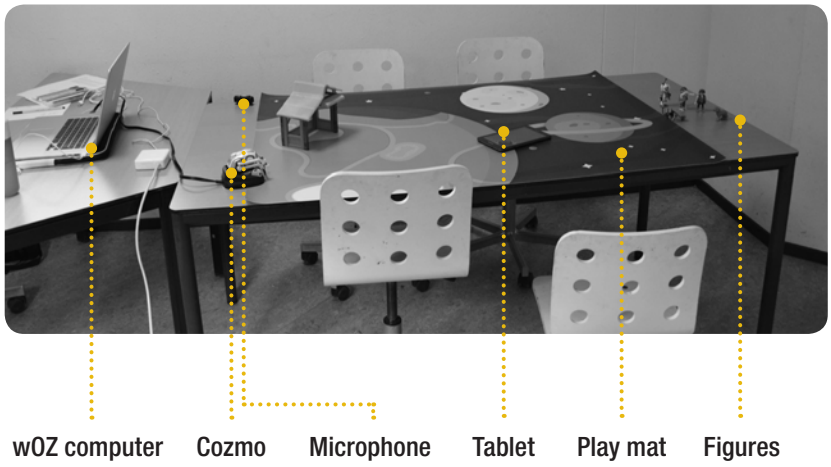


Figure 6.4 The research setup during the pilot study. The children can take place at a chair around the right table. The play mat is placed onto this table. In addition, a microphone is placed on the table to record the children's conversations. Children can play with the play mat, the dolls and Cozmo. Cozmo can communicate with the children via the tablet. On the left table the wOZ computer is placed. The table is placed perpendicular onto the play table to ensure the wOZ can control the computer input without children noticing it.

Box 6.2 Children are introduced to Cozmo and informed about the storytelling task

INTRO COZMO & STORYTELLING TASK

This is Cozmo. Cozmo is a small robot. Cozmo just learned about space and is looking forward to create new adventures in space. You may think of an awesome story for Cozmo. Cozmo cannot talk yet, therefore, it communicates with you via the tablet. Cozmo reacts to the story. It also has difficulties in driving, therefore, you are allowed to pick it up to change its position. You may create your own story using the play mat, the dolls and the robot.

DURING PLAY

The researcher controlled the robot via the wOZ computer as described in 5.3 Implementation System Components. In addition, the researcher took notes and answered children's questions. However, the researcher did not interfere actively in the story told. Children played until their story was finished, they felt satisfied or they played for ten minutes.

CLOSURE

After the playing the children were interviewed. The children were told that during the interview the robot was turned off, since the researcher could not control the wOZ during the interview as well. In this project the person controlling the wOZ used a computer to input the behavioural triggers as described in 5.3 Implementation System Components.

6.4 Sampling Method

Convenience sampling *(Ritchie and Lewis, 2014)* was used to select subjects. Subjects were sampled based on the ease of access. In addition, the subjects were selected criterion-based: a subject must be a child going to an elementary school in the Netherlands. No other criteria were used for selection. Subjects were children that were present at the day of the study at the day care facility at the University of Twente.

6.5 Measurements

OBSERVATIONS

While interacting with the prototype, the children were observed. Notable actions performed by the children were written down right away. In addition, when having permission, the children were video and audio recorded. The recordings were used to do offline observations after the activity ended. The observations were used to complement the notes taken during the playing. Observations where taken in line with the four questions as described in the goals section above.

INTERVIEWS

When the children finished playing, they were asked a few questions about their experience (Box 6.3). Due to practical reasons, such as the concentration span of the children and a limited amount of researchers, the children were interviewed in duos. In addition, at the end of the interview children were shown the six robot animations one by one. Children were then asked to guess how they thought the robot felt. Children were introduced to the task as seen in Box 6.3.

Box 6.3 Interview questions pilot study

1.

What was your story about?

2.

How did the robot feel in the story?

3.

How did you notice?

4.

What did the robot try to tell you via the tablet?

5.

I am going to show you six behaviours of the robot. Can you can tell me how you think the robot feels in each case?

Can you tell me how the robot feels now?

6.6 Results

PARTICIPANTS

The user study was performed with a total of 10 children (n = 10), resulting in five trials. The ages ranged from five to ten years. Of the children four were female and six were male.

OBSERVATIONS

At the beginning of the last trial the camera stopped recording. Therefore, for this trial the results were only based on some short notes written down by the researcher during the session.

Understanding Storytelling Task

Results of this observation can be seen in A3 Observations Pilot Study, Table A5. What can be seen from the table is that in three of the five trials children started playing immediately *[trial 1, 2, 4]*. On the contrary, in *trial 3 and 5* the children had to be encouraged to start picking up the robot to explore its response. After they picked up the robot they started playing without help. In *trial 3*, one child asked what would be shown on the tablet before the children started the activity. In *trial 5*, the children did not start immediately, since one of the children did not understand how to tell a story with the setup and asked this explicitly. The way the storytelling task was introduced to the children might have been unclear, since they were not told they had to play in order to tell a story. In none of the trials, the children communicated with each other about not understanding the storytelling task.

Storytelling

Results of this observation can be seen in A3 Observations Pilot Study, Table A4. Only in one of the trials *[trial 2]*, children started telling a story. In *trial 3* children told a story after interference of the researcher. In the other trials children mainly played to explore the robot behaviour. In none of the trials children asked for inspirational help in telling a story. Although the amount of stories told was limited, the children in all trials were continuously playing without having pauses longer than twenty seconds.

Communication between children was mainly based on individual events, such as explanations of the robot's or character's actions. On the contrary, in *trial 4* children did not communicate about individual events at all. In *trial 3* the story was told by only one of the two children. The second child mainly observed the responses of the robot and the tablet on the story told by the first child, therefore, no communication between the children was present.

Understanding Robot Behaviour

Results of this observation can be seen in A3 Observations Pilot Study, Table A6. In general in all trials children reacted to the robot's behaviour by giving exclamations, such as "Oh" or "Wooh". In addition, many children repeated Cozmo's speech or exclamations *[trial 1, 2, 4]*. Also, children often smiled or laughed when the robot showed an animation *[trial 1, 3, 4]*. Some children talked to the robot to inform or instruct it *[trial 1, 2]* or moved the character or robot away when the robot did not like another character *[trial 1, 2]*. Finally, in *trial 1* children created speech for the robot or one of the other characters.

The children often communicated about the meaning of the robot behaviour. In many trials the children said aloud how they thought the robot felt *[trial 1, 2, 4*], sometimes they specifically referred to the relation between the characters and the feelings of the robot. Some children immediately removed the characters or the robot based on the discovered emotion *[trial 2, 4]*. In *trial 1*, the children communicated the most. They often used the word "look" to receive the attention of the other child, but also raised questions aloud, such as "what will he do?". Finally, these children also instructed the other child what to do.

Understanding Tablet Content

Results of this observation can be seen in A3 Observations Pilot Study, Table A7. Different from the responses to the robot behaviour, limited responses contained solely exclamations *[trial 1]*, or speech created for characters *[trial 1]*. In *trial 2* a child asked the robot why it was sad, since the tablet only showed a sad smiley. The robot was at that point positioned on earth and a bug in the prototype resulted in only the smiley to be shown.

Like for the meaning of the robot behaviour, children often communicated about the meaning of the tablet content. In all trials the children said aloud how they thought the robot felt, sometimes they specifically referred to the character or location shown on the tablet *[trial 1, 2, 3]* or introduced an exclamation for the emotion showed *[trial 4]*. They sometimes include the words "He says" *[trial 1, 4]* in their ex-

planations to refer to the content. Some children laughed when seeing the tablet content *[trial 2, 3]*. Finally, children used the word "look" *[trial 1, 2, 3]*, pointed at the tablet, *[trial 2, 3]*, pointed at a character *[trial 3]* or pushed another child *[trial 1]* to receive the attention of the other child.

Other Remarks

Other remarks noted can be seen in A3 Observations Pilot Study, Table A8. Overall, children liked playing with the robot and the figures, since children already started playing before they were introduced to the activity *[trial 1, 4]* or continued playing during the interview *[trial 4]*. In addition, the playing either stopped by the story being finished *[trial 3]* or the researcher quitting the session *[trial 1, 2, 4, 5]*. Especially the children in *trial 4* were really obsessed by and focussed on the robot and the figures.

In almost all trials children just randomly placed the figures in front of the robot to explore its reactions *[trial 1, 4, 5]*. Multiple children placed the robot onto and in the shed to receive a response *[trial 1, 2, 5]* or placed multiple figures in front *[trial 2, 4]* of the robot.

Some children specifically looked at the robot in the face *[trial 2, 4]*, whereas others mainly looked at the tablet *[trial 2]* or changed attention between the robot and tablet continuously *[trial 4]*. It could be the tablet distracted children from paying attention to the robot. However, the tablet also often confirmed or clarified children's ideas on the robot's behaviour. In *trial 4*, a child was focused on telling the story without paying attention to either the tablet or robot. Children greeted the robot by waving to it *[trial 1, 4]*, indicating children believed the robot could see them. Because of this, they expected a reaction from the robot *[trial 1]*. Some children even instructed the robot what to do *[trial 1]*, wanted it to talk [*trial 2]* or talked to the robot *[trial 2]*.

Also, children sometimes were confused by the response of Cozmo, which probably had to do with a late wOZ response *[trial 2, 4]*. In addition, some children thought the humming sound of the robot in the neutral mode indicated that the robot was happy. Therefore, they confused the idle behaviour with the happy behaviour. *[trial 2, 4]*. Also, the pick up animation sometimes interfered and confused children, sine no image was shown on the tablet at that moment.

What also is important to note is that in one trial children thought the smilies on the tablet indicated the feelings of the characters instead of the feelings of the robot *[trial 2]*. In addition, these children saw the playing as a puzzle to figure out how to make all characters happy.

INTERVIEWS

Interview results can be seen in Table A9 in A4 Interview Results Pilot Study.

Story Summaries

Two of the stories told were based on the behaviour of the robot *[trial 1, 2]*. The children mention their story was about the robot that liked some characters and did not like other characters, thereby they pointed at the characters the robot liked and did not like. The story told in *trial 3* was independent of the robot behaviour. In this story not the robot, but the astronaut was the main character. The robot served as a sub character. In the last two trials *[trial 4, 5]* the summary question was not answered and skipped respectively, since the children did not tell a story at all.

Emotions Robot in Story

On the question how the robot felt in the story children often answered that the robot felt happy or something similar *[trial 1, 3, 4, 5]* and angry *[trial 1, 3, 4, 5]*, but also mention it felt scared *[trial 1, 4]* and sad *[trial3, 5]*. Like the story summaries showed, children understood that emotions of the robot were based on the recognition of a character *[trial 1, 2, 3]*. The emotions of the robot when seeing a specific character were often interpreted correctly. In *trial 3* the children guessed the robot felt surprised when seeing the astronaut, angry when seeing the dog and happy when seeing the man. The child figure was connected to the sad emotion instead of the disgust emotion. This connection was not correct, however, in general children had difficulties with understanding the disgust emotion. In *trial 1* the children explained the robot did not like the alien, whereas it was afraid of it. Finally, in *trial 2* the children correctly interpreted the robot liked the man. They also said the robot did not like the alien and woman, which is somehow correct, since the robot was afraid for the alien and sad by the woman, both emotions indeed different from liking.

Signalling Emotions

In all trials the children understood that the robot was communicating its emotions via the tablet. Some children specifically mention it signalled its emotions by the use of smilies *[trial 1, 3, 5]* in combination with the character faces *[trial 5]*. Only in one of the trials the children indicated they did not learn about the emotions of the robot due to its behaviour *[trial 2]*. On the contrary, in the other trials children mention to learn about the robot's emotions due to its movements *[trial 1, 5]*, its facial animations *[trial 3, 5]*, produced sounds *[trial 5]* and changing lights *[trial 5]*.

Emotion Guesses

The results on the question how the robot felt when showing specific robot animations can be seen Table A9 in A4 Interview Results Pilot Study. Not all children answered the question for every emotion, since either the emotion was not shown or they were distracted from the interview. All but one child *[trial 4]* that answered the question for the happy emotion, guessed the emotion correctly. Also, all but one child *[trial 2]* that answered the question for the sad emotion, guessed the emotion correctly. The child that did not guess the emotion to be sad, thought the robot was feeling lonely, which is still quite related to sad emotion. The anger emotion was guessed correctly by all children that guessed the emotion. The fear emotion was correctly guessed by at least half of the children *[trial 1, trial 2, trial 4, trial 5]*. The same applies for the surprise emotion. However, the children that mention this emotion to be beautiful *[trial 2]* and nice *[trial 5]* were also quite close. Disgust was the most difficult emotion for the children, since it was only guessed correctly by one child, who described the emotion as "that he does not like something" *[trial 2]*. Others came up with the emotion meaning "strict" *[trial 1]*, angry *[trial 1, 2, 5]* and happy *[trial 5]*.

6.7 Discussion

THE STORYTELLING TASK

What can be seen from the results of the study is that the setup did not sufficiently support storytelling. Although the children understood they had to tell a story, they barely did. In some of the trials children did not tell a story at all, in others the stories were just an explanation of the robot's behaviour; the robot liked some characters and disliked others. Some children included some storytelling during play by talking to the robot or changing its position. However, the children were largely obsessed by the robot and focused on exploring its behaviour, they did not focus on telling a story with the robot as a character. This could also be seen by how the children communicated: they only communicated about individual actions to explore the robot behaviour.

THE ROBOT BEHAVIOUR

In general, the children understood that the robot communicated to them both via its behaviour and via the tablet. Children responded to the robot by giving exclamations, creating character speech, repeating the robot and moving the robot. In addition, they often smiled and laughed. Children often communicated about the meaning of robot's behaviour. In general, the children understood the robot behaviour quite well. Most of children recognised the robot's emotions based on its animations, movements and sound. *Sharma, Pavlovic & Huang (1998)* indicate that the use of multiple modalities creates a more natural interaction between humans and machines, since human-human interaction also involves multiple modalities. Thus, the implementation of the robot's emotions using multiple modalities could have positively influenced the children's understanding of the robot behaviour. Also, they understood the emotion was based on the characters and locations recognised by the robot.

Children often thought the robot was more intelligent than it was. They demonstratively looked at the robot's face, since they thought the robot could see and hear them. Therefore, the children expected a response when they waved to the robot or instructed the robot via speech. In addition, they expected the robot was able to talk.

Like the robot behaviour, the children understood the role of the tablet and recognised that smilies were used to communicate the robot's emotions. Children responded to the tablet content by giving exclamations, creating character speech and by smiling and laughing. Also, the children communicated a lot about the meaning of the content. Due to the position of the smilies next to the characters in the thought bubble of the robot, some children thought the smilies indicated the emotion of the characters. Changing the position of the smilies could resolve this issue.

During the playing, children recognised the robot's emotions quite well. Children mainly recognised the happy and anger emotion, but also the sad, fear and surprise emotion were recognised often. These results are in line with the emotion guesses by the children during the interview. Both the observational and interview results shows that children had difficulties

with recognising the disgust emotion. That children recognised the happy emotion the best and the disgust emotion the worst is in line with research by *Williams, Mathersul, Palmer, Gur, Gur & Gordon (2009)*. They researched the age effects of explicit identification and implicit recognition of facial emotions among males and females across ten decades. For each group, the happy emotion was identified with highest accuracy for explicit identification, followed by fear, neutral, sadness, anger and disgust. The research also shows children in the age between six and nine mostly confuse the disgust emotion with sadness, but sometimes also with fear and anger. The results of the study show similar confusions.

A last remark: due to the wOZ setup, the messages communicated by the robot and the tablet were sometimes not in sync, or were late, confusing the children a bit.

6.8 Suggested Improvements

Essential is to improve the prototype in order to support the storytelling task better. Therefore, it is suggested to improve the children's introduction to the activity by including a goal for Cozmo. This way, children are guided into a certain direction, which might result in better stories. Cozmo's goal can also be made visible to the children during the playing to create a reminder.

Another improvement suggested is the implementation of a story line. The story line keeps track of the events that happen in the story. This way, children are informed about the actions already performed in the story so far. The overview might help the children to better remember the previous steps in the story and, because of this, tell more coherent stories.

In addition, it is suggested to provide children with a selection of story actions. This way, children are provided with building blocks that can be used to tell a story. It is suggested children can only explore the robot behaviour when they are actually telling a story; the robot could, for example, only show an animation when a story action is selected. This way children cannot just play with the robot to explore its behaviour. The need for a selection of a story action triggers active user participation and, therefore, prevent the system from solely becoming an entrainment tool (as described in 2.5 Use of Toys in Pretend Play).

Another suggested improvement is the clarification of the transition between the introduction and the start of the storytelling activity. This clarification can, for example, be realised by explicitly guiding children through the introduction on the tablet, including an explanation on how to select a story action, and by displaying a start button afterwards.

SUGGESTED IMPROVEMENTS

- Narrow down storytelling scope by introducing a goal for the robot
- Implement a story line as a reminder
- Encourage storytelling by providing children with possible actions
- Encourage storytelling by only allowing children to explore the robot behaviour when performing an action
- Lower threshold to start playing by guiding children through first action in story
- Implement an exploration phase in which children can already explore the robot behaviour
- Delete disgust emotion
- Change position emoticons
- Replace wOZ character recognition by Cozmo character recognition
- Include tablet message on robot pick up
- Start idle animation only after a certain time span after another animation finished
- Switch robot off during the introduction and interviews

Also, it is recommended to insert an exploration phase before starting the storytelling activity. In the exploration phase children can learn how to interact with the system and already explore the robot behaviour. It is expected this phase will result in the children being more focussed on the storytelling during the actual activity.

In general, the emotions and behaviour of the robot were clear. A small change that can be made to strengthen the robot's emotions even more is the deletion of the disgust emotion. The disgust emotion was not recognised by the children, and, therefore, only resulted in confusion. Also, the emoticons on the tablet could be placed next to the robot instead of next to the characters or locations inside the thought bubble. This way children most likely do not link the emoticons anymore to the emotions of the character. To further reduce any confusions concerning the emotions, the wOZ approach can be replaced by the robot sensing the behavioural triggers. In the current setup the high workload of the wOZ sometimes resulted in inconsistent or delayed responses.

Finally, some small changes that can be made to improve the setup are the addition of a tablet image when the robot is picked up, and the addition of a pause time after an animation finished before starting the idle animation. This way, any interference of the idle animation with the previous animation is prevented. Lastly, a mode in which all robot animations are turned off could be implemented. This mode allows the robot to be switched off during the introduction of the activity and the interview to ensure children are not distracted by the robot's idle behaviour.

7

A second study was performed to test and adapt the research setup before executing the final study. This section describes the updated prototype, the goals of the study, the procedure, the sampling method and the measurements. Then, the results of the study are presented. The section ends with a general discussion and a list of suggested improvements.

A second study was used to test the prototype and measurements to be used in the final study, Penfold, https://www.flickr.com/photos/ chrispenfold/16502091852

Second Study

7.1 Prototype

The prototype used in this study was an extended version of the prototype used in the pilot study (6.1 The Prototype). Changes have been made according to the suggested improvements based on the first study as described in 6.6 Results. Different from the pilot, the robot was not controlled using the wOZ. Instead, the robot itself was able to recognise figures, objects and locations by the use of markers. The robot sensed the environment for markers using its camera.

INITIATING EVENT: THE PROBLEM OF THE ROBOT

For the reasons as explained in 6.8 Suggested Improvements children are provided with an initiating event: the robot's problem. The initiating event is a story grammar element which typically is a problem (as described in Table A1).

As explained by *Sawyer (2002)*: "the skilful introduction of scaffolds - loose outlines of plots, or shared memory of a fairy tale or movie - can help to guide children's natural collaborative improvisations into a narrative structure with global coherence" (p. 343). He also says that educators could experiment with similar scaffolds. This approach in guiding children throughout the storytelling task is in line with how storytelling tasks are introduced to children at schools, as found by performing interviews with elementary school teachers previous to this research (*ter Stal, 2017*).

Therefore, to help children in telling a story with more global coherence, children are provided with the initiating event of the story; the robot's problem. Via the tablet application children are introduced to the problem of the robot, as will be explained in more detail later on. The goal of the robot is to go to the moon. However, he does not know how. Therefore, he asks the children for help. The request fits within the space theme. On the one hand, the initiating event directs the children in the storytelling process, and, on the other hand, it leaves the storytelling task sufficiently open for children to use their own creativity. This design is in line with the approach as suggested in 2.6 Discussion.

ACTIONS

The results of the pilot study (6.6 Results) showed the prototype did not yet provide the children with sufficient building blocks to tell a story. Children did not include any plans or attempts to solve a problem. On the one hand, this might have been caused by the absence of a problem, which is solved by implementation of the initiating event. On the other hand, children might not have an idea of how to include plans or attempts into their story. Plans are related to actions (as described in Table A1). Therefore, the tablet application is upgraded with an action selection screen. This screen allows children to select an action from a predefined set. The tablet selection screen asks for active user participation in order to continue playing, preventing the system from solely becoming an entertaining tool (as described in 2.5 Use of Toys in Pretend Play). Actions are always combined with at least a location, a character or an object. The actions are displayed as verbs: "goes to, finds, makes, buys, takes with, meets, talks to, gives, receives". The verbs are chosen, since they can be combined with many of the locations, objects and characters present. This way, children are guided in the storytelling process by forcing them to select an action, but the predefined set of actions is still sufficiently open for the children to use their creativity (in line with the approach as suggested in 2.6 Discussion). After each action, the robot responds. Then, children can again select an action. This sequence continues until the children believe the story is finished. The recurring sequence allows children to reflect upon their actions, which can improve their storytelling. As described by *Koops & Hoevenaar (2013)* in their Serious Gaming Lemniscate Model (SGLM), children are in the gaming state, meaning they can intuitively act on feedback. This structure in theory allows children to tell a story consisting of multiple problem - plan - consequence sequences, which fits with the structure of a good story as explained in 2.3 Narrative Elements & Story Assessment.

CHARACTERS

The six Playmobil figures as seen in 6.1 The Prototype were still used. However, each figure was equipped with an unique paper marker which could be recognised by the robot in order to identify the figure. The updated set of figures can be seen in Figure 7.1.

OBJECTS

New in this prototype are the object blocks. In this research an object is defined as "a tangible, inanimate thing that cannot perform actions, used in a story" (see 3.1 Components Inter-

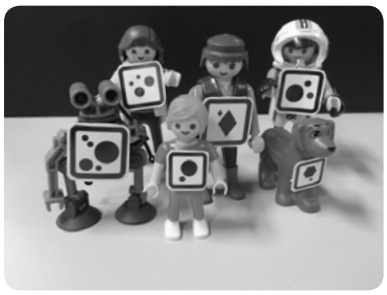


Figure 7.1 The Playmobil figures are equipped with markers which can be recognised by the robot to identify them.

Figure 7.2 The prototype is extended with object blocks. The blocks have an icon on top and are equipped with markers to be recognised by the robot on the other sides.

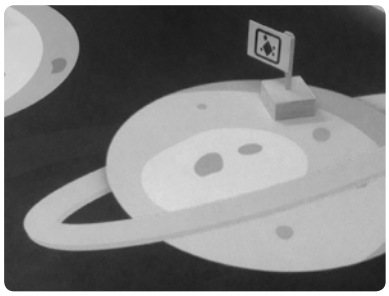


Figure 7.3 The locations on the story mat can be recognised by the robot via the use of flags with markers.

active Story). As explained before, the results of the pilot study showed the prototype did not provide the children with sufficient building blocks to tell a story. Therefore, an initiating event and actions are included. However, actions can be performed by characters and with certain objects. Hence, the prototype was extended with a set of theme-fitting objects, having associations with actions in space, namely: the rocket, to travel in space; the telescope, to watch the space; the shield, to protect against space characters; the map, to navigate in space; the plant and water drop, to create new life in space; the food and drink, to survive in space and the present, to thank other characters. However, children can also come with different purposes for the objects. Due to the lack of availability of the chosen objects among existing toys, the decision was made to use object blocks (Figure 7.1). The use of object blocks has the additional advantage of all objects having the same design. The object blocks were self-made and contained an icon of the object on one side and markers which could be recognised by the robot on the other sides.

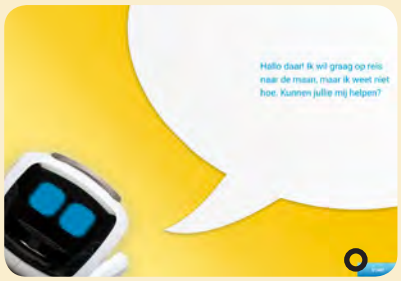
LOCATIONS

The play mat of which the design can be seen in Figure 6.3 was reused. Different from the pilot study, the different locations on the play mat could now be recognised by the robot via the use of markers (see Figure 7.3). Each location on the play mat got its own physical flag with a unique marker on it. The earth was divided into four areas, each with its own flag. Flags were chosen, since flags are associated with locations. This way, the markers could better be integrated into the story world, without distracting by being solely technical objects.

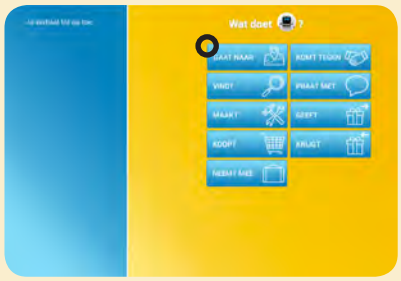
THE ROBOT

The robot reacted to the triggers listed in Table 7.1. A trigger resulted in a robot animation and the tablet showing a message from the robot. The emotions were generated randomly to encourage children to come up with explanations for the response of the robot. Children might associate a certain emotion more with the selected action than other emotions. When the robot displays an emotion that is not expected by the children, this emotion does not match the children's first associations. It could be the case they have to go beyond their regular associations between the action and emotion to come up with an explanation that fits the robot's response. This way, their creativity can be stimulated, fitting the Associative Theory of *Mednick (1962)* which describes that creative thinking is the process by which disparate elements come together in new combinations for a useful purpose.

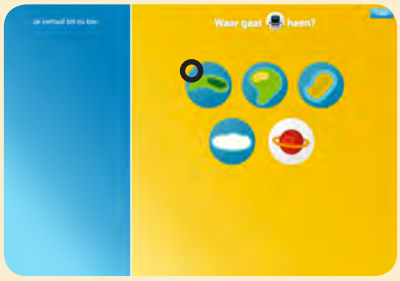
In line with the improvements discussed in 6.8 Suggested Improvements, the disgust emotion was left out. The other emotions remained unchanged, since the children understood them quite well (6.6 Results). Therefore, the animations and emoticons used were the same as in the pilot study (see Table 6.3). Only the robot behaviour for the idle mode in the N condition was added, as described in Table 7.2. Finally, the robot pick up trigger was removed. As can be seen from the results of the pilot study (6.6 Results) children sometimes got confused by the robot pick up animation. There was no additional tablet message shown, which resulted in the children not be-



1. *Start screen.* Cozmo explains he would like to go to the moon and asks for help. Pressing the button in the bottom right starts the playing.



2. *Action selection screen.* This screen allows for selection of what Cozmo needs to do. At the left an overview of the story so far can be seen. At this point, no story is created yet.



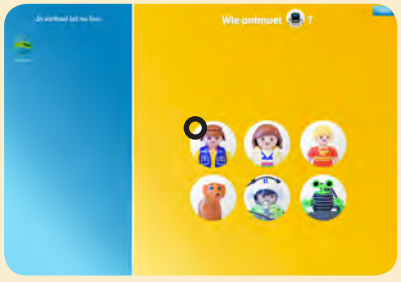
3. *Location selection screen.* The user can select where Cozmo travels in the story. Again, at the left the story overview is presented. The button in the top right can be pressed to return to the previous screen.

4. *Help screen.* The user is asked to help Cozmo by placing Cozmo onto the selected location. When Cozmo recognises the flag on the location, the next screen appears.

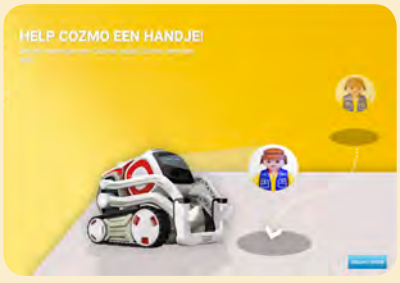
5. *Thought screen.* Cozmo provides the user with feedback by a though bubble containing the recognised location. The next screen appears after a fixed period of time. In the E condition also a random emotion is generated, resulting in an emoticon shown on the tablet and the robot playing an animation.

6. *Ready screen.* After each action the user is asked if Cozmo is ready to go to the moon.

7. *Action selection screen.* See 2. When the story is not finished yet, the user can again select an action. The story overview at the left is updated with the previous action.



8. *Character selection screen.* The user can select which character Cozmo needs to meet. At the left, the story so far. The button in the top right can be pressed to return to the previous screen.

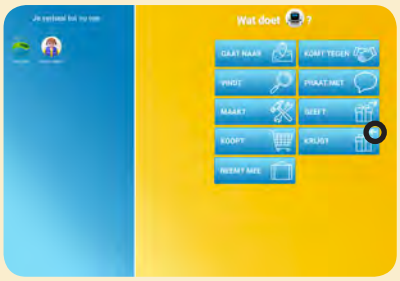


9. *Help screen.* See 4. Again, the user is asked to help Cozmo. This time the user is asked to place the selected character in front of Cozmo. When Cozmo recognises the correct character, the next screen appears.

Box 7.1 An example of a story created with the tablet application. This scenario fits the E condition, in which emoticons are shown on the tablet. In case of the NE condition, the emoticons on the tablet are turned off.

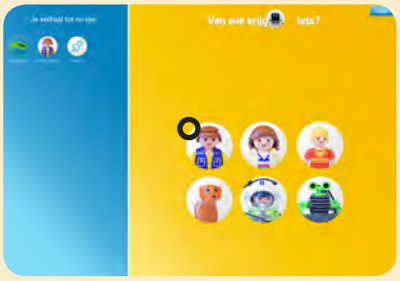
10. *Thought screen.* See 5. Again, Cozmo recognised the character and, in case of the E condition, shows an emoticon.

11. *Ready screen.* See 6. Again, the user is asked if Cozmo is ready to go to the moon or not.



12. *Action selection screen.* See 2, 7. The story is not finished yet, the user can again select the next action. The story overview now contains the previous two actions.

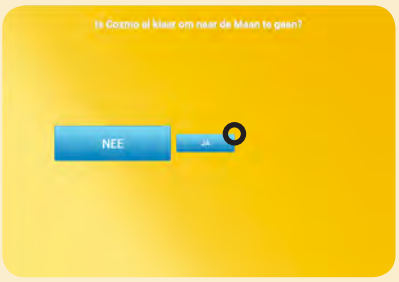
13. *Object selection screen.* The user can select the object Cozmo should, in this case, receive. The button in the top right can be pressed to return to the previous screen.



14. *Character selection screen.* See 8. The user can select, in this case, from whom Cozmo receives the object. The button in the top right can be pressed to return to the previous screen.

15. *Help screen.* See 4, 9. Again, the children are asked to help Cozmo. This time by placing the object selected in front of Cozmo. When Cozmo recognises the correct object the next screen appears.

16. *Thought screen.* See 5, 10. Cozmo recognised the object received from the character and, in case of the E condition, shows an emoticon.



17. *Ready screen.* See 6, 11. Again, the user is asked if Cozmo is ready to go to the moon or not. This time, "yes" is pressed.

18. *Help screen.* See 4, 9, 15. When the user believes the robot is able to go to the moon, the user is asked to help Cozmo by placing it onto the moon. When the robot recognises the flag the end screen appears.

19. *End screen.* Cozmo is at the moon and thanks the children. In the NE condition the robot also plays a happy animation and a happy emoticon is shown on the tablet. Pressing the button in the bottom right allows to play again (return to 1).

ing able to make the connection between the animation and the cause. Hence, for the ease of understandability, the trigger and corresponding robot behaviour were removed.

THE TABLET

The tablet application was largely changed with respect to the pilot study. An overview of a scenario in which a story is told with the tablet can be seen in Box 7.1. As explained before, this version of the prototype includes the robot's request. When starting the tablet application, the robot introduces its problem and asks the user for help *(Step 1 in* Box 7.1*)*. In addition, after finishing an action children are asked if the robot is already ready to go to the moon (*6, 11, 17*), which they can answer with a "yes" to continue telling the story, or with a "no" to take the robot to the moon. When the robot reaches the moon, he thanks the children (*19*). Also new are the action selection screens (*2, 7, 12*), followed by a location (*3*), character (*8, 14*) or object selection screen (*13*). In addition, help screens are introduced to inform the children they have to help the robot a bit to correctly recognise figures, objects or location markers. Children are asked to position the character (*9*) or objects (*15*) close to the robot or the robot close to a location flag (*4, 18*). Instructing the children to help the robot drastically decreases the environment scanning time of the robot. Letting the robot scan the environment completely would have resulted in a large pressure on the concentration span of the children. In addition, the robot's battery would run out much faster. The thought screens (*5, 10, 16*) are still the same as in the pilot, showing either the robot with a location, character or object, with or without an emoticon depending on the condition. The last extension of the tablet application is the story line. At the left side of a selection screen the story line is shown. This way, children are informed about the actions already performed in the story so far. The overview might help the children to better remember the previous steps in the story and, because of this, tell more coherent stories.

Throughout the storytelling process the different actions, including characters, objects, locations and emotions, are saved in a list. When finishing a story (i.e. when the robot has reached the moon), the list is saved into a log file on the tablet.

7.2 Goal

The second study focused on testing the research setup before running the final study. This way, the setup could still be adapted to ensure it suits the goals of the final study. The study included three dimensions, namely the understanding of the interaction of the children with the updated prototype, the prototype's support for storytelling and the feasibility of the measurements to be used in the final study. The questions to be answered by the study are listed below.

UNDERSTANDING INTERACTION PROTOTYPE

- **Do the children understand the robot's overall goal in the story?**
  Rationale: if children do not understand the robot's overall goal in the story, stories might be more difficult to compare with stories told by children who did understand the robot's goal.

- **Do the children understand how to select story elements on the tablet?**
  Rationale: in order to tell a story it is essential children understand how to select story elements on the tablet.

- **Do the children understand how to place the object blocks an figures in front of the robot after selection?**
  Rationale: children's understanding of this action is essential to not unnecessary slow down the storytelling process.

- **Do the children understand they have to move the robot towards a selected location?**
  Rationale: like for the previous question, children's understanding of this action is essential to not unnecessary slow down the storytelling process.

SUPPORT STORYTELLING

- **Does the prototype sufficiently support storytelling?**
  Rationale: if the prototype does not support storytelling, no stories can be told and, therefore, differences in storytelling between the two conditions cannot be observed.

FEASIBILITY MEASUREMENTS

- **Do the children understand the interview questions?**
  Rationale: when the children do not understand the interview questions, their answers most likely do not represent their opinion on the subject of the question.
- **Do the log files actually represent the stories told?**
  Rationale: when the log files do not represent the actual stories told, the logs cannot be used to determine the story elements present in the stories in order to compare differences in stories told in the two conditions
- **How do children communicate about the selected story elements?**
  Rationale: to be able to track the stories told from the communication between the children, it is essential to understand how they communicate.

7.3 Procedure

In this study both, condition NE, the condition without robot emotions and condition E, the condition including robot emotions, were tested. The robot behaviour and tablet content per condition can be seen in Table 7.1. An ethical approval from the University was acquired for the study. In addition, children participating in the study had permission of their tutors/parents to participate and to be recorded for research purposes. Children played in independent trials, meaning they only played one of the two conditions. This approach was used, since dependent trials could result in children already being biased by the condition played first. In this study this could be especially risky when children play with the full version of the prototype (condition E) before playing with the limited version (condition NE). During the study, children played in duos. This way, the largest amount of groups could be made, resulting in the largest amount of trials to be compared. However, children were still able to benefit from collaboration. At the beginning of the day, children performed in the NE condition. In the afternoon, children performed in the E condition. This order was used to prevent children in the NE condition from creating high expectations of the robot, based on what the children who had already played in the E condition told them. The approach also reduced workload for the researcher, since just one condition switch had to be made during the day.

THE SETUP

The study was performed in a separate room. In the middle of the room a table was positioned with some chairs around it. The play mat was placed onto the table. Another table was attached to the table with the play mat to be used for the computer. This way, the researcher could look at the robot's camera view, without children noticing it. Before playing, Cozmo was placed onto its adapter, in order to increase its battery life span. The figures and object blocks were placed next to the play mat. The tablet and location flags were placed onto the play mat. The camera was placed onto a tripod next to the table and installed in such a way that the actions performed by the children could be observed. An overview of the setup can be seen in Figure 7.4.

INTRODUCTION

Children played in groups of two created by the teacher of the class. When entering, the children were asked to sit down on one of the chairs. Then, the video recording was started. The researcher took place behind the computer. The children were shortly introduced to the robot and explained he communicated sometimes via the tablet, since he was not able to talk yet. Then, they were informed about the procedure of the study, consisting of three steps: the exploration of the tablet interaction, the tell of a story and the execution of the interview.

EXPLORATION TABLET INTERACTION

Before telling a story, the children were allowed to explore the tablet interaction. What could be seen from the results of the pilot study (6.6 Results) is that children were mainly exploring the robot behaviour during this study and were not focused on telling a story. Therefore, the exploration phase was included to reduce the exploration during play, hopefully resulting in an increase of focus on storytelling during play. In addition, in this way the children already get to know the tablet interaction, minimizing difficulties in understanding during play.

The researcher helped the children during the exploration phase. The tablet application was started and set to the "Action selection screen" (screen nr. 2 in Box 7.1). Then, the researcher asked the children to read the text on the tablet and helped them with reading when necessary. After reading, the children were encouraged to explore the interaction by selecting an action of their own choice. After the response of the robot on the action, the tablet returned to the "Action selection screen" again and the researcher took the tablet from the children. The researcher explained them the robot had a request for them and restarted the tablet application, now set to the "Start screen" (screen nr. 1 in Box 7.1). The tablet was given back to children and again they were encouraged to read the text and start telling the story.

TRIGGER	ROBOT BEHAVIOUR	
	Condition NE	**Condition E**
Idle	Idle animation according to Table 7.2.	Idle animation according to Table 6.3.
Recognition character	No change: still playing the idle animation	Random emotion, animation according to Table 6.3.
Recognition object	No change: still playing the idle animation	Random emotion, animation according to Table 6.3.
At moon (Recognition flag)	No change: still playing the idle animation	Happy emotion, animation according to Table 6.3.
At another location (Recognition flag)	No change: still playing the idle animation	Random emotion, animation according to Table 6.3.

Table 7.1 Triggers with corresponding robot behaviour and tablet content for both conditions.

SITUATION	FACIAL ANIMATION	MOVEMENT	SOUND
Idle (condition NE)	Blinking and moving eyes	No	No

Table 7.2 Robot behaviour in the idle mode for the NE condition.

TABLET CONTENT	
Condition NE	**Condition E**
No correlated content, content according to the children selecting story actions	No correlated content, content according to the children selecting story actions
Cozmo with: • A thought bubble containing an image of the character recognised	Cozmo with: • A thought bubble containing an image of the character recognised • An emoticon
Cozmo with: • A thought bubble containing an image of the object recognised (and an image of the character performing an action with the object in case this is applicable)	Cozmo with: • A thought bubble containing an image of the object recognised (and an image of the character performing an action with the object in case this is applicable) • An emoticon
Cozmo positioned at the moon, with: • A speech bubble containing a thank message	Cozmo positioned at the moon, with: • A speech bubble containing a thank message • A happy emoticon
Cozmo with: • A thought bubble containing an image of the location recognised	Cozmo with: • A thought bubble containing an image of the location recognised • An emoticon

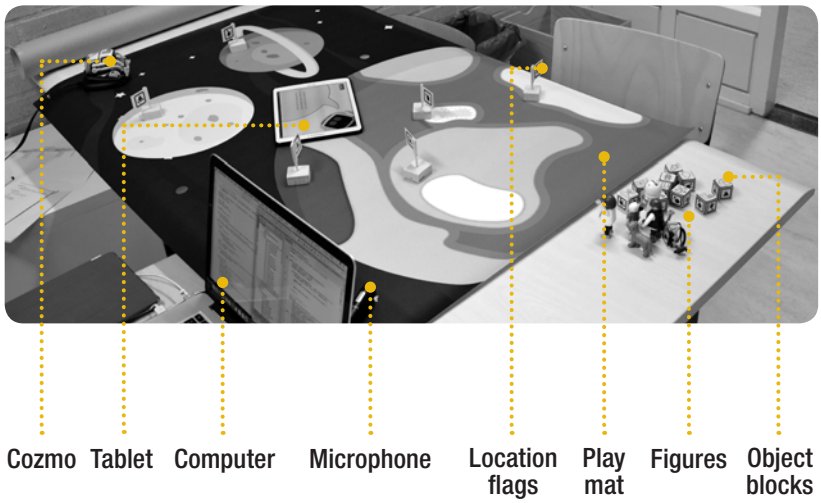


Figure 7.4 The research setup during the second study. The children take place at a chair around the table. The play mat is placed onto this table. The location flags are placed on the play mat. In addition, a microphone is placed on the table to record the children's conversations. Children play with the play mat, the figures, the object blocks and Cozmo. Children can create story actions by using the tablet. The researcher sits behind the computer running the Cozmo program placed onto a small table attached to the play table.

DURING PLAY

During play, the researcher took notes and answered children's questions. The researcher did not actively interfere in the story told. However, when the children experienced difficulties with recognition of the markers, the researcher helped the children by looking at the robot's camera view on the computer to instruct the children to move or rotate the object blocks, figures, flags or the robot or performed the action himself. The researcher explained the technical issue as the robot having a bad sight. Later on, children started moving around the objects themselves in order to be recognised. Also, when the children did not understand the interaction around the recognition, the researcher interfered. In addition, children were helped with reading when necessary. Children played until they felt satisfied or when time was up (maximum of ten minutes).

CLOSURE

After the playing the children were interviewed. To ensure the children were not distracted from the interview by the robot, the robot was turned off. For the same reason the researcher took the tablet.

PLAYING FULL VERSION PROTOTYPE

To ensure children had a more equal experience over the conditions, the children that performed in the NE condition got some time at the end of the session the explore the full version of the prototype. Upfront, the children were not informed about the two conditions, so they did not know they were playing with a limited version before. The researcher restarted the robot and tablet application and children could play for the time that was left. Children could play, but were not observed and interviewed.

7.4 Sampling Method

The sampling procedure used was the same as the procedure during the pilot study (see 6.4 Sampling Method). Subjects were children that were in the third and fourth grade of a Dutch elementary school, resulting in the age of the participants ranging from six to eight years.

7.5 Measurements

OBSERVATIONS

While interacting with the prototype, the children were observed. Notable actions performed by the children were written down right away. In addition, when having permission, the children were video and audio recorded. The recordings were used to do offline observations after the activity ended. The observations were used to complement the notes taken during the playing. Observations were taken in line with the questions as described in the goals section above.

INTERVIEWS

When the children finished playing, they were asked a few questions about their experience. Due to practical reasons, such as the concentration span of the children and a limited amount of researchers, the children were interviewed in duos. The interview questions asked can be seen in Box 7.2.

7.6 Results

PARTICIPANTS

The user study was performed with children that were in the third and fourth grade of a Dutch elementary school. A total of 33 children (n = 33) participated. The children were spread over seventeen trials, nine for the NE condition (n = 18) and eight (n = 16) for the E condition. The amount of children of the conditions do not add up to the total number of children, since one child performed twice. The ages of the children ranged from six to nine years (M = 7.08 years, SD = 0.82 years). Of the children fifteen were female and nineteen were male. The children were equally divided over the conditions. Also, it was taken into account children with different ages were distributed over the conditions equally. Nine females and nine males performed in the NE condition (age: M = 7.06 years, SD = 0.73 years) and seven females and nine males in the E condition (age: M = 6.94 years, SD = 0.93 years). Only two duos were mixed-gender duos.

OBSERVATIONS

Since the amount of stories told by the children differed, the observations were for all trials based on the first story told. In all trials the children at least told one story. By comparing solely the first stories, the differences in the learning effect for the children that told multiple stories compared to the learning effect for the children that only told one story, was minimised. A description of the observations can be seen in A6 Observations Second Study. During trial *NE9* and *E8* the microphone stopped recording. Therefore, for these trials the results were only based on the notes of the researcher during the session.

Understanding Tablet

What can be seen from the observations is that in all trials the children understood the tablet interaction. The children correctly selected the story elements on the tablet.

Communication Selections

Over the trials three main ways of communication about which story element to be selected can be seen: selection by mentioning the story element directly, selection by mentioning the story element indirectly and selection without talking aloud. The direct selection form means children talk to each other aloud in which they specifically mention the story element to be selected. In case of indirect selection, they do talk aloud, but do not specifically mention the story element. However, they refer to the story element, mostly by the use of indicative pronouns in combination with pointing at the element. Finally, children can also not talk aloud, but just

1.

If you go home after school, what would you tell your parents/siblings about what you did here?

Rationale: This question was asked to see which experience was the most prevalent according to the children and worth telling other people about. If they only tell about the robot and not about storytelling, something might be wrong.

2.

What did you think of telling a story?

Rationale: This question was asked to see how children felt about the session. If children like the activity it is more likely they learn more. As described by *Keller-Hamela (2016)* and *Read & MacFarlane (2006)* yes-or-no questions make the child try to guess what the adult wants to hear and answer according to this assumption. Therefore, it is chosen to use a Smileyometer, as described by *Read & MacFarlane (2006)* instead. *Yahaya & Salam (n.d.)* use a similar measurement scale for assessing children perceived motivation level of the children in for using a persuasive multimedia learning environment. The particular Smileyometer used in this study can be seen in Figure 7.5.

3.

What do you think of the robot?

Rationale: This question was asked for similar reasons as the previous question. Also, the same Smileyometer was used.

4.

Could you shortly explain to me what your story was about?

Rationale: This question was asked to see if children remembered their story and what story grammar elements (2.3 Narrative Elements & Story Assessment) they used. It is specifically interesting to see if they tell about the robot's emotion, since their answers could possibly be used as indicator for differences between the two conditions.

5.

How did the robot feel in the story? How did you notice?

Rationale: This question was asked to see if children recognised the robot emotions in case of the E condition and how they filled in the robot emotions for the NE condition. This question could possibly be used as indicator for differences between the conditions.

6.

Did you adapt your story to the emotion of the robot? Why? How?

Rationale: This question was asked to see if children adapted their story when the robot showed emotions that did not fit with the story they had in mind. This question could possibly be used as indicator for differences between the two conditions, since in the NE condition there is no need to change around the story, since no emotions are present.

Figure 7.5 Smileyometer

Box 7.2 Interview question second study

pressing the buttons. In many of the trials all three ways of communicating were present *[trial NE1, NE4, NE7, E5, E6]*. In others just direction communication *[trial E3]*, indirect communication *[trial NE2]* or a combination of direct and indirect communication *[trial NE3, NE6, E2, E4]* was present. Finally, some children made use of a combination of direct communication with directly pressing buttons *[trial NE5, NE8, E1, E7]*.

Quality Story Logs

In most of the trials the story logs represented the story told *[trial NE2, NE4, NE5, NE6, NE7, NE8, NE9, E1, E2, E3, E4, E5, E6, E7, E8]*. However, in some of the trials the application was restarted, either due to a bug in recognition *[trial NE1]* or by the children accidentally clicking away the application on the tablet *[trial NE3]*. Therefore, in these cases a new story was told and the story elements used before the restart were not saved. In addition, many children also told very small stories *[trial NE1, NE2, NE3, NE5, E2]*, containing just one story action before the robot travelled to the moon. For these reasons, the logs were not studied.

Understanding Placement Objects Blocks and Figures

Most of the children understood how to place the object blocks and figures in front of Cozmo in order to be recognised. They interpreted the tablet content of the help screen correctly *[trial NE2, NE3, NE6, NE7, NE8, NE9, E1, E2, E4, E6, E7, E8]*.

Other children rotated the object blocks in such a way the icon was rotated towards Cozmo instead of on top *[trial NE4, NE5]*. Some children expected the robot to drive towards the object block or figure *[trial NE5]*. Also, some children thought they had to drag the virtual object block or figure over the line on the tablet *[trial E3]* or placed the tangible object block or figure on the virtual object block or figure on the tablet *[trial E5]*. However, when the researcher interfered and explained how the interaction worked, all children performed the right actions later on. Finally, in one trial *[NE5]* children thought they had to place both, the figure and object block, in front of the robot when an action included both.

Understanding Movement

In almost all of the trials the children understood from the help screen on the tablet that they had to move Cozmo to the selected location *[trial NE3, NE4, NE5, NE6, NE7, NE8, NE9, E1, E2, E4, E5, E6, E7, E8]*. Like observed for the placement of object blocks and figures, some children were dragging over the line on the help screen of the tablet to move the virtual Cozmo *[trial NE2]*. In trial *NE1* the children did not have a look at the tablet, so they did not understand what to do. When the researcher then explained they had to look at the tablet they were a bit doubtful if they were allowed to pick up the robot, the researcher had to encourage them. Only the children in *trial E3* had no clue at all about what to do, therefore the researcher explained it to them. Later on, they handled the situation correctly.

Child Remarks about Robot

Many children asked if the robot could or why the robot could not listen *[trial NE1, NE4]*, drive *[trial NE1, NE3, NE4, NE7, E7]* and talk [*trial NE2, E7]*. One child *[trial E1]* even said: "My robot at home is able to talk". Two boys *[trial NE3, E7]* became really impatient and asked in a more general way: "Why doesn't he do anything?". What is remarkable is that the more irritated way of asking about its characteristics ("Why can he not...") was only used by boys *[NE3, NE4, E7]*. Their expectations might have been different. Some remarks made by the children that could also have to do with their expectations included a thought of the robot to be larger *[trial NE5]*, a though of the robot being able to listen *[trial NE6]*, a question if one could make the robot angry *[trial Ne3]*, a question if the robot was a real robot *[trial NE1]* and a question if the robot was real [*trial E3]*.

Some children specifically referred to Cozmo's eyes, by saying: "It seems like it from its eyes, yes" *[trial NE2]*, "He can also make its eyes small" *[trial NE5]*, "He blinks" *[trial NE8]*", "Cozmo has blue eyes and rectangular ones" *[trial NE8]* and "Oh his eyes" *[trial E1]*. Children sometimes specifically mentioned they liked the robot by using sentences, such as: "Oh that is a cute one" *[trial NE1]*, "Oh he is nice" *[trial NE1]* and "Cozmo is funny" *[trial NE4*].

Randomness Emotions

By looking at the observations it is expected that children have expectations about the robot's emotions. Some children mentioned their reason to select an action upfront. As an example, in *trial E1* selected the food to ensure the robot would not die. In *trial E4* children selected the rocket to ensure

the robot could fly. In these trials, the children probably expected the robot to react positively, since the actions prevented something "bad".

No matter if the actual robot emotion matched the emotion they expected, many children just took the actual emotion for granted. They mostly split the emotions in either positive or negative and reacted accordingly. Some repeated what the robot said *[trial E5, E6],* whereas others explicitly mentioned how they thought the robot felt *[trial E5, E6].* Other children specifically indicated that the actual emotion did not fit with the emotion they expected. They tried to come up with a reason for the actual emotion. As an example, in *trial E5* children suggested that the robot wanted to talk to another figure when showing a negative emotion when seeing a figure. Their suggestion indicates they probably expected the robot to be happy. These children sometimes also indicated they did not expect a certain robot emotion ("Sad, but why?"), but simply accepted it. Children often confirmed it when the actual emotion met the emotion they expected. They mentioned things, such as: "That is what you want" *[trial E8],* "Yes, he said yes. Okay, this is good, this is good. He needs the friend as a space man" *[trial E5]* and "Okay, this figure is in your team" *[trial E8].* Interesting to note is that the robot showed a positive emotion (happy or surprise) in all these examples.

What can also be seen from the observations is that the children did not often reused items. They mainly selected unused items *[trial E2, E3, E5, E6, E7].* The children probably wanted to explore the robot responses on all items individually. Other reasons why children did not reuse items were too limited time due too reading difficulties *[trial E6]* and not reusing items when the robot reacted negatively the first time *[trial E7].* When children did reuse an item, it seemed they did not notice that the emotion was different *[trial E1, E2, E6, E7]* or did recognise a different emotion, but just took it for granted *[trial E3, E6].* For example, children responded by "but he did not have such a happy face", referring to the robot being happy the first time *[trial E3]* and "then he was afraid" referring to the robot being afraid the first time *[trial E6].* In *trial E5* children used the dog independent from robot's emotion more often, they probably just liked the dog. In just one trial the children actually wondered why the robot showed a different emotion than before *[trial E4].* They tried to seek for a reason and provided the robot with other items to see how this influenced its emotion. In *trial E7* the robot was afraid the first time a child selected the present. When the other child then selected the present, the robot turned happy. This resulted in the first child being indignant and upset, since the robot was not happy when he selected the present.

Other Remarks

Many children greeted the robot by talking to it *[trial NE3, NE4, NE8, E3, E7]* or waving at it *[trial NE2, NE3].* Some children talked to the robot during play *[trial E5]* or repeated the sounds he made *[trial E5, E6].* Also, some children stroked the robot *[trial NE4, E8].* These observations indicate the children perceived the robot as a character.

Children often expected the "go to" action could be selected to send the robot to the moon *[trial NE1, NE6, NE7, E1].* After the researcher explained this was not possible yet, they sometimes came up with reasons why the robot was not able to go to moon yet *[trial NE1, E1*]. One child did not understand and asked: "How do you have to go to the moon actually?" *[trial E4].* In one trial *[NE6]* children thought the action "goes to" meant the robot used a map, since the icon of the action was a map. A similar situation occurred in trial *NE8* in which the children also thought the robot would use the object of the icon when pressing the corresponding action button. Something else which was observed more often is children reacting to the tablet with the robot's thought bubble after an action. Children often reacted in a similar way to "he saw him" *[trial NE1, NE3, NE7, NE8, E1, E3]*, indicating the robot recognised what was in front of it.

In many trials some story content was present. Children included causality by describing reasons for the occurrence of actions or emotions. Children mentioned arguments, such as: he wants to make more friends *[trial NE4]*, he should wear its suit *[trial NE3, NE5]*, he needs food, otherwise he dies *[trial E3]* and he needs a rocket to go to the moon *[trial E3, E4, E5*].

In some trials children explicitly said they liked the activity *[trial NE4, NE7, E5].* However, one child continuously asked when they could play with the robot, whereas the other child seemed to like telling the story already *[trial NE3].* Again this was a boy, which is in line with previous results.

Finally, a last remark. Only in *trial E8* the children actively looked at the storyline. In this trial the children were reminded by the fact that they already used the dog many times.

INTERVIEWS

Results of the interviews can be seen in A5 Interview Results Second Study. The child that performed twice was only asked the questions once, namely after the first session.

Tell at Home

When asking the children what they would tell about the activity at home they mainly answered they would tell they worked with a robot *[trial NE1, NE2, NE3, NE5, NE6, NE8, E1, E3, E4, E6, E7, E8]*. Some children specifically mentioned they helped the robot *[trial NE3, NE4, NE9, E4]*. Some children included descriptions of characteristics of the robot, such as its name *[trial NE2, NE7]*, the robot design *[trial NE3]* and the goal of the robot *[trial NE6]*, in their answer. Besides descriptions of the robot, the children also mentioned other aspects of the setup, such as the play mat *[trial NE5]*, the figures *[trial NE5, NE6, NE7, NE9]*, the object blocks *[trial NE9]* and the tablet *[trial NE6, NE8]*. In line with this, children also referred to actions, such as the ability to bring to robot to a location *[trial NE5, NE6, NE7, E1, E4]*. They sometimes described it as if they went to a certain location in space themselves *[trial NE9, E5, E8]*. hat can be seen is that in none of the trials children mentioned telling a story. A final note: some children would also tell that they liked the activity *[trial NE7, E4, E6]*.

Appreciation Storytelling

The majority of the children, twenty-five, pointed at the most happy smiley to indicate their appreciation of the storytelling task. Five children pointed at the happy smiley and three at the neutral smiley. In the NE condition the appreciation was as follows: thirteen children pointed at the most happy smiley, four at the happy smiley and one at the neutral smiley. In the E condition these smilies were pointed at twelve times, one time and two times respectively.

Appreciation Robot

Like for the appreciation of the storytelling task, the majority of the children, twenty-nine, pointed at the most happy smiley to indicate their appreciation. Three children pointed at the happy smiley and only one at the neutral smiley. In the NE condition the appreciation was as follows: sixteen children pointed at the most happy smiley and two at the happy smiley. In the E condition children pointed at the most happy smiley thirteen times, and only once at the happy and neutral smiley.

Story Summary

Many children had difficulties with telling a story summary. In some cases children could not come up with a summary at all *[trial NE1, NE5, NE8, NE9, E2, E6]*. Others only shortly mentioned the story was about the robot *[trial NE1, E3]*. Some children mentioned the goal of the robot: wanting to go to the moon *[trial NE3, NE4, E1, E4]*. Also, some children referred to single actions in the story, such as the robot meeting a character *[trial NE7, E5, E8]*, the robot taking objects *[trial E4, E5]* or the robot playing *[trial NE2]*. Only a few children specifically mentioned connections between story actions, such as the robot wanting a shield to protect himself *[trial NE3]*, the robot arranging a rocket or map to go to moon *[trial NE4, E4]* or the robot meeting with an astronaut to get information about space *[trial E4]*. In one trial *[trial E3]* the children mentioned the robot needed to look at something.

Feelings Robot

All children that answered this question thought the robot was happy in the story. Children sometimes described the happy emotion by the word "nice". Asking the children why they thought the robot felt happy often lead to an explanation referring to the robot's end goal, such as: "The robot wanted to go to the moon and he is there now" *[trial NE1, NE2, NE4, NE5, NE7, E4]*. Other explanations given were: "He is happy, because I am happy" *[trial E8]*, "He is happy, because we helped it *[trial NE9]* and "He is happy because we taught him something" *[trial E6]*. In trial *NE2* the children specially referred to the word "Joepie (Joehoe)" shown on the tablet when the robot reached the moon. Only in two cases the children explicitly mention the robot's animations, such as a change of the face or movements *[trial NE, E1]*.

In some trials children also mentioned other emotions, such as anger *[trial NE3, E1, E3, E5, E8]*, fear *[trial E3]* and sadness *[trial E8]*. What can be seen is that mostly children in the E condition came up with other emotions. Children in trial *E5* described the robot's emotion as: "not so happy". In one trial the children explicitly mentioned the reason for the robot feeling angry, namely: "The robot did not want to get tools" *[trial E8]*. In trial *NE7* children described the robot's emotion as "funny", and in trial *NE9* the children called the robot tired, since he was not able to drive.

Adaptation Story

On the question if the children adapted their story to the responses of the robot on previous actions, children mainly answered they did not, they continued with what they already thought of themselves *[trial NE4, NE7, NE8, NE9, E1, E2, E4, E6, E7, E9]*. In two trials the question was not asked *[trial NE6, NE8]*. In two other trials children did not answer *[trial NE1, NE2]*. In trial *NE3, E3* and *E5* the children answered with yes, but could not explain why or how they adapted it or came with an explanation not fitting the question.

7.7 Discussion

UNDERSTANDING INTERACTION PROTOTYPE

Goal Robot

What could be seen from the observations and interviews is that children understood the goal of the robot. They also understood they needed to help it. Children's story summaries and answers on the question what they would tell at home both contained references to the goal of the robot and its request to help it.

Overall Tablet Interaction

The observations showed that, in general, children understood the interaction with the tablet. Children understood how to tell a story. Some aspects of the tablet sometimes led to confusion. The aspect that confused the children the most was the fact that it was not possible to select the moon under the "goes to" action. Also, children sometimes thought the icons on the action buttons referred to the robot using the object shown as an icon.

Placement Object Blocks & Figures

Overall the children understood how to use the object blocks and figures and how the robot recognised them. Some children needed a bit of help the first time, but afterwards they interacted with the object blocks and figures correctly. Only the help message on the tablet sometimes led to confusion, since the children did not understand they had to perform an action in the physical world. The children thought they had to perform an action in the virtual world.

Movement Cozmo

The children understood they had to move the robot to a selected location. As for the placement of the object blocks and figures, children sometimes received help the first time. Also, sometimes there was confusion around the help message.

SUPPORT STORYTELLING

Compared to the pilot study, children already told more extended stories. However, the activity was still more like play than a storytelling activity. Different from in the pilot study, children sometimes included cause-effect reasoning for why certain actions happened, such as "he needs food, otherwise he dies". Also, they sometimes included why the robot felt a certain way by including arguments, such as: "he does not like that character". Cause-effect reasoning according to actions occurred in both conditions, whereas emotion reasoning only occurred in the E condition. The latter fits with the robot not showing any emotions in the other condition. Children mainly split the emotions into positive ones (surprise, happy) and negative ones (fear, anger, sadness) and responded accordingly. Different from in the pilot study, in the interview children did often provide a cause-effect reasoning for the robot's feelings. However, they often only referred to the final robot emotion. They said the robot was happy, since he wanted to go to the moon and he got there. They did not always mention the emotions of the robot throughout the rest of the story. This mainly occurred in the E condition, which logically follows from the fact that the robot only showed emotions in this condition. On the one hand, the limited reference to other emotions than happiness might indicate the emotion connected to the goal is most important for children. On the other hand, they might also just remember the happy emotion the best, since it occurred last.

Although children included some reasoning, the reasoning was mainly based on the individual action or emotion, children did not take the overall goal into account. Therefore, the reasoning did not connect the different story elements to a story.

Whereas children told more extended stories, children still had difficulties in creating a story summary. This could be because they could not remember the story or by the fact that they did not create a story at all. Children might just have clicked through the tablet application without being aware of how the selected story elements influenced the story. Children often did not mention much more than that they were helping the robot, and that the robot wanted to go to the moon. Therefore, the prototype might not sufficiently support the story creation process yet.

FEASIBILITY MEASUREMENTS

Interview Questions

Children all answered the question on what to tell at home. In many cases the children would tell they did something with a robot. They barely mentioned the storytelling. This might indicate

the children liked the robot the most, and did not care that much about the storytelling. However, some others also included other elements of the activity, which indicate they found these elements relevant mentioning. It could indicate they liked the activity, but also that they disliked the activity. However, from the observations could be seen children sometimes specifically mentioned they liked the activity. Not much difference in answers can be seen between the two conditions.

Also, all children answered the questions on how they appreciated the storytelling task and the robot. The storytelling task was rated a bit less good than the robot. However, the children often rated both aspects with five out of five on the Smileyometer. This is in line with research by *Read & MacFarlane (2006)*. According to them, the Smileyometer is not very useful for young children. For children younger than ten years old the variability of the responses with the use of a Smileyometer is very low, since these children tend to choose the highest (most positive) score. Another explanation could be the children tend to please the researcher (known as suggestibility) by providing the answer the think is most desirable. However, it could actually be the children really liked both the activity and robot that much, since the observations also show their appreciation. Not much difference between the two conditions could be discovered. So, independent of the behaviour of the robot the children really liked both the task and the robot.

Although the children were not always able to answer the question or answers to the question were limited, the question about the story summary was understood by the children.

The last question might not have been that clear to the children. In many cases the researcher had to repeat the question and provide the children with two options; if they changed the story around or not. Still, some children did not answer the question. Other children often just repeated a part of the sentence spoken by the researcher. Many children said something similar to "I thought of something myself". Some children answered "yes", but just one group could really explain how and why they changed their story around. The lack of explanation given by the children could indicate they did not understand the question or that they were not busy with telling a story throughout the activity.

Communication Selection

What could be seen from the observations is that children often communicated about which story elements to select directly. However, they also indirectly referred to what to select or just pressed the buttons, without talking about the selection.

Log Files

The story logs mainly represented the stories told. However, they could not always be used to track the story, due to bugs in recognition or children accidentally clicking away the application. In addition, sometimes children tell many small stories, consisting of only one action. It might be the case they indirectly continue a story over the different sessions. Therefore, solely relying on the log files makes comparison of the stories told by different groups of children sometimes unreliable. And, since many stories consisted of just one action, only taking the stories consisting of a minimum number of actions would not be representative. Therefore, a comparison based on the logs was not made during this study.

RANDOMNESS EMOTIONS

The randomness of the robot's emotion did not seem to interest the children that much. First of all, children were often not interested in reusing items, since they wanted to explore the robot's response on all individual items. Therefore, the children's responses on different robot emotions for the same item could barely be observed. If the children reused an item and the robot showed a different emotion than before, they did not notice the different emotion or just took the difference for granted. Only a very few children came up with a reason for the different emotion. Therefore, the current system barely triggered children's creativity by thinking of original solutions fitting the robot's emotion.

OTHER

Although children understood how to work with the prototype, their expectations sometimes did not match the characteristics of the prototype. Almost all children knew they would be playing with a robot, since it was needed to explain the activity in order for the schools to participate. Therefore,

children already had expectations before the activity started. What could be seen from the observations is that the children asked many questions about what the robot was able to do. Children mainly expected the robot to drive, listen and talk, since they asked about these characteristics. That children had expectations was also derived from the observation of children greeting the robot, children waving at the robot and children talking to robot. Some children even got irritated when the robot did not perform as they expected. These observations indicate children expected the robot to be a more intelligent character than it actually was. What should be noted is that it were mainly the boys who got irritated when the robot did not meet their expectations. Some gender differences might be present here. As an example, in the research by *Schermerhorn, Scheutz & Crowell (2008)* males tended to think of a robot as more human-like than females, who saw the robot as more machine-like. Differences in expectations might be related to this finding.

Although their expectations sometimes did not match the actual activity, children liked playing with the robot. They mention this during play or in the interviews. Some children also indicated they liked the activity in general.

7.8 Suggested Improvements

SUGGESTED IMPROVEMENTS PROTOTYPE

- Implement questions after action selection and after the tablet screen with Cozmo's thought bubble to force children to reason
- Implement that a minimal amount of actions is required before a story can be finished
- Improve distinction icons actions and objects
- Reduce confusion "go to" action
- Require robot to recognise both the object block and figure in case of action including both
- Reduce confusion help screen

PROTOTYPE

What can be seen from the results of the study is that children's storytelling increased compared to the pilot study, but that it is still not very extended. To help children to tell a more extended and coherent story, it is suggested to ask the children a "Why-question" after each action. This way, the children are forced to think of reasons for selecting a certain action. In addition, a similar question can be asked after the tablet showed the robot with a thought bubble. In the case of the NE condition, the children can be asked how the robot feels and, in case of the E condition, why the robot feels a certain way. Including this questions encourages children to include the robot's emotions in the story, instead of wondering why the robot reacted in a certain way. The questions can make the children aware of the fact that thèy have to come up with the reasons.

Also, it is suggested to adapt the prototype in way a minimal amount of story actions is required to be able to finish a story. This way, children cannot tell stories consisting of just one action and it is prevented that children indirectly continue their story of the different sessions.
In addition to the two changes as described above, some less important improvements can be made. The improvements as explained below are not expected to be essential for the sto-

rytelling process, since children already told stories without these improvements. Therefore, these improvements do not receive the focus.

The first aspect of the prototype that can use some attention is the "to go" action. It would be an improvement if a solution is implemented in which children can still bring the robot to a location on the play mat, but do understand they cannot use the action to bring the robot to the moon. It would even be better when children understand from the beginning on how to bring the robot to the moon, instead of finding out after pressing "yes" on the ready screen. However, this solution should not be at the cost of the amount of actions in the story.

In addition, some children confused the action icons with the robot taking the object on the icon. It would be an improvement if the distinction between the icons of the actions and the objects can be made much clearer.

Another small improvement which can be made is requiring to place both the object block and figure in front of the robot in case of an action including both.

A last small improvement could be to update the help screen content on the tablet. Some children were confused they suddenly had to perform an action in the physical world instead of in the virtual world. In a later stage, the robot could even drive to the object blocks, figures and locations himself. This way, the help screens can be deleted and misinterpretation of the content cannot occur anymore.

MEASUREMENTS

It is suggested to update the interview for the next study by leaving out the questions about what to tell at home, the appreciation of the activity and the appreciation of the robot Although the first question provided useful answers, it is not expected asking the question in a next study will lead to new insights. The same is expected for the appreciation of the storytelling activity and the robot. Due to the skew in answers with the Smileyometer, it is suggested to gain information about how children like the storytelling activity and the robot by the use of observations in order to increase reliability. Removing the questions from the interview allows for new questions to be asked. It is also recommended to delete the last interview question, since it was most likely the children did not understand the question. The other two questions, the story summary question and robot feelings question were understood by the children. Besides, these questions provided information about what the children thought is important in the story. When updating the prototype, asking the question may lead to different answers. Therefore, it could be useful to again ask the children these two questions in the next study.

In addition to updating the interview, keeping track of the story told can also be improved. The log files in some cases did not match the story told. Children clicking away the application could not be avoided and bugs in recognition can be minimised, but can still happen due to dependence on the wireless connection. Therefore, it would be helpful to have the camera recording the selections of the children to complement the story logs if necessary. Since children often indirectly talked aloud about the story elements to be selected, or not even talked about the selections aloud, solely recording sound would not always be sufficient to track the story told. Some children sometimes pick up the tablet to better be able to read what is on it, therefore, the camera should be positioned in such a way that in these cases it can still record the selections.

SUGGESTED IMPROVEMENTS MEASUREMENTS

- Interview: delete the tell at home question, the appreciation of the activity question, the appreciation of the robot question and the adaptation of the story question
- Logging: setup camera to record story selections to complement log files if necessary

8

The final study focused on two aspects of the project. First, the response of the children to the implemented tablet questions was researched. Secondly, the study researched the quality of the stories created by the children in both conditions. The stories of both conditions were then compared to see if any difference in storytelling existed in order to answer the overall research question. This section describes the updated prototype, the goals of the study, the procedure, the sampling method and the measurements. Then, the results of the study are presented. The section ends with a general discussion.

The setup during the final study. In the front: the processing computer, in the back: the play mat with the tablet, figures and object blocks.

Final Study

8.1 The Prototype

The prototype used in this study is largely the same as the prototype used during the second study (as described in 7.1 Prototype). The characters, objects, locations, actions and robot behaviour remained unchanged. However, the content of the tablet application did change. The changes are described below.

CHANGES TABLET APPLICATION

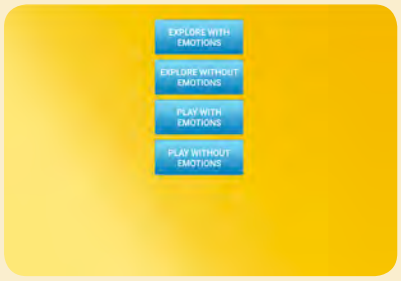
- "Why-questions" implemented after each action selection screen and thought screen on the tablet
- Minimally three actions are now required before a story can be finished
- Extra screen implemented on the tablet to select the mode (exploration vs. play) and the emotion condition (with or without emoticons)
- Exploration mode: no problem statement, no question "Is Cozmo ready to go to the moon?"
- Play mode: children introduced to problem statement, question "Is Cozmo ready to go to the moon?"
- Intro screen: additional introduction text explicitly saying children can help the robot by creating a story
- End screen: word "joepie" *"joehoe"* deleted

THE TABLET

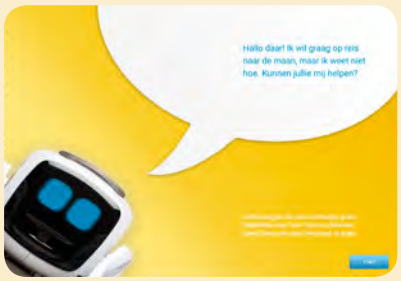
The extended scenario of Box 7.1 can be seen in Box 8.1. The two major improvements as suggested in 7.8 Suggested Improvements have been implemented into the prototype. After each action children are asked why the particular action occurs in the story. The children can type in the answer on the tablet (Step 3-II/8-II/14-II in Box 9.3). A similar question is asked after the thought screen (Step 5/10/16 in Box 7.1) is displayed on the tablet. The children are asked to think of how the robot feels in case of the NE condition and asked why it feels a particular way in the E condition (Step 5-II/10-II/16-II in Box 9.3). The "why-questions" create a reflection for the children. Children are encouraged to shift towards a learning state in which they rationally reflect upon their experience. The learning state is part of the Serious Gaming Lemniscate Model by *Koops & Hoevenaar (2013)*. An advantage of the implementation of the "why-questions" is that it increases active user participation, preventing the system from solely becoming an entrainment tool (as described in 2.5 Use of Toys in Pretend Play). Besides, the questions might interrupt children's storytelling, but do not restrict it (which is in line with the approach as described in 2.6 Discussion). The second improvement made is that at least three action sequences are required before the ready screen (Step 6/11/17 in Box 7.1) appears and the children can take the robot to the moon to finish the story.

In addition, small practical improvements are made. First of all, a mode selection screen (Step 0 in Box 9.3*)* is implemented to easily switch between the different modes (exploration vs. play) and conditions (with or without emotions). This way, the researcher can easily switch conditions without having to re-upload the tablet application. Also, an introduction text is added to the intro screen (Step 1 in Box 9.3*)* explicitly saying children can help the robot by making a story, reducing the need for the researcher to stress this. Finally, on the end screen the word "joepie" *"joehoe"* was deleted, since some children based the robot's emotion on this word.

Box 8.1 Extensions scenario Box 7.1 based on the updated tablet application. The screens replace the screens with the same number in Box 7.1, or are inserted after the screen with that number (in case of nr-II). The screens again fit the E condition. In case of the NE condition the question asking for an explanation of the robot's specific emotion is replaced by a general question: "Why does Cozmo feel like this?".

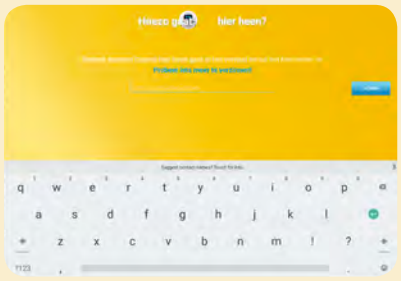


0. *Mode selection screen.* The researcher can select the mode of the application. The mode can be set to either play or explore, determining whether the goal of the robot is shown or not shown respectively. Also, the researcher can select if emotions should be included or not.



1. *Start screen.* Cozmo explains he would like to go to the moon and asks for help. Pressing the button in the bottom right starts the playing. In addition, a general explanation is added in which children are asked to create a story in which the robot reaches the moon.

3-II/8-II/14-II. *Action explanation screen.* The user is asked to explain why the action is needed, in this case, why Cozmo travels to a certain location. In case of a character or object selection the user is asked a similar question.



3-II/8-II/14-II. *Action explanation screen - Error.* When the user does not enter a sufficient amount of text (< 8 tokens), a message is shown asking to come up with a bit more.

5-II/10-II/16-II. *Emotion explanation screen.* The user is asked to explain why Cozmo feels a certain way. In case of an insufficient amount of text, the same message as for 3-II/8-II/14-II is shown.

8.2 Goals

The first goal of this study is to research the main change of the prototype: the implementation of the tablet questions. Secondly, the study researches the quality of the stories told. These results can then be used to see if any differences in the stories of the two conditions exist in order to answer the overall research question as stated in 1.2 This Research.

TABLET QUESTIONS

- **How do the tablet questions affect children's storytelling?**
  Rationale: the implementation of the questions resulted in a change in the tablet interaction compared to the previous study. The questions might result in a different way of storytelling.

QUALITY STORIES

- **How well do children include narrative elements into their stories?**
  Rationale: the more children include narrative elements into their stories, the higher the quality of their stories (as described in 2.3 Narrative Elements & Story Assessment). In addition, the better the narrative elements are connected, the higher the quality.

8.3 Procedure

The final study tested again both conditions: condition NE, the condition without robot emotions, and condition E, the condition including robot emotions. The procedure of the study was largely equal to the procedure in the second study (7.3 Procedure). The only small difference took place during the exploration phase of the tablet application.

EXPLORATION TABLET INTERACTION

The only small difference compared to the other study is the researcher selecting the correct exploration mode before providing the children with the tablet. After the exploration phase, the researcher reloaded the application and selected the correct play mode.

8.4 Sampling Method

The sampling procedure used was the same as the procedure during the first and second study (see 7.4 Sampling Method). Like in the second study, subjects were children that were in the third and fourth grade of a Dutch elementary school, resulting in the age of the participants ranging from six to eight years. The school, however, was a different school than the school that participated in the second study.

Box 8.2 Interview question final study

8.5 Measurements

OBSERVATIONS

Observations were performed in a similar way as in the second study (described in 7.5 Measurements). The selections on the tablet and the content of the stories told by the children around the selections were observed. In addition, noteworthy aspects concerning the newly added questions were noted.

Quality of the Stories

Based on the selections on the tablet and the story told around them, the stories were analysed. First, the quality of the story grammar was rated. The Index of Narrative Complexity (INC) created by *Petersen, Gillam & Gillam (2008)* as explained in 2.3 Narrative Elements & Story Assessment was used as a guideline. Since stories told by the children in the previous study (7.6 Results) only consisted of actions/attempts and internal responses and the prototype did not change drastically compared to the prototype of the second study, it was expected the stories of the children in this study would contain similar narrative elements. Therefore, the stories of this study were not rated for the other narrative elements of the INC. Stories were only judged on the quality of reasoning for the occurrence of actions and the presence of emotions. Due to the presence and absence of emotions, the corresponding reasoning was different between the E and NE condition. Using the scoring instructions for the internal response category of the INC for both conditions would have resulted in an unfair situation. Children in the NE condition would always at least have received one point, since the system already provided them with an emotion. Thus, "one overt statement about a character's psychological state not causally related to an event or problem" would always present. Therefore, the reasons were scored according to their added value to the content that was

1.

What do you think of creating a story?

Rationale: this question was asked to see how children perceive the storytelling task. If children perceive it either as too challenging or too easy, the task might not optimally promote children's development. Again, the Smileyometer was used (Figure 7.5). The following words were placed underneath the smilies: very difficult, difficult, neutral, easy, very easy.

2.

Could you shortly explain to me what your story was about?

Rationale: this question was asked for similar reasons as described in Box 7.2.

3.

How did the robot feel in the story? How did you notice?

Rationale: this question was asked for similar reasons as described in Box 7.2.

4.

What do you think of the questions to be answered on the tablet? [Helpfulness]

Rationale: this question was asked to see how children think the questions contribute to the creation of a coherent story. If children do not perceive the questions as helpful, they might not be motivated to answer them seriously. The Smileyometer was used with underneath: very unhelpful, unhelpful, neutral, helpful, very helpful.

5.

What do you think of the questions to be answered on the tablet? [Difficulty]

Rationale: again, this question was asked to see how children perceive the tablet questions. If children think answering the questions is either too challenging or too easy, the questions might not optimally promote children's storytelling. The Smileyometer was used. The following words were placed underneath the smilies: very difficult, difficult, neutral, easy, very easy.

already provided. The scoring instructions can be seen in Table 8.1. In addition to the calculations of the story grammar scores, a qualitative analysis on the content of the stories was performed. The actual content of the reasons children came up with for the occurrences of the actions and emotions were compared over the conditions.

INTERVIEWS

The interviews were also performed in a similar way as in the second study (described in 7.5 Measurements). Questions asked during the interview can be seen in Box 8.2.

8.6 Results

PARTICIPANTS

The user study was performed with children that were in the third and fourth grade of a Dutch elementary school. In total 30 children (n = 30) participated. The children were spread over fifteen trials, eight for the NE condition (n = 16) and seven (n = 14) for the E condition. The ages of the children ranged from six to eight years. Exactly half of the children were female and the other half were male. Children were spread over the conditions, such that children with the same age were similarly distributed over the two conditions. This approach resulted in the gender of the children not being equally spread over the conditions. Eleven females and five males performed in the E condition and four females and ten males in the NE condition. Three duos were mixed-gender. As described in the second study (8.7 Discussion), boys tend to have different expectations of the robot's characteristics than girls. Boys may like playing in the E condition more compared to girls, since boys tend to have a stronger preference for the robot behaviour in condition E than girls. Therefore, the unequal distribution of the gender over the conditions might have influenced the results. However, due to this unequal distribution influence of the gender on children's storytelling cannot be tested.

OBSERVATIONS

Selections Tablet

The results in Table A13 and Table A14 show how often children selected certain actions, characters, objects and locations. The action most often selected was "goes to" *[trial NE3-a1, NE4-a2, NE5-a1, NE8-a1, E1-a2, E2-a1, E3-a1, E6-a1]*. The actions "finds" *[trial NE1-a1, NE2-a3, NE7-a1, NE8-a2, E2-a2, E6-a2]*, "buys" *[trial NE1-a2, NE5-a3, E4-a1, E5-a1, E5-a2, E7-a1]* and "brings" *[trial NE2-a1, NE5-a2, E1-a1, E3-a3, E4-a2, E6-a3]* were all selected six times. The rest of the actions in order from most frequently chosen to less frequently chosen are: "meets" *[NE6-a1, E1-a3, E3-a2, E4-a3, E5-a3]*, "talks to" *[trial NE3-a3, NE4-a3, NE6-a2, NE6-a3, E7-a2]*, "gives" *[trial NE2-a2, NE3-a2, E7-a3]*, "makes" *[trial NE4-a1, NE7-a2]* and "receives" *[trial NE1-a3, E2-a3]*. What can be seen is that all actions are used by the children. An overview of the relative frequencies of the action selections per condition can be seen in Figure 8.1. The graphs do not show any large difference between the two conditions.

For the object selections the order of frequency of selection was: the suit *[trial NE2-a3,NE4-a1, NE8-a2, E1-a1, E3-a3, E4-a1, E5-a2, E7-a3]*, the rocket *[trial NE1-a1, NE5-a3, NE7-a2, E5-a1, E6-a3, E7-a1]*, the present *[trial NE1-a3, NE3-a2, NE7-a1, E2-a2]*, the telescope *[trial NE1-a1,NE5-a2, E2-a3]*, the food and drink *[trial NE2-a2, E4-a2]*, the map *[trial E6-a2]* and the shield *[trial NE2-a1]*. The plant, water drop and tools were not selected. An overview of the relative frequencies of the object selections per condition can be seen in Figure 8.2. For most of the objects, the graphs do not show large differences. An observation that might be interesting is that children selected the suit relatively more in the E condition than in the NE condition.

For the character selections the order of frequency of selection was: the dog *[trial NE3-a2, NE4-a3, NE6-a2, E1-a3, E7-a2]*, the woman *[trial NE3-a3, NE6-a3, E3-a2]*, the alien *[trial NE6-a1, E4-a3, E7-a3]*, the astronaut *[trial E2-a3, E5-a3]* and the man *[trial NE1-a3]*. The child was not used at all.

Lastly, the locations most often selected were the South Pole *[trial E2-a1, E3-a1, E6-a1]* and the planet *[trial NE3-a1, NE4-a2, NE8-a1]*. Europe *[trial E1-a2]* and Madagascar *[NE5-a1]* were only selected once. The children did not select Africa in any of the trials.

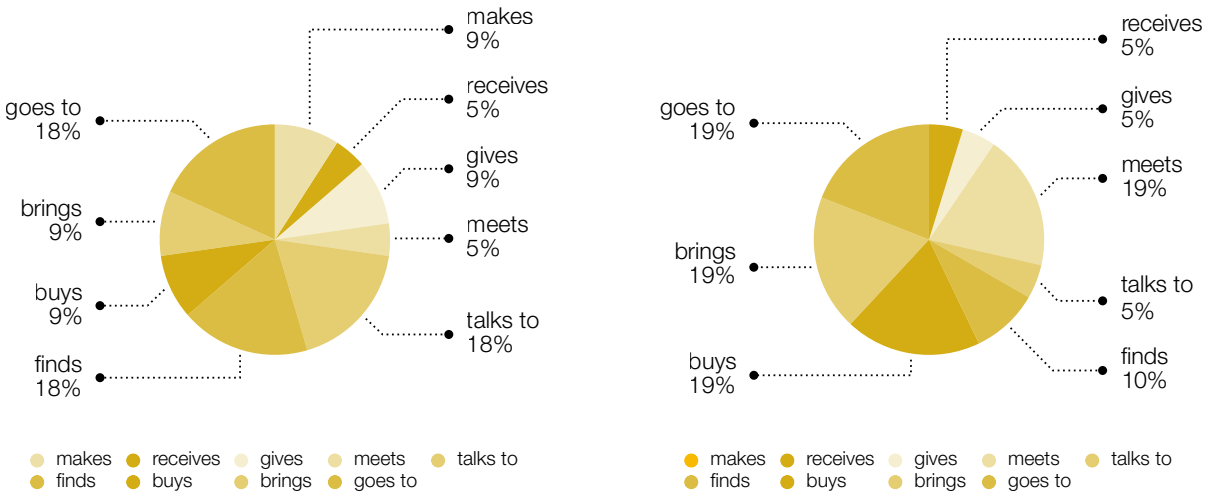


Figure 8.1 Relative frequency action selections for both conditions. Left: NE condition, right: E condition.

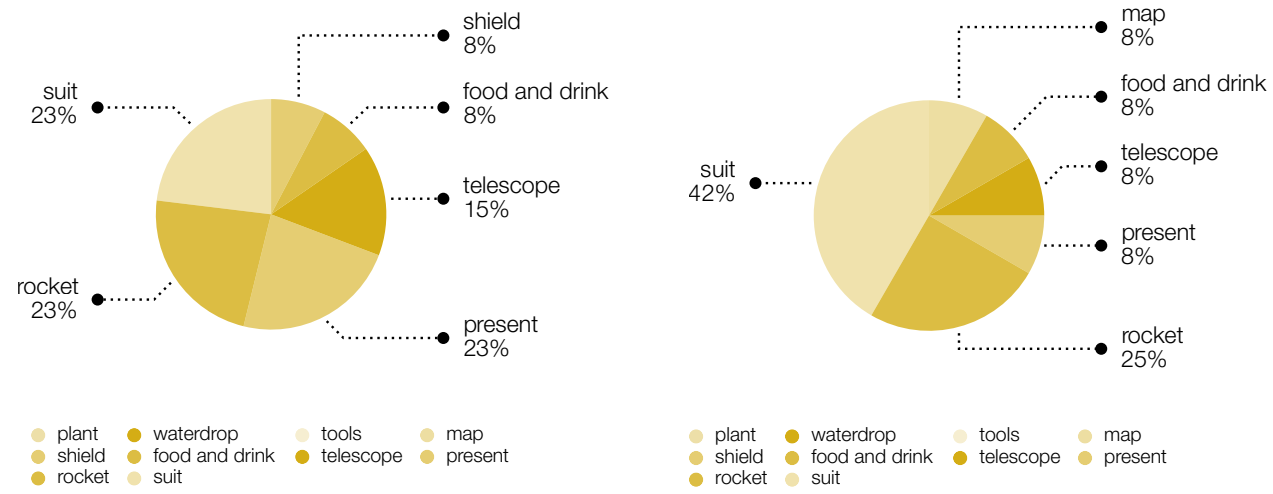


Figure 8.2 Relative frequency object selections for both conditions. Left: NE condition, right: E condition.

	0 POINTS	1 POINTS	2 POINTS
Action reasoning	No causal relation between reason and action	Local causal relation between reason and action (i.e. global goal robot not taken into account)	Global causal relation between reason and action (i.e. global goal robot taken into account)
Emotion reasoning [NE condition]	No emotion given	Either an emotion or a reason is given (no distinction local or global reasoning)	An emotion with a reason is given (no distinction local or global reasoning)
Emotion reasoning [E condition]	Only an emotion is given	Local causal relation between reason and emotion (i.e. global goal robot not taken into account)	Global causal relation between reason and emotion (i.e. global goal robot taken into account)

Table 8.1 Annotation instructions story grammar. The action reasoning scoring instructions are the same for both conditions, the emotion reasoning scoring instructions differ per condition.

	CONDITION NE		CONDITION E	
	M	**SD**	**M**	**SD**
Total score	6.00	2.68	7.00	2.94
Total score actions	2.67	1.37	3.57	1.99
Total score emotions	3.33	1.37	3.43	1.27

Table 8.2 Means and standard deviations for the total story grammar scores per condition.

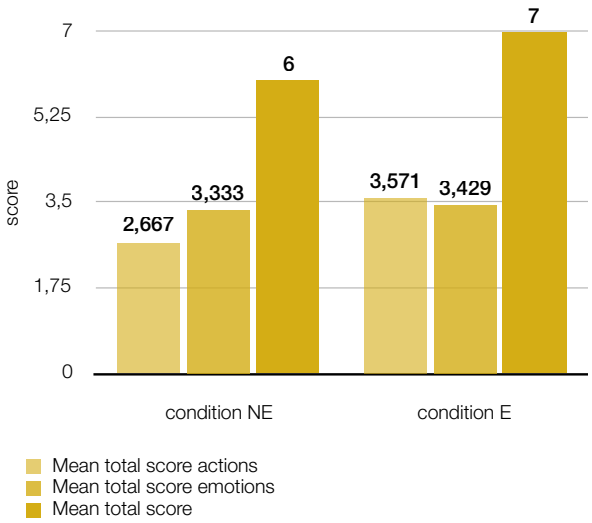


Figure 8.3 Means and standard deviations for the total story grammar scores per condition.

STORY ELEMENT	NE4	SCORE	E4	SCORE
Action 1	Makes [suit]		Buys [suit]	
Reason Action 1 (a1)	"Omdat hij naar de maan wil". *"Because he wants to go to the moon".*	*2*	"Niet ademen op de maan". *"Not breathing on the moon".*	*2*
Emotion	**n.a.**		Sad	
Reason Emotion 1 (e1)	"Hij voelt zich blij". *"He feels happy".*	*1*	"Dat hij niet in de raket wilt". *"That he does not want to go into the rocket".*	*2*
Action 2	Goes to [planet]		Brings [food and drink]	
Reason Action 2 (a2)	"Om aliens te ontmoeten". *"To meet aliens".*	*1*	"Anders heb je geen eten in de raket en dat moet wel". *"Otherwise you do not have any food in the rocket and you must have".* [to go to the moon]	*2*
Emotion	n.a.		Sad	
Reason Emotion 2 (e2)	"Blij". *"Happy".* --> Too short: "Blij, hij kan Nederland zien". *"Happy, he can see the Netherlands".*	*2*	"Hij wil geen eten". *"He does not want food".*	*1*
Action 3	Talks to [dog]		Meets [alien]	
Reason Action3 (a3)	"Woef zeggen". *"Saying woof".*	*0*	"Maan". "Moon". --> Too short: "Maan, raket, eten en ruimtepak". *"Moon, rocket, food and space suit".*	*0*
Emotion	n.a.		Sad	
Reason Emotion 3 (e3)	"Samen adopteren". *"Adopt together".*	*0*	"Omdat er is geen ruimtemannet-je". *"Because there is no little space man".*	*1*

Table 8.3 Examples of the build-up of the story grammar score for NE4 and E4 based on the story elements selected and answers typed in by the children. The complete overview can be seen in Table A13, Table A14 and Table A15.

Story Grammar Scores

Based on the tablet selections and reasoning (Table A13), the quality of the stories of the children was rated. To be able to compare the trials, *trial NE7* and *NE8* were not taken into account, since these stories only consisted of two action sequences instead of three. In the first round, all stories were annotated by two annotators. The annotation instructions can be seen in Table 8.1. Disagreements were identified and discussed leading to a refinement of the original annotation instructions. The annotators agreed upon scoring a reason for global coherence if any reference to the moon was included. Based on the updated definition of global coherence reasoning, both annotators revised their annotations, leading to a substantial inter-annotator agreement (Cohen's Weighted Kappa of 0.67). Finally, differences between the annotators were resolved by discussion. For the NE condition the results are given in Table A13 and for the E condition the results are given in Table A14.

As an example the build-up of the story grammar score for *trial NE4* (see Table 8.3) is as follows: action reasoning a1 contains a reference to the robot's goal ("wants to go to the moon"), which is a global reasoning (2 points). The emotion reasoning e1 contains an emotion ("happy"), but no reasoning (1 point). a2 contains a local reasoning ("to meet aliens"), but no reference to the robot' goal (1 point). e2 contains both an emotion ("happy") and a reason ("to see the Netherlands") (2 points). a3 does not contain any reason (0 points) and e3 does not contain any emotion (0 points), resulting in a total score of the story of 6 points.

For *trial E4* the score build-up (see Table 8.3) is as follows: a1 contains a global reasoning ("...on the moon") (2 points). e1 contains a reference to an emotion ("does not want") and a reason ("to go into the rocket") (2 points). a2 contains a reasoning referring to the robot's goal ("...and you must have") (2 points) and e2 only contains a reference to an emotion ("he does not want") (1 point). a3 does not provide any reasoning (0 points) and e3 only contains a local reasoning ("because there is not little space man") (0 points). The total score for this story is 8 points.

What can be seen from the results is that the differences in the scores between the trials are quite large: the total score ranged between two and eleven points. This large variation can also be seen from the high standard deviations in Table 8.2 and Figure 8.3. For all total scores, the results of both conditions are relatively similar. Although means are higher for the E condition, also the standard deviations are often higher. Given the similarity in means and high standard deviations, it is decided not to pursue a further quantitative analysis of the data, since too little differences between the conditions can be observed. Instead, a qualitative analysis of the video data is performed and described in the next section.

Reasoning Actions

The results in Table A14 include the reasons children came up with for why a certain action was part of the story. Below the reasons, receiving at least 1 point, are discussed. Independent of which action was selected, children often argued the action took place because the robot liked it or wanted it to happen *[trial NE1-a2, NE1- a3, NE3-a3, NE7-a1, E2-a1, E7-a3].* Another reason children came up with more often was the robot wanting to go to or the robot needing to go to the moon. This applied for actions concerning the suit *[trial NE4-a1, E3-a3*], but also for actions using the rocket *[trial NE5-a3, NE7-a2, E5-a1, E6-a3]* and the map *[trial E6-a2].*

An object that often received a similar reasoning for being used in the story was the suit. Children often mentioned the robot needed the suit to be able to breathe *[trial NE8-a2, E1-a1, E4-a1, E5-a2].* The rest of the reasons for the objects largely varied. Some reasons directly related to the standard functionality of an object, such as: the rocket, to go flying *[trial NE1-a1]*; the telescope, to look at the stars *[trial NE5-a2]* and to look far with *[trial E2-a3].* Reasons less directly connected to the functionality of the object were: the shield, for the sun *[trial NE2- a1]*, and the food and drink, since the alien wants to eat humans *[trial NE2-a2].*

A reason mentioned more often for the robot meeting or talking with a character was the robot thinking the character was sweet. This was the case for the dog *[trial NE6-a2]* and the woman *[trial NE6-a3, E3-a2].* Other reasons children came up with were: the astronaut, because it knows how to steer the ship *[trial E5-a3]*; the dog, because it searches for its owner *[trial E1-a3]* and because someone loves dogs *[trial NE3-a2].*

Children mentioned the robot meeting friends as a reason to go to a specific location, which was the case for Europe *[trial E1-a2]* and the South Pole *[trial E6-a1].* Other reasons for going to a location were: the planet, to meet aliens *[trial NE4-a2]* and to see a rocket *[trial NE8-a1]*; Madagascar, because it is nice weather over there *[trial NE5-a1];* and the South Pole, because the robot could not go to the moon yet *[trial E3-a1*].

Reasoning Emotions

Also these results can be seen in Table A14. Below the reasons for the feelings of the robot, receiving at least 1 point, are discussed.

In most of the trials in the NE condition the children solely described the robot's feeling as similar to happy *[trial NE1-e1, NE1-e2, NE1-e3, NE2-e1, NE2-e2, NE2-e3, NE4-e1, NE4-e2, NE6-e1, NE6-e2, NE6-e3, R7-e1, NE7-e2]*. Some children specifically included a reason for the robot being happy: it is nice at the planet *[trial NE3-e1]*, it can see the Netherlands *[trial NE4-e2]*, it got there *[trial NE5-e1]*, it has sufficient money *[trial NE5-a3]*, it sees a rocket *[trial NE8-e1]* and it is at the moon *[trial NE8-e2]*. Only in one trial the children mentioned the robot not being happy, because it missed its mum *[trial NE5-e2]*.

For the E condition, the robot's emotions varied. The reasons the robot was happy were: because it finally found someone *[trial E1-e3]*, because it sees the flags *[trial E2-e2]*, because it thinks: "Oh I have a present" *[trial E2-e2]* and "Oh is that mine?" *[trial E2-e3]*, because it is warm over there *[trial E2-e1]* and because it is afraid to go alone *[trial E7-e3]*. It only happened once that the robot was surprised. The reason children came up with to support this emotion was: because it wants to *[trial E1-e1]*.

Reasons for the fear emotion mostly were logically connected to the fear emotion: the robot is alone *[trial E1-e2]*, it does not know her *[trial E3-e2]* and it is afraid it will go into the fire *[trial E6-e3]*.

However, the proposed reasons for the angry and sad emotion were quite similar. The reasons often included "he doesn't want" or "he can't". For the angry emotion the reasons were: it cannot yet *[trial E5-e1]*, it does not want to wear a suit *[trial E5-e2]* and it does not want to go into the rocket *[trial HE7-e1]*. For the sad emotion the arguments were: it does not want to go to the moon *[trial E3-e3]*, it does not want to go into the rocket [*trial E4-e1]* and it does not want food *[trial E4-e2]*.

A last reason given for the angry emotion was: it did not see any human *[trial E5-e3]*. For the sad emotion the other reasons given were: there is not a little space man *[trial E4-e3]* and two reasons specifically referring to the robot's end goal: we brought it to the wrong place *[trial E6-e1]* and it is not at the moon yet *[trial E7-e2]*.

Remarks Questioning

These observations can be seen in Table A16. In both conditions many children had problems with spelling and asked how to write certain words *[trial NE2, NE3, NE4, NE5, NE6, E2, E5]*. Often, either the other child or the researcher dictated how to write the word. On the one hand, children helped each other with spelling *[trial NE3, NE4, NE5, E1, E2, E3, E4, E5, E6, E7]*. They, for example, dictated each other *[trial NE5, E3, E4]* or pointed at the correct letter on the tablet *[trial E2, E3]*. On the other hand, the children sometimes clearly mentioned the other child being wrong *[trial NE1, NE3, NE4, NE5, NE8, E1, E3, E4, E5, E6, E7]*. Some of the children criticising the other child's language skills asked if they should take over the typing *[trial NE3, NE4]*, to which the other child responded by either giving away the tablet *[trial NE4]* or by telling she could manage herself *[trial NE3]*.

In addition, many children had difficulties with immediately coming up with answers on the "why-questions". They often said they did not know the answer *[trial NE3, NE4, E3, E6]*. Also, other observations indicate they had difficulties with answering the questions *[trial NE4, NE5, NE6, E1, E3, E6]*. There are no indications that children had more difficulties with answering the questions in one of the two conditions. In *trial E5* the children specifically indicated they really did not understand why the robot was angry. Some children were a bit uncertain if the reasons they came up with were okay. They sometimes sought for approval of the researcher *[trial NE1, NE2]*. On the contrary, some children already came up with what the robot needed to do to go to the moon before clicking the start button. They suggested using a rocket *[trial NE1]*, driving *[trial NE2]*, making a ship *[trial NE4]* and doing exercises *[trial NE4]*.

Some children got more and more irritated by constantly having to answer the questions *[trial NE4, NE5, NE7]*. Also, the children that were typing were sometimes distracted and had to be reminded by the researcher they had to finish up the typing *[trial NE1, E4]*. In some cases the researcher typed the reason into the tablet, since the children had difficulties with typing *[trial NE6, NE8, E4*].

Some final observations consist of a child mentioning aloud he was impressed by the reason the other child came up with *[trial NE4]* and another child laughing about what she had came up with herself *[trial NE5]*. In *trial E6* a child specifically mentioned the need to come up with something logical in order to go to the moon. In *trial E4* a child said: "I know now!". This exclamation might indicate he saw the storytelling task as a exercise to be solved.

In some of the trials children nicely collaborated in coming up with the reasons. The person that came up with a reason typed it in on the tablet *[trial NE1]* or reasons were created in turns *[trial E6]*. Others typed sentences collaboratively *[trial E1, E4, E7]*. However, in some trials mainly one of the two children came up with the reasons and typed them *[trial NE2, NE4, NE5, NE7]*. In addition, it seemed that children shifted the responsibility for coming up with a reason to the other child when they did not have a clue themselves *[trial NE3, NE5, NE6, NE7, NE8, E3, E4, E6]*. The shifting might also have to do with them not liking to type. On the contrary, the children also argued about who's turn it was next, indicating children wanting to perform the reasoning or typing themselves *[trial NE3, NE6, NE8, E3, E4, E6]*.

Other Remarks

These observations can be seen in Table A16. When one child was typing on the tablet, the other child did not always have something to do. Some children calmly waited until the other child finished typing *[trial NE6, NE7, NE8]*, whereas others were impatient and started playing with the objects on the table *[trial NE7, E5]*, started looking *[trial NE1, NE2]* or even walked around *[trial NE6]*. Besides, children often argued about who could perform the next action. In general they often mentioned statements, such as: "May I?" and "It is my turn" *[trial NE6]*. Also, they specifically used the statements for reading *[trial NE2, NE6]*, the placement of object blocks and figures in front of Cozmo *[trial NE2, NE6]* and the selection on tablet *[trial NE3, E3]*.

The following results largely agree with the results of the second study (7.6 Results). Children often referred to the characteristics of the robot by asking if the robot could or why the robot could not talk *[trial NE1, NE5]*, drive *[trial NE2, NE3, NE4, NE5, NE6, NE7, E4]*, laugh *[trial NE6]* and move its arms *[trial NE1, NE6]*. Or in more general: "Why doesn't he do anything?" *[trial NE8]*. Again, some children got really irritated the robot did not meet their expectations. In *trial NE2* a boy asked at least five times why the robot did not move. Also, some children referred to the robot's eyes *[trial NE1, NE3, NE7, NE8]*. Other remarks by the children concerning the robot were: "He is cute" *[trial NE2, E4]* and "Is he a boy?" *[trial NE6]*. Others stroked the robot *[trial NE6, e3]* or talked to the robot *[trial NE6, trial E4]*. What can be noted is that the questions and remarks concerning the robot's characteristics mainly occurred in the NE condition. Although the robot was also not able to talk and drive distances in the E condition, the absence of these characteristics was apparently not worth mentioning in this condition.

In the NE condition children often reacted to the content of the thought screen on the tablet similar to the children in the second study. They mentioned things, such as "He saw him" *[trial NE6, NE4]* and "He got him" *[trial NE5]*. Also, some talked to Cozmo by asking: "Yes, what?" *[trial NE5]*. Others explained what they saw on the screen: "the little rocket" *[trial NE4]* or, when providing the robot with the present, explained that it already knew what was in it *[trial NE3]*. On the contrary, in the E condition children did not respond to the thought screen of the tablet, they were focused on the behaviour of the robot. They either smiled *[trial E1, E7]* or laughed *[trial E2, E3, E5]* when the robot performed an animation. Also, they explained it liked/did not like something *[trial E3]* or explicitly mentioned its emotion *[trial E1, E4, E5, E7]*. In *trial E2* they mentioned what they thought the robot was thinking: "oh". In other trials children indicated they did not understand its behaviour. They used the word "huh" in *trial E4, E6* and asked why the robot did not want anything after it reacted angry three times in a row in *trial E5*.

Also, like in the second study, children often immediately selected the "goes to" action, since they expected to be able to bring the robot to the moon when selecting this action *[trial NE4, NE8, E2, E3, E6]*. In addition, in two trials children explicitly mentioned they liked the activity *[trial NE1, E6]*. In one trial children thought they had to move the virtual object block over the line on the tablet *[trial NE2]*.

Another observation is that children explicitly mentioned they already used certain object blocks and figures as if they introduced a new rule they cannot use them twice, or they do not like using them twice *[trial NE5, NE6,EH6]*. Although they do not specifically mention, children in the other trials also tended to use only object blocks and figures they did not use before. This preference can be caused by the children being most interested in exploring the robot responses. Therefore, they mainly explored the response of the robot on every element possible, before re-using elements.

In two trials children did not understand how Cozmo travelled to a certain location, they mentioned: "But how do we place him on the planet then?" *[trial NE4]* and "How does he get to the moon then?" *[trial E3]*.

INTERVIEWS

The results of the interviews can be seen in Table A17 and Table A18.

Difficulty Creation Story

For the question how the children perceived the storytelling task, most (seven and four respectively) selected the "very easy" *[trial NE1, NE2, NE5, NE7]* and "easy" smiley *[trial NE3, NE4, NE7, NE8]* in the NE condition. Two children selected the "neutral "smiley *[trial NE3, NE6]* and only one child selected the "very difficult" smiley *[trial NE6]*. In the E condition even more children (eleven) selected the "very easy" smiley *[trial E1, E2,HE3, E4, E5, E7]*. Two selected the "easy" smiley *[trial E5, E6]* and just one child selected the "neutral" smiley *[trial E6]*.

Story Summary

In the NE condition children often referred to the moon in their story summary *[trial NE1, NE7, NE8]*, some children specifically mentioned the robot (wanting) to go to the moon *[trial NE3, NE5, NE6]*.

The rest of their summaries mostly consisted of just a list of individual story elements *[trial NE2, NE3, NE4, NE5, NE6]*. Children did not include any causal relations. Some children explained the story by talking about the robot in third person *[trial NE1, NE3, NE6]*. Others hardly referred to the robot *[trial NE4, NE5]*. In just one trial *[NE2]* the children did not answer the question. What can also be seen from the results is that in none of the trials in the NE condition children mention emotions in their story summary.

In all trials of the E condition the children not only talked about the moon, but also mentioned the robot (wanting) to go to the moon. Also, all summaries were explained by talking about the robot in third person. Different from in the NE condition, some children did include causal connections. Children in *E4* referred to the robot using the rocket to go to the moon. In *E5* the children mentioned the robot going to the shop to buy a rocket and suit, the robot meeting a man, since he could help to go to the moon and the robot using the ship to go the moon. Different from the NE condition, some children included emotions in the summary *[trial E3, E5]*. In both trials even a relationship between the cause and the emotion was mentioned. In *trial E3* the robot was happy because it was at moon and in *trial E*5 the robot was angry because it met a man.

Feelings Robot

Like in the second study (see 7.6 Results), all children in the NE condition described the robot's emotion as similar to happy. The reason for the robot being happy most often was again the robot wanting to go to the moon and finally ending up there *[trial NE3, NE6, NE8]*. Other reasons given for its emotion were it never had been to space before *[trial NE4]* and the robot liking to watch the blocks *[trial NE7]*. In one trial children referred to the robot's eyes *[trial NE2]*. Only one group *[trial NE5]* came up with a different emotion than happiness. The children in this trial explained the robot also felt sad, because it missed its mum. Also, they explained it was happy because it liked the stuff it had.

Different from the NE condition, only in one trial in the E condition children mentioned the robot being happy because it ended up at the moon [*trial E1]*. Others did describe the robot's feeling as happy, but connected the emotion with a character *[E1, E7]*. In *trial E2* children also thought it was happy, but they could not explain why. In *trial E3* children explained the robot being sad and anxious, referring to a specific character. In *trial E7* children also connected the emotions to the characters (angry at the dog, happy by the astronaut), but also to an object (afraid of the rocket). In *trial* E6 the children mentioned sadness, however, they only explained the emotion was shown on the tablet. Finally, in *trial E5* children mentioned the robot being angry without given a reason.

Help Questions

For the question how the children thought the "why-questions" helped them in creating a story seven children selected the "very helpful" smiley *[trial NE1, NE2, NE5, NE7, NE8]* in the NE condition, followed by four children that selected the "helpful" smiley *[trial NE4, NE5, NE8]*. In addition, two children selected the "neutral" smiley *[trial NE3, NE7]*, one child the "very bad" smiley *[trial NE3]* and two children did not answer the question *[trial NE6]*. For the E condition more children (ten) selected the "very helpful" smiley *[E1, E2, E4, E5, E6]*. However, just one child selected the "helpful" smiley *[trial NE7]*. Lastly, one child selected the "bad" smiley *[trial NE7]* and two children the "very bad" smiley *[trial NE3]*.

Difficulty Questions

In the NE condition the children rated the difficulty of answering the "why-questions" often (eight and four times respectively) as "very easy" *[trial NE1, NE2, NE5, NE7, NE8]* and "easy" *[trial NE1, NE3, NE4]*. Also, they selected the "neutral" *[trial NE5]* and "difficult" smiley once *[trial NE3]* and the "very difficult" smiley twice *[trial NE6]*. For the E condition less children selected the "very easy" smiley, namely six *[trial E2, E3, E4, E5]*. Three children selected the "easy" smiley *[trial E4, E5, E6]*, four the "neutral" smiley *[trial E1, E6, E7]* and just one the "difficult" smiley *[trial E7]*.

8.7 Discussion

TABLET QUESTIONS

The questions on the tablet added a whole new dimension to the storytelling activity. What can be seen from the results is that many children had difficulties with spelling and typing. Although it was not expected they would type flawlessly, it seemed the children felt they were judged on their language and typing skills. The feeling of judgment might also be the reason why children often corrected each other; the children correcting might wanted to show that théy knew how to spell. Some children might not have felt comfortable with answering the questions, since they felt insecure about their spelling and typing skills. Consequently, the questions on the tablet could have had a negative effect on children's storytelling. Such a negative effect is not desirable, the prototype should in the first place focus on the storytelling process itself.

Children often shifted the responsibility for answering the questions to the other child. Although the shifting can be caused by the children's doubts around their spelling or typing skills as explained above, they could actually have had difficulties with answering the questions. On the other hand, similar to their feelings around the spelling and typing task, children might have had the feeling they were judged on the quality of the reasons they came up with and, thus, have been cautious with answering.

Also, some children got annoyed by the repetitive cycle of questions. The cycle of questions could have negatively affected their motivation to tell a story. The effect was more present in the NE condition than in the E condition, which could have been caused by the lack of motivational triggers due to the absence of robot behaviour in the NE condition. Children liked exploring the robot behaviour. The ability to explore the robot behaviour could have been a motivational trigger to answer the questions. What can also be seen is that in the NE condition more often only one of the two children mainly came up with reasons. This could again have to do with the limited amount of motivational triggers.

Answering the questions took a lot of the playing time. Therefore, little time was left to explore the robot's responses, which could have resulted in children enjoying the activity less compared to the second study. Almost all stories told by the children only consisted of three actions. After the third action they could finish the story by bringing the robot to the moon. At this point, the children's curiosity about the robot's response when being at the moon could have been larger than their motivation to continue their story. This could have been caused by the little time to explore the robot's responses during play due to the questions as described above. The right balance between answering questions and exploring the robot's responses has to be found. A better balance between the two can also ensure the children are more focused and concentrated on the activity.

When looking at the children's opinion about the helpfulness of the questions for storytelling a large skew towards the most positive answer can be seen. This skew is in line with research by *Read & MacFarlane (2006)* as already explained in 7.7 Discussion. According to them, the Smileyometer is not very useful for young children. For children younger than ten years old the variability of the responses with the use of a Smileyometer is very low, since these children tend to choose the highest (most positive) score. Therefore, the answers might not be that reliable. However, it could also actually be the case children thought the questions helped them in creating a story. Although this would be contradictory to the observation that some children got annoyed by the repetitive cycle of questions as explained before.

A similar skew can be seen for the children's opinion on the difficulty level of the storytelling task and the difficulty of answering the questions in particular. The skew can be seen for both conditions. The opinion of the children was in large contrast with the observations. Observations actually showed many children did have difficulties in answers the questions. During the interview, children could have had the feeling they would be judged if they found the questions difficult to answer, which could have been the reason for the skew.

QUALITY STORIES

What can be seen from the results is that the story grammar scores largely varied across the different trials. The same observation can be seen in both conditions. Therefore, using this

setup, no influence of the presence of the robot behaviour on the children's reasoning can be seen. It is assumed that differences between the trials are caused by individual characteristics of the children participating in the trials. Children in trials gaining a larger story grammar score could actually be more creative, but also have better concentration, language or collaboration skills. In a next study individual differences between children could be tested upfront by letting the children perform in a "normal" storytelling task independent of the system. The story grammar scores of the stories told with the system could be normalised for the story grammar scores for the stories told in the "normal" storytelling task. This way, an indication of relative storytelling performance of the children in the storytelling task with the system with respect to the "normal" storytelling task is gained.

When looking at the content of the reasons concerning the actions, it can be seen that children often came up with still quite superficial actions, such as the robot liking something or they only repeated the robot's end goal. Furthermore, they used many standard associations for objects. They did not come up with very creative solutions. The lack of creative solutions might indicate children did not try to come up with creative answers, since they were not explicitly asked or that they perceived the activity as a game in which they had to fulfil a goal-directed task: bringing the robot to the moon. Also, it could indicate that the children found it difficult to come up with creative reasons. This might also be the reason the less concrete objects were not used that much. Children especially had difficulties with coming up with reasons why the robot should meet or talk to certain characters.

When looking at the reasons concerning the robot's emotions it can be seen that differences exist between the two conditions. In the NE condition, children had to come up with their own emotions, resulting in that in all trials, except one, the children described the robot's feeling as happy. These results agree with the answers of the children on the question how they thought the robot felt in their story. Apparently children tend to have a preference for the happy emotion. This preference might be caused by the children perceiving the activity as a puzzle or game in which they have to fulfil a goal-directed task; bringing the robot to the moon. Therefore, the children did not see the need (or not even thought) of including conflicts and negative emotions, since these prevent the robot from reaching it's goal. Successful goal-oriented actions would always make the robot happy. In the E condition children used much more varying emotions, indicating they recognised the emotions given by the prototype. The answers on the question how they thought the robot felt in their story confirm that the children recognised multiple emotions, and, besides, indicate they were also able to remember them. Consequently, the reasons in the E condition were different from the NE condition. Whereas in the NE condition children only came up with the robot wanting to go to the moon and being at the moon as a reason to be happy, they barely mention this argument in the E condition. In the E condition the children connected the robot's emotion to individual actions, characters, objects and locations. Though, this difference in reasoning could also be caused by the design of the system in which the "why-questions" asked differ amongst the conditions. The "why-question" in the NE condition solely asks for an explanation of the emotion, whereas the question in the E condition asks for a reason for the occurrence of an emotion and it is, therefore, more likely answers on this question include causal reasoning. Due to occurrence of also negative emotions, children sometimes had to solve a conflict. The actual emotion of the robot did not match the emotion the children expected. As an example, in *trial H5* children said the robot bought a suit, since it could not breath without. Therefore, the children expected the robot to react positively, but it became angry. They solved the conflict by explaining that the robot did not want to wear the suit. The reasons children came up with for the occurrence of the emotion had to solve the conflict between the actual and expected emotion of the robot. These reasons often included "he does not..." or "he does not want...", which was never the case for the NE condition.

What could also be seen is that in the E condition children tended to categorise the robot's emotion as either positive or negative. Whether the robot felt surprised or happy, a difference between

these emotions could not be seen from the reasons; for both emotions the children argued the robot liked what happened. The same applies for the sad and angry emotion; for both emotions the children argued the robot did not like what happened.

A difference between the NE and E condition can also be observed from the story summaries given by the children during the interview. In the NE condition children did not include any emotion in their story summary, whereas they did in a few trials in the E condition. The difference might be caused by the emotion playing a more crucial role in the stories in the E conditions, or the children simply better remembering the emotion due to the corresponding robot behaviour. Secondly, in the E condition the story summaries were more often told from a third person perspective. This might indicate the children in the E condition saw the robot more as a character in their story and, therefore, it takes a more crucial role in the story summary. Also, in two trials in the E condition the story summary included some causal relations between actions in the story, this did not happen in any of the trials in the NE condition.

COLLABORATION

As explained before, children often shifted the responsibility for answering the questions to the other child. This shifting happened in both conditions, but more often in the NE condition. Also, in the NE condition it happened more often that just one of the two children mainly came up with reasons. In addition, in many trials children wanted to perform actions with the tablet, placement of objects and figures and movement of the robot themselves, but this happened more often in the NE condition. Oh the contrary, children performing actions in turn or performing single actions collaboratively occurred more in condition E than in condition NE. What can be seen from these observations is that children tended to be more active in the E condition than in the NE condition. This difference could have been caused by a different amount of motivational triggers thanks to the presence or absence of the robot's emotions.

OTHER

What can be seen from the results is that children most frequently selected the "goes to" action, which matches with the findings in the second study (7.6 Results). They selected this action often as the first action. It is hypothesised this preference is caused by the children expecting they can use this action to bring the robot to the moon, and thereby, fulfil the robot's goal. On the contrary, this preference might also be caused by children expecting the robot to drive, something they are really interested as observations showed.

Although some preferences exist in the actions, the children used all actions in their stories. However, the frequency of occurrence of the actions might have been related to the order of the actions. The frequency of selections largely corresponds with the order of the actions from left top to right bottom. The presence or absence of this effect can simply be tested by changing the order of the actions and counting the frequency of occurrences accordingly.

Children did not use all objects. The children probably did not find all of them relevant. It could also be the case children had more difficulties with making a logical connection between the more abstract objects, the tools, water and plant, and the robot's goal of wanting to go to the moon.
Children brought the robot most often to the planet and the South Pole. This preference might have to do with the planet being most related to the moon and, therefore, chosen by the children. The same could apply for the South Pole, since it is white. On the other hand, an explanation for the selection preference could be that these two locations receive more interest of the children, since they are less standard locations. A similar reason could apply for the children's preference for using the dog. Meeting and having conversations with animals is less realistic. Children could tend to select actions that are not possible in real life. On the other hand, children could just like dogs.

Children often wanted to perform the selection on the tablet or placement of characters or objects in front of the robot themselves. This desire could indicate children especially liked these aspects of the activity. In addition, the behaviour of the robot did not match the expectations of the children. This mismatch is in line with the findings of the second study as discussed in 7.7 Discussion. Also, children again selected the "goes to" action assuming they could use this action to bring the robot to the moon. Finally, their responses on the thought bubble of the robot on the tablet were also in line with the previous study. These observations were expected, since the suggested improvements for these effects (discussed in 7.8 Suggested Improvements) were not yet passed through the prototype.

A final remark: during this study it was observed that children often thought they could only use story elements once, or wanted to use them just once. This effect could have affected their storytelling. This observation was not made during the second study. Presence of the effect during the final study might have been caused by the added "why-questions".

9

This section provides an overview of the implications of the results of the different studies performed in this research. In addition, an overview of the limitations of the research and a new research goal are provided. The section ends with the conclusion of the research.

Results of the different studies are synthesised, TC MORGAN, https://www.flickr.com/photos/tcmorgan/7372944070

Discussion & Conclusion

9.1 Implications Results

The research used a user-centred design approach consisting of three user studies. This section discusses the patterns seen in the results of the studies.

NEW APPROACH

This research investigated a new approach when it comes to interactive storytelling. Existing systems either focus on tangible smart toys or allow children to tell a virtual story in the shape of a "power-point" consisting of several scenes with imagery. The approach in this research combined a tangible smart toy with a virtual world on a tablet. The research raises interesting issues when it comes to design of such a system as explained in the remaining of this document.

CHILDREN LIKE ACTIVITY

What could be seen in all studies is that children liked the activity with the system. Children were mostly focused on the robot. The appreciation of the activity could have been caused by the novelty-effect as explained in 9.2 Limitations.

Although the expected robot's characteristics not always completely matched the actual characteristics of the robot, the children still enjoyed the activity. A few children showed some signs of irritation by the repetitive cycle of "why-questions" that prevented them from exploring the robot behaviour. This irritation could have been affected by them not being used to typing on the tablet. However, in the end, also these children liked the activity.

CHILDREN UNDERSTAND TABLET & EMOTIONS

Although some improvements can still be made, in general, children understood how to tell a story with the tablet application. In addition, they understood the robot's emotions, if present. Throughout the research some changes have been made in the tablet content and emotions, reducing confusion. Children's understanding of the tablet interaction and the robot emotions implies the basis of the system setup fits the children's development stage and can, therefore, be used as a guideline in further development.

COLLABORATION PATTERNS

Children collaborated in different ways. Sometimes they discussed the next actions aloud, directly or indirectly, and sometimes they just pressed buttons on the tablet without using verbal communication. These patterns were present in both conditions. In some duos one of the children mainly performed the actions, whereas the other child merely observed. This type of collaboration was more often present in the NE condition. In other duos children performed actions in turns or performed single actions collaboratively, this way of collaborating was more often observed in the E condition. Individual characteristics and the composition of duos (which was decided upon by the teachers) might have affected the interaction between the children.

The implementation of the questions in the last study changed the dynamics between the children. Children got more often distracted, due to the waiting time. Also, the activity required spelling and typing skills. Therefore, children often shifted the responsibility for answering the questions. The shifting could indicate they did not like this part of the activity or found it difficult. The shifting occurred in both conditions, but more often in condition NE. Throughout all studies children wanted to perform actions with the tablet, placement of objects and figures and movement of the robot themselves, but again this happened more often in the NE condition. What can be seen from these collaboration patterns is that both children tended to be more active in the E condition than in the NE condition. This difference could have been caused by a different amount of motivational triggers thanks to the presence or absence of the robot's emotions.

ACTIVITY & STORYTELLING

According to the definition in 2.1 Storytelling storytelling involves five aspects, namely: the presentation of a story, the presence of interactivity, the use of language, the use of actions and the encouragement of the listeners' active imagination.

Looking at this definition it can be doubted if the current prototype actually triggers storytelling. The first aspect, the presentation of a story, was not present in many stories "told" during the user studies. In 2.2 What is a Story? a story is defined as "a narrative that links a set of events in some kind

of causal sequence". The stories "told" in the user studies contained events, mainly because children were forced to select actions on the tablet. However, only in a few stories these events were linked in a causal sequence. More often the events were stand-alone events of which the order could also have been different. The second aspect, interactivity, is clearly not present in the activity. The activity does not involve an active listener, therefore, a two-way interaction between a teller and listener was not present. Throughout the activity children used language, the third aspect of storytelling. However, it can be doubted if language was used for storytelling. In the final study, children mainly used spoken and written language when answering the "why-questions". In all studies language was used to communicate about what to do and to communicate about the tablet interaction and responses of the robot. The fourth aspect, the use of actions was sometimes present in the stories "told". Some children used vocalisation and talked as if they were the robot. But, the main action used was the physical movement of the robot, figures and object blocks. Although children were forced to change the position of these elements in order to continue, the movement of these elements added to the story by showing the interaction between the different elements and the story world. As explained, the activity did not involve an active listener. Thus, the final aspect, encouragement of the listener's active imagination was also not present. It can be seen that not all storytelling aspects were yet present in the activity with the current prototype. However, the prototype can be adapted to better support storytelling. First of all, listeners can be included. This aspect can be included by involving an audience during the activity or by children retelling or rewriting the stories told. The main challenge is to make children aware they have to tell a story. If so, they have to be stimulated to include more causal relations between the events in the story.

ACTIVITY & PRETEND PLAY

As defined in 2.4 Pretend Play play is "any activity that is engaged in for the purpose of fun, rather than survival". Clearly, the user studies showed that children were having fun during the activity, allowing the activity to be labelled as play. But, can the activity also be labelled as pretend play? The same section defines pretend play as "the projecting of a supposed situation onto an actual one, in the spirit of fun rather than for survival". As explained, the children enjoyed the activity. But did they also project a situation onto what was literally happening? It is suggested this was most often not the case. Children did not always add a layering of mental representation over reality, they mainly played in reality. Although the locations on the play mat were not real, actions fit with what the robot actually did: going to a location (on the play mat) and seeing a character or an object. However, this could be linked to the use of tangible toys and the play mat, increasing the concreteness of the stories told, and, therefore, reducing the need for pretend play. Children mainly added some kind of mental representation when answering the "why-questions". Reasons children then came up with contained elements they were not yet provided with. As an example, children described the robot going to the South Pole to meet animals, however, the animals were not actually there. Also, some children described the robot going to Madagascar, because it likes the nice weather over there, whereas the weather cannot actually be seen.

Also, considering the skills trained during pretend play as described in 2.4 Pretend Play it can be doubted if the activity can be labelled as pretend play. First of all, children not necessarily had to use divergent thinking skills for the activity. But, language skills were often trained. Language skills were mainly trained when answering the system's "why-questions". In addition, children often communicated with each other about the next story actions. However, as described before, collaboration patterns differed. In some cases children barely communicated verbally. Thus, children not necessarily jointly developed narrative abilities. Executive functions were trained during the activity. Children's control over their thoughts, actions and emotions was triggered in situations, such as the robot not behaving as expected or in a conflict with the other child. Social emotional skills were certainly trained. Children had to collaborate and,

therefore, learned to negotiate and cooperate. Also, the design of the system allowed children to train their social understanding. The "why-questions" asked encouraged children to think from the robot's perspective. They had to create mental states. The robot emotions in the E condition strengthened this aspect.

THE ROBOT AS A TOY

The interaction of the children with the robot does not completely fitted the interaction with a toy in pretend play as described in 2.4 Pretend Play. Children barely invested the robot with their images and feelings, especially in the NE condition. In this condition, children only described the robot's emotion as happy. They did not come up with this emotion spontaneously, but were forced to do so by the "why-questions" asked. In the E condition there was no need to invest the robot with feelings, since they were already given. The absence of the investment of feelings can be caused by the activity actually not fitting pretend play as described before. 2.4 Pretend Play also describes that children imbue toys with personalities, resulting in the toys becoming characters. In the NE condition imbuing of personalities barely happened. However, the results of this research indicate that in the E condition children saw the robot as a character, since they often used a third person perspective when retelling the story as described in the previous section.

ACTIVITY AS A GAME

As described before, the activity could be labelled as play. In addition, the activity showed some aspects of storytelling and pretend play, but could not be labelled as either one of the two. Is there any other category the activity might fall into? Most likely, the activity approaches a game. As described by *Merriam-Webster (2017)* "a game is a structured form of play, usually undertaken for enjoyment and sometimes used as an educational tool". Key components of games are goals, rules, challenge, and interaction. The activity fits the definition of a game, since it includes play, enjoyment and has an educational purpose. However, not all key components are present. Although interaction is clearly present, it can be doubted if the activity is challenging. Certainly rules are not implemented. Nevertheless, it seemed some children thought rules were implemented. These children were trying to find out "the rules" by exploring the robot's responses. Therefore, they might have perceived the activity as a game.

Many of these children tended to see the game as a puzzle. *The Cambridge Dictionary (2017)* defines a puzzle as: "a game or toy in which you have to fit separate pieces together, or a problem or question that you have to answer by using your skill or knowledge". On the one hand, children could see the activity as a puzzle, since they were introduced to the robot's demand in the beginning of the activity. On the other hand, children tended to introduce a problem themselves. Many children introduced a task of figuring out how the robot became happy and used the responses of the robot to see if they were on the right track. However, this type of interaction was only present in the E condition, since the robot did not show any emotions in the NE condition.

STORYTELLING IMPROVED, BUT LIMITED

As described before, it can be doubted if the activity involved real storytelling. Although, from the pilot on, children understood they had to tell a story. However, during the pilot there was no need for the children to actually tell a story in order to play with the robot. Therefore, almost no storytelling was present, whereas the amount of storytelling increased during the follow-up studies.

Throughout the research the system's support for storytelling was improved by including a goal for the robot and a selection of actions. The children understood the goal of the robot, which helped them in having a direction for the story. Also, the actions that could be performed with object blocks and figures could guide the children in their stories.

The "why-questions" implemented for the final study increased storytelling a bit more. However, children's storytelling was still limited. The questions resulted in more cause-effect relationships between story elements. However, children had difficulties with answering the questions. The reasons they came up with were mostly locally coherent and not globally coherent (i.e. they did not take the robot's goal into account). On the contrary, sometimes they just repeated the robot's goal. The questions asked could have been too

general, and, therefore, not be optimal to trigger storytelling.

What can be seen is that the system's support for storytelling is still limited. More specific questions and story suggestions could increase the system's support for storytelling as explained in more detail in 10.1 Recommended Improvements Prototype.

POSSIBLE INFLUENCE EMOTIONS

Although quantitative analysis of the story grammar scores of the stories of both conditions did not show any differences in the quality of the stories told, the qualitative analysis indicates some differences. The qualitative analysis showed children in the NE condition mostly used the happy emotion in their story during play, whereas in the E condition the emotions varied. Accordingly, children only mentioned the happy emotion in the NE condition against multiple emotions in the E condition when retelling the story afterwards. The reasons children came up with for the occurrence of the emotions contained more conflicts than in the NE condition. It was expected the reasons in the NE condition contained more conflicts, since the robot showed negative emotions in this condition. In addition, the children in the E condition more often used a third person perspective when retelling the story. Although observations (such as children waving or talking to the robot) throughout the research indicate children see the robot as a character regardless of its emotions, the fact that children retell their stories from a third person perspective indicates they perceived the robot even more as an autonomous character.

CHILDREN'S RESPONSES ON RANDOM EMOTIONS

In the second study, the randomness of the robot emotions did not seem to interest the children that much. Children were often not interested in reusing elements, since they wanted to explore the robot's response on all individual elements. If the children reused an element and the robot showed a different emotion than before, they did not notice the different emotion or just took it for granted. Only a very few children came up with a reason for the different emotion. Since children had to answer the "why-questions" in the final study, they had less time to select actions. Therefore, in this study, children reused elements even less. Thus, the children's responses on different robot emotions for the same element could barely be observed.

The children's responses on the robot showing a different emotion than expected could be observed. Children often selected actions with a reason (in the final study triggered by the "why-questions"), resulting in them expecting a certain emotion. In the second study children noticed when the emotion did not match with their expectations, but just took the actual robot emotion for granted. In the final study, the children's responses were different, since the children were forced to come up with a reason for the robot's emotion thanks to the implementation of the "why-questions". When the actual robot emotion matched the expected emotion, the children often repeated the reason for selection the action: the effect fitted the cause. However, more interesting were the situations in which the robot's emotion did not fit with the children's expectations. In these situations children had to solve this conflict. The "why-questions" forced the children to come up with a reason for the mismatch. They triggered the children to come up with original solutions, the children were trained in cause-effect reasoning. This type of interaction could have been related to the children perceiving the activity more as a puzzle as described before.

In short, the current system triggered children's creativity in situations in which children had to solve the mismatch between the expected robot emotion and the actual robot emotion, but barely triggered children's creativity by coming up with original solutions fitting different robot emotions for one element.

9.2 Limitations

A ROBOT IS NOVEL

Results of the studies showed the children liked playing with the robot. However, it is likely the children did not have a similar experience with this particular robot before. When using the system to tell stories more often, it is expected the novelty effect will occur. The novelty effect is the tendency for performance to initially improve when new technology is instituted, not because of any actual improvement in learning or achievement, but in response to increase interest in the new technology. As described by *Sung, Christensen & Grinter (2009)* several long-term studies in human-robot interaction show that novelty effects that promote initial engagement typically wear off after a short period of time. An example they provide is research by *Kanda, Sato, Saiwaki & Ishiguro (2007)*. They propose a mechanism for two social communication abilities for robots: the forming of long-term relationships and the estimation of friendly relationships among people. The robot they developed, Robovie, was deployed in a classroom for nine weeks. The engagement of the elementary school children was observed. At first, children were excited and wanted to play with the robot, but over time the frequency of interaction and the number of playful interactions decreased.

What can be learned from these studies is that similar effects could be present when using the system of this research for a longer period of time. When the storytelling activity mostly relies on stimulating the children to tell stories by using robot responses, it is likely children's motivation to tell stories will drop over time. On the other hand, when children are less interested in exploring the robot's responses their attention could actually be shifted towards the storytelling. The influence of the novelty effect can be reduced when each time the activity is a slightly different one. Implementation of aspects such as robot deliberation, more story content specific questions, support for multiple themes and personalisation (described in more detail in 10.1 Recommended Improvements Prototype) could lead to this perception. The variety in the activity caused by these aspects, could help to retain the attractiveness of the activity over time.

PROTOTYPE DEVELOPMENT & RESEARCH INTERMINGLED

During this project the development of the prototype and the emotional behaviour research were intermingled. Although both aspects of the project provided valuable insights, combining the two without handing in on quality was, on second thoughts, a challenge and probably out of the scope of the project. Since the prototype was created from scratch, several design circles were needed for the prototype to reach a sufficient level in order to test the influence of the robot's emotional behaviour. The end status of the prototype during this project did not reach this level yet. It is expected that splitting the project into two phases would have resulted in better results. The first phase could have focused on the development of the prototype and the second phase could have focused on the research concerning the influence of emotional behaviour of the robot. By splitting both aspects, each aspect would have received the full focus. Also, this method would have resulted in more condensed user studies. During this project, the user studies investigated both aspects concerning the prototype and aspects concerning the influence of emotional behaviour. Although the user studies provided useful insights for both aspects, it is expected that user studies specifically designed for one of the aspects would have provided better results.

DESIGN OF TWO CONDITIONS

To test the influence of the emotional behaviour of the robot on children's storytelling two conditions were designed. Initially the conditions were designed in such a way that they were the same except for one factor: the presence of robot emotions. However, throughout the research the prototype evolved in such a way that actually more factors might have been different among the conditions. The first factor is the amount of reactivity of the robot. In condition NE the robot not only lacked emotions, its reactivity was also limited compared to the E condition, since the robot only responded to children's actions via the tablet. To solve this difference in reactivity, the robot in the NE condition could be extended with neutral behaviour. This way, the influence of the amount of reactivity is reduced and the conditions are optimised to investigate the influence of emotional behaviour.

The presence or absence of robot emotions resulted in another differ-

ence between the conditions, namely a difference in the "why-questions" asked. Implementation of the same "why-question" concerning the emotion of the robot was not possible. "Why does the robot feel [EMOTION]?" was not applicable to the NE condition, since the robot did not show any emotion. Therefore, the question was adapted to "How does the robot feel?". Although this adaptation was believed to be the best solution to limit the differences between the conditions, the adaptation resulted in the two conditions not being completely comparable. This limited comparability resulted in difficulties when assessing the quality of stories told. Since the quality of the stories was partly based on the answers to the "why-questions", the story quality scoring schemes could not be the same for both conditions. Although both scoring schemes were designed to test the value added by the children to the information they had already been given, the use of two different scoring schemes is not ideal. After all, differences between the story quality ratings in the two conditions could have been affected by the differences in the scoring schemes used, and, therefore, not solely reflect actual differences in the story quality.

BIASES

To make a school participate in a study, it is ethically required the school and the children's parents or caregivers are informed about the details of the study. Therefore, many children knew up front they would be performing in an activity with a robot. By using the word "robot" certain expectations about its characteristics could have been created. *Alves-Oliveira, Petisca, Janarthanam, Hastie & Paiva (2014)* studied the expectations that children have regarding social robots in two particular contexts: a futuristic classroom and in their personal home. The results of their study suggest that children expect robots to be able to evoke and engage in social interactions and to present mental qualities, integrating the technology in this process. *Bhamjee, Griffiths & Palmer (2010)* examined children's perception and interpretation of robots and robot behaviour. Results indicated that children can hold multiple understandings of robots simultaneously and that they tend to attribute animate characteristics to robots. Similar expectations could have been present in the children participating in this study, resulting in a mismatch between the expected robot characteristics and the actual characteristics of the robot. This mismatch could have influenced how the children interacted with the robot and told stories around it.

In addition, children participating in the study were consecutively taken from the class for a small period of time. This procedure was used in order to create a convenient setup for the children and the teacher by allowing the teacher to continue with the regular class programme as good as possible. However, children returning to class could talk to the other children about the activity and, thereby, influencing the children that still needed to participative. Especially children performing in the E condition informing children that would participate in the NE condition could have affected the research. The chance that the robot characteristics expected by the children performing later mismatched the actual robot characteristics increased. This mismatch could have negatively effected the children's motivation during play.

COMPOSITION TRIALS

During the research the composition of the duos was not a controlled design factor, since it was out of the scope of the project. However, it is possible that the composition influenced how children played in the activity. The composition of the duos was up to the teachers. For that reason, some groups were mixed gender and others only consisted of boys or girls. The composition of the duos may have affected the interaction between the children. Also, the relationship between the children (friends or solely class mates) may have affected how children interacted. Therefore, differences in interaction between the children based on the composition of the duos may have influenced the children's storytelling.

9.3 New Goal: a System for Story Fragment Creation

The executed research raised many new, fundamental, questions. This section describes several relevant issues. The issues are described to raise awareness of their existence. To find solutions to the issues they have to be researched in more detail.

STORYTELLING VS. CREATIVITY

At the beginning of this research stimulating creativity was named as the main reason to design an interactive storytelling system. However, the research specifically focused on storytelling as a form of creativity. The designed prototype was evaluated and adapted to better support storytelling. Although children could come up with original solutions during the activity, actual support of the system was not researched. Children that performed well in the storytelling task not necessarily came up with more original solutions than children that performed less, and the other way around.

But what is actually the link between creativity and storytelling? Does better storytelling always involve more creativity? Although richer and more complex stories can definitely be triggered through creativity, this is not necessarily the case. Do we want to support children in telling more complex and richer stories, which can also be original? Or do we want to support children in coming up with original ideas, with storytelling solely functioning as a tool? Depending on the focus, the system design changes. Therefore, deciding on the focus is essential for the success of the system.

STORYTELLING VS. STORY CREATION

"Storytelling" and "story creation": this research did not make a distinction between the concepts. The term storytelling as defined in 2.1 Storytelling was used as a guideline for both concepts. However, the two concepts differ from each other. Story creation focuses on the raw story content, the fabula of the story: "the way in which an event unfolds, the 'brute chronology' of the narrative" (Holquist, 1990 as cited in *Pantaleo, 2004*). Storytelling focuses on organising this content, functioning as the syuzhet of the story: "the plot, the order and manner in which events are actually presented in the narrative" (Cuddon, 1999, as cited in *Pantaleo, 2004*). In addition, according to the definition used storytelling involves an active listener, which is not necessarily the case for story creation. Thus, defining story creation and comparing the definition with the one of storytelling to sharpen the difference between the two is valuable.

Also, it is useful to re-evaluate the definition of storytelling. The current definition might actually not fit with all storytelling activities. As an example, visual storytelling, such as silent movies and comics without words, cannot be labelled as storytelling according to the current definition, since the activities do not involve language. Therefore, one could think of replacing the term "language" with the term "a medium". Then, a wider range of activities can be labelled as storytelling.

The issue described above raises the question what type of activity the current system actually supports: storytelling or story creation? As described before, the activity did not contain all characteristics of storytelling. Therefore, it is suggested to label the activity as story creation. Children did not organise story content according to a narrative plot, but solely created raw story content. It can also be questioned if the children's summarising of the story during the interview actually involved storytelling or can better be labelled as solely reporting.

Based on the new definitions it can be decided which of the two activities should be supported by the system. The decision depends on whether or not the activity is offered in the form of pretend play. Can pretend play namely be labelled as a storytelling or a story creation activity? As described before, the activity offered by the current system did not completely overlap with pretend play. Pretend play involves acting on the spot and often lacks coherence around a narrative plot. Therefore, pretend play probably better fits with story creation. Based on the type of activity (storytelling or story creation) selected, the design of the system can be adapted in order to support the activity the best.

COMPLETE STORIES VS. STORY FRAGMENTS

Another issue raised is if pretend play involves the creation of complete stories, or solely involves the creation of story fragments. The executed research focused on the creation and evaluation of complete stories. However, children do not create stories including a narrative plot in pretend play; pretend

play merely includes story fragments (small-scale stories) that are not necessarily linked. This is in line with work of *Sawyer (2002)*. He describes that children's improvisational play rarely results in complex narratives structures with global coherence. Each child's turn in interaction successively builds on the prior turns of the other children, resulting in a step-by-step emergence of a narrative. But, even though global coherence is not present, one can identify component elements of narratives that connect across multiple turns, forming pockets of local coherence. Sawyer's research indicates it is not realistic to expect children to create complete and structured stories with the system.

Actually, the system as designed merely focused on support of story fragments, whereas the evaluation took place on complete story level. When holding on to the activity as a pretend play activity, the focus of the system and evaluation should be on the creation of story fragments. On the other hand, when shifting the focus to the creation of complete stories, pretend play can be removed.

CREATION OF STORIES AND STORY FRAGMENTS THROUGH SCAFFOLDING

The designed system influences the stories created by children. The research showed in particular that providing children with a demand results in them talking about this demand during and after play and children acting according to this demand. In addition, children relate story actions to a goal and talk about a goal during and after play when they are provided with this goal (in this research the goal of the robot). By additionally providing children with story actions related to this goal, they create causal relationships between the actions and the goal. Moreover, a combination of robot emotions and "why-questions" leads to children talking about causal relationships between story actions and emotions and using a variety of emotions in their stories. The combination specifically results them reasoning about conflicts between the story actions and the emotions. Also, the combination strengthens the children's perception of the robot being a character. Finally, the need to answer "why-questions" results in children creating causal relations between the robot's emotions and the story actions. Children connect the emotions to single story actions instead of solely the robot's end goal.

These examples indicate that children construct smaller and larger cohesive story fragments using the system. Contributions of the system (such as the "why-questions" and robot emotions in the current design) may trigger the children to form richer and larger cohesive story fragments, which could eventually could lead to them forming more complex and richer stories. In that way, the system serves as a tool for instructional scaffolding: a learning process designed to promote a deeper level of learning (*Sawyer, 2005*). Scaffolding is the support given during the learning process which is tailored to the needs of the children with the intention of helping them to achieve their learning goals. Via scaffolding, children can integrate the contribution from the system with more input from themselves. In an ideal situation, the contribution of the system is as small as possible, whereas the children add as much as possible extra input.

An interactive storytelling system has the potential to include the three essential features (*Wood & Wood, 1996*) of scaffolding. Firstly, the interaction between the children and the system is collaborative. Secondly, the system has the possibilities to support learning taking place in the children's zone of proximal development. Vygotsky (1978) defines the zone of proximal development as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (as cited in *Wertsch, 1984*). Thirdly, the support and guidance provided by the system can gradually be removed as the children become more competent.

What can be learned from the executed research is that providing children with more system input can potentially help them with creating more coherent and richer stories.

MODEL STORY QUALITY

Under the issues described above lies the need for a guideline in story evaluation. In this research the model described in 2.3 Narrative Elements & Story Assessment was used. However, it is questionable if the model was val-

uable for the activity the system supported in the end. The model focuses on storytelling, not on story creation, whereas the activity more involves story creation. In addition, children create story fragments instead of complete stories. Therefore, questions raised are: "What is a good story?", "What is a richer and more complex story?" and more specifically: "What are good story fragments created in pretend play?" and "How can we measure the quality of these story fragments?".

It is difficult to compare a story created with the system with a story as described by current models in literature. Current models do not focus on stories created in pretend play, but on activities mainly in the form of writing or telling. These stories involve a narrative plot consisting of a beginning, middle and an end, which is most often not the case in the activity supported by the system. A model that fits the story fragments as created in the pretend play activity by the system is essential, since the model functions as the basis for the system design. In addition, with such a model the quality of the story fragments created can be measured and used to evaluate the system. Before creating this model the issues as described before have to be decided upon, since they affect the model.

MODEL CREATIVITY

Similar questions as in the previous section can be asked for creativity: "When is a story more creative?" and "How do we measure creativity in story creation?", both referring to creativity in the sense of producing something that is original: new in form and content. A creativity model is specifically relevant when deciding to focus on creativity (with storytelling solely as a tool). An example of a way to measure children's creativity in the current setup is counting how much children add to the tangible world that is given. This solution refers to 2.5 Use of Toys in Pretend Play which describes that toys connect children's tangible world to their imagination. When a toy, in this case the robot, better triggers children's creativity, this connection improves. Children can express this increase of connection by using more elements than present in the tangible world they are given. One could, for example, count how often children come up with new characters, locations and objects. However, this way of measuring creativity does not yet evaluate how children use the elements they are already provided with and how they combine elements in their story fragments.

BALANCE INPUT SYSTEM & INPUT CHILDREN

When the focus of the system is reshaped and a story quality model and creativity model are created, it is still the question how much the system should contribute to the children's story fragment creation process to best function as a scaffolding tool. What balance between the system's and children's input is desirable? In the current system children receive relatively much input from the system and contribute just a little to the story fragments themselves. Ideally, a small system input leads to a large contribution of the children. The balance between system's and children's input connects to the scaffolding learning theory as described before. The system's input can be reduced when children become more competent, leading to an increase of the children's input.

Thus, what can be learned from all the issues described in this section is that they lead to a new research goal: researching how to design an interactive system for story fragment creation in pretend play.

9.4 Conclusion

This research investigated a new approach for an interactive storytelling system. Different from existing projects, the proposed system combines a tangible smart toy with a virtual world. Throughout the research a prototype consisting of a little robot and a tablet application was designed. The research was executed using a user-centred design approach including three user studies. The user studies were used to evaluate the prototype and adapt it according to the outcomes.

The results of the studies show the prototype may function as a basis for further development of an interactive storytelling system, since children understood how to work with the prototype and liked playing with the robot and the tablet. The robot's responses can function as motivational triggers for the children, since the children like to explore them. Nonetheless, the activity yet barely incorporated pretend play; it better approached a puzzle game. Furthermore, the results show the

stories told by the children became more extensive and coherent over the different prototype versions. However, the stories told with the latest version of the prototype were still limited.

The final study specifically tested the influence of emotional behaviour of the robot on children's storytelling. Two conditions were compared: condition NE in which the robot did not show any emotions and condition E in which the robot showed emotions. The aim of the final study was to answer the following research question:

"What is the effect of emotional behaviour of a character toy on children's storytelling?"

No direct influence of the implemented emotional behaviour of the robot on the quality of the stories told by the children could be found. Although the story grammar scores of the stories varied, no differences between the two conditions were present. The large variety within the stories was probably caused by individual differences between the children. However, qualitative analysis showed some differences in children's storytelling and their story summaries. In the E condition, children tended to tell stories including more emotions than in the NE condition. These children also included more emotions in their story summaries. In the NE condition, children had to come up with emotions themselves, which resulted in them only using the happy emotion in both the story and the story summary. Children might have perceived the activity as a puzzle in which they had to fulfil a goal-directed task; bringing the robot to the moon. Therefore, they did not see the need (or not even thought) of including conflicts and negative emotions, since these prevent the robot from reaching its goal. Furthermore, in the E condition the children tended to link emotions better with individual actions in the story than during the NE condition. The difference could also be seen by the presence of more causal relationships between actions and emotions in the children's story summaries. Though this difference could also be caused by the design of the system in which the "why-questions" asked differ amongst the conditions. Moreover, the story summaries in the E condition were told more often from a third person perspective, which could indicate children saw the robot more as character in the story than in the other condition. Therefore, the children recall the story by explaining it around the robot, instead of by providing just a list of events that happened in the story. Additionally, in the E condition children mainly took the randomness of the robot's emotions for granted. However, the "why-questions" triggered them to come up with reasons to match the random emotions with the story. Finally, children collaborated according to different patterns, in the E condition both children tended to be more active than in the NE condition.

The research shows the system has possibilities to be used for instructional scaffolding. However, the prototype might not sufficiently be developed to test the influence of the robot's emotions on children's storytelling. In addition, the influence of the difference in the amount of robot reactivity between the two conditions might have been large compared to the influence of the difference in emotional behaviour. The research raised many new issues, such as the link between creativity and storytelling, the type of activity to support: story creation or storytelling and support for the creation of complete stories or creation of solely story fragments. Therefore, it is recommended to resolve these issues and optimise the prototype before the influence of emotional behaviour of children's storytelling can be further investigated. Consequently, follow-up research is suggested (10.2 Recommended Follow-up Research).

EFFECTS EMOTIONAL BEHAVIOUR

- No influence on story grammar scores
- Larger variety emotions used in stories and in story summaries
- Stories and story summaries contain more often causal reasoning opposite of just a list of actions
- Story summaries more often described from a third person perspective

10

Based on the results of the studies during this research recommendations can be made. This section provides an overview of the recommendations for improvement of the prototype and recommendations for further follow-up research.

Based on the results in this research recommendations for future work are given, Guillaume, https://www.flickr.com/photos/will_84

Recommendations

10.1 Recommended Improvements Prototype

First of all, it is recommended to implement the aspects described in 7.8 Suggested Improvements that not yet have been implemented. In addition, a set of other improvements are recommended. These recommendations are described in this section.

TABLET INTERACTION

In addition to the recommendations for the robot behaviour, it is recommended to change some aspects of the tablet application.

Reminder Goal Robot

What could be seen from the results of the studies is that children not always selected actions with the robot's end goal in mind. Therefore, it is suggested to remind children of the robot's end goal during play. This reminder can, for example, be implemented by showing the robot's goal on the action selection screen. The reminder might help children to tell more global coherent stories instead of stories with mainly local coherence.

Content Specific Questions

"Why-questions" were implemented into the system in order to increase children's awareness of the occurrences of events in their story. However, as seen from the results of the user studies children's storytelling was still limited. When comparing the implemented questions with the type of questions teachers ask during storytelling activities (described in 3.4 Deliberative Behaviour & Storytelling) it can be seen that the questions implemented might have been too general, and, therefore, not optimal to trigger storytelling. It is expected implementation of more specific questions increases the system's support for storytelling. In order to ask more specific questions, the content of children's stories should be analysed. Based on the content of the story so far, the system could ask questions that go into more depth on the story content. Examples of more specific questions are: "And what is the robot going to do with the rocket he made?", "What does the robot use the tools for he bought?" or "How does the alien react when he receives the present from the robot?". However, this solution can be a technological challenge, since it asks for a well-designed algorithm that maps questions to the story content.

Characters Asking Questions

As an attempt to reduce the children's annoyance around the repetitive cycle of questions, it is suggested to replace the general formulation of the questions by the robot asking the question from his perspective. The question can still be shown on the tablet. When other characters are involved, they can also ask the question, seen from their perspective. Asking the question's from the character's perspectives could increase the children's perceived autonomy of the characters. In addition, By formulating the questions in a general way, children could connect the task to a teacher role, whereas the characters might be more connected to the peer role. A peer is someone one can learn from in an interactive and reactive way on the same hierarchical level. According to *Cassell, Ananny, Basu, Bickmore, Chong, Mellis ... & Yan (2000)* an activity is more valuable if children have a playmate that collaborates. This observation could lead to the children being more involved in the story and motivated to answer the questions.

Suggestions

The results of the studies showed that children often had difficulties with telling a story. To that end, it is recommended to extend the system with suggestions to help the children with telling a story. Implementation of suggestions is also a desire of teachers (*ter Stal, 2017*). Suggestions can be shown to the children when they have difficulties to come up with something themselves (i.e. after a period of idle interaction with the tablet). For example, a question with a built-in suggestion for the next action in the story can pop-up at the tablet: "What about asking the alien?". As explained before, to be able to ask such specific questions, the content of the story has to be analysed. Another way of providing children with suggestions is showing them words (or images) associated with the story theme. The image shown can also contain one of the locations, figures or object blocks present These images can inspire children for the content of their story.

ROBOT BEHAVIOUR

What can be seen from the results of the studies is that many children asked questions or placed remarks about the characteristics of the robot. Reducing the mismatch between the expectations of the children and the actual characteristics of the robot could increase the children's motivation during play. To reduce the mismatch, the robot behaviour can be extended. Additionally, the activity can be promoted to schools without using the word "robot".

Autonomous Driving

First of all, it is recommended to implement autonomous driving by the robot, since this functionality was frequently expected by the children. Technically it is already possible to let the robot to drive for himself. Using the robot's camera and existing marker detection algorithms the robot can drive towards objects that have a marker. In addition to the robot driving towards locations selected by the children, it is also possible it suggests a different location for the story by driving to another location.

Robot Speech

Another extension suggested is the implementation of robot speech. Children often expected the robot to talk. Using the tablet application children can select or even type in sentences which can be spoken by the robot. This way, conversations can play a larger role in their stories. As seen in 2.3 Narrative Elements & Story Assessment conversations are part of the story grammar. The quality of the children's stories could be increased when including conversations. However, this solution requires an accurate text-to-speech (TTS) unit. In the current version of the robot only an English-based TTS unit is present. Using the current TTS unit is, thus, not feasible.

Pick Up Objects

A last suggestion is to use the robot's ability to move objects with his arms in the storytelling process. The story actions can become more tangible for the children when the robot executes them in the real world. Imagine the children selecting the "give" action to provide the alien with a present. The robot could actually drive towards the object block with the present and move the present towards the alien using his arms. This way, the robot truly gives the present to the alien.

Include Deliberation

The story suggestions as proposed to be implemented on the tablet, can also be provided to the children via the robot. In order to do so, the reactive behavior of the robot can be extended with deliberation. The robot can provide children with suggestions by asking questions as described before, but ask them from its own perspective. As an example, instead of asking the general question “What about asking the alien?”, the robot can ask: “I can ask the alien?”. The question can also be framed differently, to directly portray the robot's (deliberative) desire: “I want to meet the alien”. This approach can even be taken a step further. The robot could communicate its desires by immediately driving towards a location, character or object, in the example by driving towards the alien figure. The general way of providing children with associative words or images on the tablet can also be changed by the robot showing these words or images on the tablet. For example, the word or image can be presented in the robot's thought bubble.

By extending the robot behaviour, it is assumed that children perceive the robot as a more lively, autonomous character. This perception could strengthen the robot's role as the main character in the story. In addition, extending the robot behaviour increases the amount of robot responses possible. A larger amount of robot responses could lead to more variety within the activity and, therefore, keep the novelty effect from waning. By extending the behaviour, the robot can actually start performing actions himself, instead of solely reacting to the instructions of the children. This way, the robot's role as the main character in the story can be extended to a peer role in which it also provides children with suggestions. However, the biggest pitfall when extending the robot behaviour is that children can become focused on exploring the robot behaviour instead of on the storytelling.

GENERAL

Reduce Need for Spelling and Typing Skills

The "why-questions" of the prototype used during the final study added a complete new dimension to the storytelling activity. Many children had difficulties with spelling or typing, shifting the focus of the activity from storytelling to spelling and typing. Initially, it is recommended to adapt the system to ensure children can focus on storytelling. In a later stage, the system could always be extended with spelling tasks. One way to remove the need for a sufficient level of spelling and typing skills is to let the children describe their reasons aloud. Implementation of a microphone would solve the problem. Additionally, implementing an accurate automatic speech recognition (ASR) unit would increase possibilities. With an ASR unit the children's ideas can be analysed and used to implement personalised responses. However, this solution is not realistic when looking at the current state of ASR. ASR is not sufficiently developed yet

to be reliable. Another solution to get around the children's spelling and typing skills is to provide children with a selection of possibilities on the tablet. However, using such a selection limits the children's creativity in coming up with other reasons. Using a combination of selections and typing might be a good compromise. For example, children could select the start of a reasoning from a predefined set and then finish the sentence themselves by typing.

By reducing spelling and typing during the activity children can spend more time on actually telling a story. They might tell longer and better stories, since they can select more story actions in the same time span. In addition, reducing spelling and typing could increase the children's motivation, because more time is left to explore the robot responses.

Stimulate Collaboration

What could be seen from the results of the studies is that children like to perform the following aspects of the activity themselves: selecting actions on the tablet, placing objects or characters in front of the robot and moving the robot. To ensure the execution of these tasks are equally divided amongst the children a solution can be to sense which child performs an action and to use this information by the robot to approach and interact with the child that does (not) perform actions. The robot's face recognition algorithms can also be helpful for this solution.

Support of Multiple Themes

To increase the educational value it would be an advantage if the system can support multiple themes. Support for multiple themes allows the children to tell a variety of different stories. In addition, the theme can be adapted to the theme handled in class to use the storytelling task as an extension of the regular program. Cohesion between the regular program and the content of the storytelling activity is a wish of teachers (*ter Stal, 2017*).

In order to support multiple themes, the characters, objects and locations should be able to change accordingly. To support the use of locations fitting the theme the play mat can be replaced by a screen on which varying locations can be projected. In addition to the locations, the tangible characters and objects can be replaced by virtual objects and characters, which makes it possible to change them easily. However, tangible objects and characters help children that have difficulties in understanding the virtual world. Hands-on actions on physical computational objects can

RECOMMENDED IMPROVEMENTS PROTOTYPE

- Tablet: implement a goal reminder, content specific questions and suggestions, ask "why-questions" from character's perspectives
- Robot behaviour: implement autonomous driving, speech, object pick ups and deliberation
- Reduce spelling and typing by selections or speech
- Stimulate collaboration by the robot interacting with the children,
- Support multiple themes to increase educational value
- Include a teacher back-end to support differentiation
- Use storyline as a guideline for other storytelling activities, such as writing or retell tasks
- Use multiple robots to include character interactions and conflicts into the stories

make abstract concepts more accessible to children *(Antle, 2013)*. Therefore, it is recommend to hold on to tangible objects and characters. A different solution that allows for flexibility of the type of objects and characters is the use of tangible blocks with markers. The children can, for example, attach paper with self-drawn characters and objects that fit the story theme on the blocks. Thanks to the markers the characters and objects can still be identified by the robot, however it does not know what it is it is looking at.

By the support for multiple themes, the storytelling system can be upgraded from a system for a one-time experience to an educational system which functions as an extension to the regular program. In addition, multiple theme support could keep the novelty effect from waning, since children could perceive the same activity with a different theme as a different activity.

Differentiation via a Teacher Back-end

When support of multiple themes is implemented, the system could even be extended with a back-end system for teachers. Teachers could, for example, provide children with a problem statement, ending of the story or other story restrictions. This is in line with how teachers provide regular storytelling tasks in class (*ter Stal, 2017*). In addition, such a back-end allows for differentiation of the storytelling task between children. What can be seen from the results of the final study (8.6 Results) is that large variations in the quality of children's stories exist. The differences might be caused by differences in individual characteristics of the children, such as creativity, concentration or collaboration. Such a teacher back-end can include a list of settings which the teacher can adapt to the individual level of the children. For instance, the teacher can select if the problem statement or the "why-questions" as present in the current prototype should be shown. Not all children have problems with telling stories. Showing aspects, such as the problem statement or the "why-questions", can restrict the creativity of these children, since their storytelling is interrupted. For children that do have difficulties with telling stories the problem statement and questions can be helpful. By allowing the teacher to change aspects of the storytelling activity, the activity can be optimised for each child.

Storyline as Guideline for another Activity

The educational value of the system can also be increased in a different way. The storyline currently logged on the tablet can be saved digitally or printed. The storyline is a tangible result of the storytelling activity which children can take home. Also teachers prefer to have a tangible result. They can use these results as input for grading (*ter Stal, 2017*). But, the storyline can also be used as a guideline for another storytelling activity. The storyline can function as a plot generation tool, providing a list of key events. Based on this list, children can, for example, be asked to retell the story or be asked to write a story. In this way, the system would function as a tool to create a list of key events that can be used by the children. Using the system with the robot's responses, the children already experienced part of the story in the physical world. These experiences could function as inspiration for the children for the follow-up activity.

Use of Multiple Robots

The system can also be extended with multiple robots. The robots, all characters in the story, can interact with each other. First, the system can be adapted by adding actions to the action selection screen that could be performed with multiple robots. When selecting such actions, both robots can respond. The presence of multiple robots can inspire children to integrate more characters in their stories. Responses of both robots can inspire the children to adapt their story by including the interaction between the robots. Character interaction, such as in the form of dialogues, can increase the quality of the story (see 2.3 Narrative Elements & Story Assessment). The current figures cannot interact. Therefore, ideally all figures are replaced with robots, allowing all characters in the story to interact with each other. To adapt the characters to the story theme, it is desirable that the appearance of the robots can be adapted. As an example, tangible accessories can be used to change the appearance of the robots.

Differences in the robot's individual goals can lead to conflicts in the story. As an example two robots can have the desire to go to the moon using the rocket, whereas the rocket only has place for one of the two. Such conflicts can encourage children to adapt their story accordingly. Conflicts and plans to solve them can increase the quality of the story (see 2.3 Narrative Elements & Story Assessment). Additionally, each robot can be linked to an individual child. This can affect the collaboration between the children, since each child is responsible for fulfilling the goals of his or her robot. In a later stage, all robots can be implemented with deliberation.

10.2 Recommended Follow-up Research

Along with the improvements for the prototype described above, some follow-up research is recommended. First of all, it is recommended to research the issues as described in 9.3 New Goal: a System for Story Fragment Creation. The aspects described below can be research additionally.

GO BACK TO THE TEACHERS

It is recommended to go back to the elementary school teachers to gather their opinion on the current status of the system. Brainstorm sessions or focus groups with multiple teachers could provide insight in how they would use the system in class. They might have valuable ideas about how to improve the system's support for storytelling. Implementation of these ideas could improve the educational value of the system.

INVOLVE THE PARENTS AND CAREGIVERS

Children's parents or caregivers play a role when it comes to the use of the system in a home context. In this research parents and caregivers were not involved in the design process of the prototype. However, it would be valuable to receive their opinions on the system. As for the teachers, brainstorm sessions and focus groups could be organised. In a first stage, sessions with solely parents and caregivers could be organised. Parents and caregivers might have different opinions and come up with different ideas than teachers. Later on, joint sessions with teachers and parents and caregivers could be organised to allow them to brainstorm upon and discuss each others ideas. These sessions could help to gain additional information to improve the system.

RESEARCH GENDER DIFFERENCES

Another recommendation is to study possible gender differences, since the results of the studies indicated some gender differences with respect to the expectations of the robot's characteristics could be present. Boys and girls might have different interests when it comes to the robot's behaviour. Also, the way children play in general according to their gender can be researched. If any differences exist, the system can be adapted in order to adapt to the children's interests.

FOLLOW-UP STUDY WITH CHILDREN

It is recommended to perform a next study with children when the system is improved according to the aspects described in 10.1 Recommended Improvements Prototype, fundamental issues are resolved, the teachers' and parents' opinions are processed and the system is adapted according to any gender differences.

Support Storytelling

Using an updated story quality model (9.3 New Goal: a System for Story Fragment Creation), the quality of the stories told by the children using the updated system can be tested again. Also, it can be researched if the balance between storytelling and exploration of the robot behaviour has improved. An aspect which not yet have been addressed in the user studies performed so far, is to what happens if children tell more stories in a row. Do the stories change over time? Does replaying, for example, influence the length or the quality of the stories told? Also, are the stories told in one row somehow connected? Do they tend to be different episodes or can they be seen as stand-alone stories? Another interesting issue to address is to see what happens when children use the system more often. Does regularly playing affect how children tell stories and does it affect factor, such as the children's motivation?

FOLLOW-UP RESEARCH

- Execution of brainstorm sessions or focus group with elementary school teachers and parents and caregivers to gather their opinion and ideas around the current prototype
- Research gender differences to optimise the system to the interests of each gender
- Execute a follow-up study with children to test again the effect of the updated prototype on storytelling, the effect of the presence or absence of emotions, the effect of random emotions or emotions according to an emotional model and the effect of the presence or absence of deliberative behaviour

Influence Robot Emotions

Next to the effects of the changes of the system on the storytelling, the effect of the presence or absence of robot emotions can be researched again. Although quantitative analysis in the last study of this research analysis showed no differences, the qualitative analysis indicated that some differences might be present. Therefore, it is seen as valuable to test the influence of the robot emotions again after updating the system. Implementation of autonomous driving, speech and object pick ups increases the responsiveness of the robot independent of the presence of emotions. This way, the robot in the NE condition becomes more interactive compared to the robot currently used in the NE condition. In the current situation differences between the conditions are largely influenced by the presence or absence of reactivity that comes with the presence or absence of the emotions. Therefore, the current situation not solely tested the difference between the presence and absence of robot emotions. In the new situation, the conditions become better comparable. The robot is already more reactive in the NE condition, since it can drive, speak and pick up objects. In the NE condition, the robot behaves having a neutral emotion, whereas in the E condition the same robot behaviour is present, but the robot shows different emotions. Therefore, testing the updated system could better test the influence of the presence of robot emotions on children's storytelling.

Random Emotions vs. Emotional Model

Instead of implementation of random robot emotions as in the prototype used in this research, emotions can be implemented according to an emotional model. Then, the children's responses on the random robot emotions can be compared with children's responses on the robot emotions implemented according to this model.

To test how children respond to different robot emotions for items already used, the study procedure has to be adapted. The executed research showed children barely reused items, therefore, different robot emotions for the same item did not occur often. To trigger the reuse of items, children can, for example, be provided with with less items or more time to perform the activity. How to design an emotional model has to be researched, but, as an example, the model can be based on a decision tree consisting of the robot's goal and the story actions that can be performed. Actions more logically connected to the goal are placed closer to the goal in the tree than actions not logically connected. An action closer to the go may result in a positive emotion of the robot, whereas an action further away from the goal results in the robot showing a negative emotion. As an example, when the robot's goal is to go to the moon and the children select that the robot makes a rocket, the robot turns happy. On the contrary, the robot turns angry when he is provided with a bouquet of flowers, since he cannot use the flowers to go to the moon. Children may see the positive robot emotions as a confirmation of them being on the right track. This way, cause-effect reasoning is stimulated. Whereas the implementation of emotions according to such a decision tree may help children in creating better cause-effect reasoning in their stories, it may also negatively affect their creativity. Original ideas can be far away from the robot's goal in the decision tree, whereas they may actually still fit the goal (e.g. the bouquet of flowers could also be used as a "rocket" on which the robot can sit in order to travel to the moon). When children figure out the rules of the emotional model, children may use this knowledge to plan their story upfront. Children can make use of the known robot emotions in their story. But, in order to do so children need to have sufficient playing time to explore the "rules" of the emotional model.

In short, on the one hand, random robot emotions may trigger children to come up with original solutions. On the other hand, an emotional model may result in children planning their story upfront and implementing cause-effect reasoning thanks to the robot's positive emotion as a conformation. However, one should watch out this type of interaction does not increase the children's perception of the activity being a puzzle. The opportunity exists to research which of the robot emotion implementations best fits the activity.

Influence Deliberation

When implementing deliberative behaviour of the robot, the influence of this behaviour on children's storytelling can be tested. Two conditions can again be compared: one condition in which the deliberative behaviour of the robot is switched off, and one condition in which the deliberative behaviour of the robot is switched on. In addition, it can be interesting to measure how the children's perception of the robot changing with the presence or absence of deliberative robot behaviour. For example, do they perceive the robot more as a character in the story?

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Appendices

A1 Index of Narrative Complexity

NARRATIVE ELEMENT	0 POINTS	1 POINT
Character A character is any reference to the subject of a clause in a narrative.	No main character is included, or only ambiguous pronouns are used. **Examples:** • They were walking. • He was walking.	Includes at least one main character with non-specific labels only. *Note:* only code each character one time. **Examples:** • Once there was a boy. • The boy was walking.
Setting A setting is any reference to a place or time in a narrative.	No reference to a specific or general place. **Examples:** • The boy and the girl were walking.	Includes reference to a general place or time. **Examples:** • The boy and girl were outside. • It was daytime. • One day, they went to the park.
Initiating Event An initiating event is any reference to an event or problem that elicits a response from the character(s) in a narrative.	An event or problem likely to elicit a response from the character is not stated. **Examples:** • The girl looked at the boy. The boy and girl were walking in the park.	Includes at least one stated event or problem that is likely to elicit a response from the character, but there is no response directly related to that event. **Examples:** • The girl was walking in a park and saw a spaceship land (event/problem) and she saw some aliens, and she saw a dog, and a table and...
Internal Response An internal response is any reference to information about a character's psychological state including emotions, desires, feelings or thoughts.	No overt statement about a character's psychological state.	One overt statement about a character's psychological state not causally related to an event or problem. **Examples:** • The dog was sad, the girl was happy.
Plan A plan is any cognitive verb reference that is intended to act on or solve an initiating event. It must include a "cognitive verb" that indicates a plan. *Note:* the plan and the action/attempt can share the same clause (see 2 points example b)	No overt statement is provided about the character's plan to act on or solve the event or problem. **Examples:** • The girl was very excited and she ran out to meet the aliens	One overt statement about how the character might solve the complication or problem. **Examples:** • The girl thought that it would be neat to go and meet the aliens.

2 POINTS	3 POINTS
Includes one main character with a specific name for the character. **Examples:** • Once there was a boy named Charles.	Includes more than one main character with specific names. **Examples:** • Once there was a boy named Charles and a girl named Mary.
One or more references to specific places or times. **Examples:** • Once there was a boy and a girl walking in Central Park. • They were walking at night.	n.a.
Includes at least one stated event or problem that elicits a response from the character(s). **Examples:** • The girl was walking in a park and saw a spaceship land and she saw some aliens (IE). The girl started to run away (action).	Two or more distinct stated events or problems that elicit a response from the character(s). **Examples:** • The girl was walking in a park and saw a spaceship land and she saw some aliens (IE-1). The girl started to run away (action). But while she was running, ehr shoe got stuck in a hole (IE-2). She quickly knelt down and took off her shoe to get unstuck (action).
One or more statements about a character's psychological state causally related to an event or problem. **Examples**: • The aliens' landed. Sara saw the ship and was terrified.	n.a.
Two overt statements about how the character might act on or solve the event(s) or problem(s). **Examples:** • The girl was very excited and she told the boy that she wanted to go meet the aliens. • The boy was very scared so he decided to sneak away quietly.	Three or more overt statements about how the character might act on or solve the event(s) or problems.

NARRATIVE ELEMENT	0 POINTS	1 POINT
Action/Attempt Actions are taken by the main character but are not directly related to the IE. Attempts are taken by the main character(s) that are directly related to the IE.	No actions are taken by the main character. **Examples:** • There is a girl. There is a boy. It is sunny.	Actions by main character are not directly related to the IE. **Examples:** • The boy and the girl were walking in a park. • They saw a boy alien waving.
Complication A complication is an event that prohibits the execution of a plan or action taken in response to an initiating event Note: a complication can also be a second initiating event. In this case code both a complication and initiating event.	No complications.	One complications that prohibits a plan or action from begin accomplished. **Examples:** The spaceship landed. The girl decided to get away from the aliens and started running from the spaceship. While she was running, her shoe got stuck in a hole. She could not get away from the aliens.
Consequence A consequence resolves the problem or does not resolve the problem. It must be related to the IE and be explicitly stated. Note: a consequence for one episode can often be the IE for another.	No consequence to the action/ attempt is stated. **Examples:** • She got away from the boy and walked out onto the grass • The alien girl had a dress on	One consequence. **Examples:** • The spaceship landed. The girl went out to see them. The aliens were scared of her. They ran back to the ship and flew off.
Formulaic markers A formulaic marker is any standard utterance used to mark the beginning or ending of a narrative. For example: the end, once, once upon a time, they lived happily ever after.	No formulaic markers.	One formulaic marker **Examples:** • Once upon a time
Temporal markers For example, when, next, then, immediately, instantly, after, again, already, always, before, lately, now, once, presently, rarely, today, weekly, while.	No temporal markers.	One temporal marker **Examples:** • The girl walked over the aliens. "Then" they all ate some lunch. • "After" the aliens landed, the girl screamed.
Causal adverbial clauses For example: because, since, so that, therefore, as a result, consequently, thus, hence .	No causal adverbial clauses.	Once causal adverbial clause **Examples:** • The aliens were not nice to the girl because they were scared.

2 POINTS	3 POINTS
Attempts by main character are directly related to the IE. **Examples:** • The girl thought that it would be neat to go and meet the aliens so she got away from the boy and walked out on the grass.	n.a.
Two distinct complications that prohibit plans or actions from begin accomplished. **Examples:** The girl was walking in a park and saw a spaceship land and she saw some aliens (IE-1). The girl started to run away (action-1). But while she was running, her shoe got stuck in a hole (complication-1/IE-2). She quickly knelt down and took off her shoe to get unstuck (action-2) but she was shaking too much to get er shoe off (complication-2).	n.a.
Two consequences. **Examples:** • They told their parents the spaceship was in the park. “but their parents didn’t believe them.” When they took their parents to the park “the spaceship was gone”. • The boy wanted a frog. He went to the woods to find one. He couldn’t find a frog. He decided “he really wanted a dog”.	Three or more consequences.
Two or more formulaic markers **Examples:** • Once upon a time...The end.	n.a.
Two or more temporal markers **Examples:** • “When” the girl saw the aliens, she ran out to meet them. She “already” knew they would be nice.	n.a.
Two or more causal adverbial clauses **Examples:** • The aliens were not nice to the girl because they were scared. Since they were mean, she ran away.	n.a.

NARRATIVE ELEMENT	0 POINTS	1 POINT
Knowledge of dialogue Knowledge of dialogue is registered by a comment or statement made by a character or by characters engaging in conversation.	No dialogue.	One character makes a comment or statement **Examples:** • He said "Ow" • He said "Don't come over there"
Narrator evaluations Narrator evaluations are any explanation provided in the story to justify why an action or event took place.	No narrator evaluations.	One narrator evaluation **Examples:** • She ran up to say hello to the alien. She always wanted to meet one.

Table A1 Index of the narrative complexity story coding form by *Petersen, Gillam & Gillam (2008).*

2 POINTS	3 POINTS
Two or more characters engage in conversation **Examples:** • He said “Oh look, there is an alien” and she said “Oh, lets go see them”.	n.a.
Two or more narrator evaluations **Examples**: • She knew that it was an alien spaceship. Everyone knows about UFOs. • He wanted to run from the aliens. They were his worst nightmare.	n.a.

A2 Technical Solutions Reactivity

STIMULUS - SENSORS MATRIX

Stimuli can be labelled according to the five senses. The table below labels possible stimuli for the interactive storytelling system according to the three senses: sight, hearing and touch (smell and taste are excluded). In real life some stimuli can be sensed using multiple senses, however, in this overview the stimuli are only mentioned once. The stimuli are categorised by the sense mostly used by humans to identify the stimulus. Per stimulus is noted what technology can be used to sense the stimulus. Thus, a sensor used to measure the occurrence of a stimulus not necessarily has to sense via the sense of the category. The list is not meant to be a complete overview, but to function as a guideline. Sensors included are the more common sensors, which are sufficiently available and are not too expensive.

SENSE	STIMULUS	SENSORS
Sight	**S1** Position in space	• RFID tag in toy, RFID readers in environment • Microsoft Kinect • Touch table/screen • Pressure sensors in environment • Proximity sensors in environment
	S2 Recognition other character, object	• RFID readers and tags in toys • Camera (with computer vision and face recognition)
	S3 Recognition user	• Camera (with computer vision and face recognition) • Identify user by account (check account login) • Identify user by use of individual control interface
	S4 Recognition facial expression user	• Camera (with computer vision and face recognition)
	S5 Closeness (and collision detection) environmental location, character, object, user	• RFID tags and readers into objects and characters • Microsoft Kinect • Touch table/screen • Camera (with computer vision and face recognition) • Infrared sensors • Pressure sensors • No sensors: system keeps track of positions individual components, calculates distances between components and provides individual component with distances required
	S6 Closeness (and collision detection) specific environmental location, character, object, user	• RFID tags and readers into objects and characters • Touch table/screen (that can track individual objects) • Camera (with computer vision and face recognition) • No sensors: system keeps track of positions individual components, calculates distances between components and provides individual component with distances required

SENSE	STIMULUS	SENSORS
	S7 Appearance other character, object, environment, user	• Camera (with computer vision) • No sensors: system keeps track of appearance individual components and transfers appearance data to other components if needed
	S8 Own appearance	• Camera (with computer vision) • No sensors: system keeps track of appearance individual components
	S9 Light intensity	• Photoelectric cell
Hearing	**S10** Whom or what produces the sound	• Microphone (with automatic speech-recogniser to distinguish sounds, based on frequency etc.) • No sensors: system keeps track of which component produces a sound and transfers data to other components if required
	S11 Type of sound (i.e. music, voice, background sound)	• Microphone (with with automatic speech-recogniser to distinguish sounds, based on frequency etc.) • No sensors: system labels produced sound with a category and transfers data to other components if required (limits free creation of sound)
	S12 Content sound	• Microphone (with automatic speech-recogniser) • No sensors: only fixed amount of sound fragments can be used of which the content is known, system transfers data to other components if required (limits free creation of sound)
	S13 Loudness sound	• Microphone
Touch	**S14** User touch	• Pressure sensor • Button press (button integrated in toy) • Finger touch (tablet integrated into toy) • Camera (with computer vision and face recognition)
	S15 Not being used for a certain time	• Combine S14 with a timer
	S16 Force touch, collision	• Pressure sensor
	S17 Movement	• Accelerometer • Inertia Measurement Unit

Table A2 Overview sensor technology that can be used to for a character toy to sense the environment for stimuli

REACTIVITY - TECHNOLOGY MATRIX

Characters can respond to stimuli. The table below shows how each response can be realised using technology or via direct user control, in case using technology ends up not being feasible.

RESPONSE	EXAMPLE BASED ON STIMULUS	TECHNOLOGY
Change appearance	*Stimulus:* toy arrives at the South Pole [S1 Position in space] *Response:* toy changes clothes; puts on a warm hat *Indication behaviour:* recognition	• Change image on a display • Remove/add layer of physical clothes • Pick up and attach or remove physical accessories
Change posture	*Stimulus:* toy recognises friend [S2 Recognition other character, object] *Response:* toy moves arm in the air (waving) *Indication behaviour:* greeting	• Toy integrated with motors, arms, legs and head can be moved independently • Toy only contains a flexible body, move flexible body
Change facial expression	*Stimulus:* toy returns home [S1 Position in space] *Response:* facial expression changes into a happy, relax expression *Indication behaviour:* feelings	• Change animation on a display • Move mechanical eyes
Change speech	*Stimulus:* toy not used for a long time [S15 Not being used for a certain time] *Response:* toy asks: "Hello, do I have a role in this as well?" *Indication behaviour:* need for attention	• Use standalone speaker, or speaker integrated into the character, to allow the character to speak a predefined sentence
Change sound	*Stimulus:* user picks up toy by pressing much force [S16 Force touch, collision] *Response:* "Ouch!" *Indication behaviour:* feelings	• Use standalone speaker, or speaker integrated into the character, to allow the character to produce a predefined sound
Change position	*Stimulus:* toy does not want to listen to the music [S12 Content sound] *Response:* toy moves away from the music *Indication behaviour:* opinion	• Character integrated with motors to autonomously drive towards another location

Table A3 Overview of possible responses toys and possible realisations using technology or direct user control. The second column contains examples of responses based on stimuli.

USER CONTROL

- User selects a new image to be shown on a tablet integrated into the toy
- User draws a new image to be shown on a tablet integrated into the toy
- User changes included tangible clothes or accessories for other tangible clothes or accessories
- User creates own clothes by using drawing and crafting

- User rotates arms, legs and the head around pivot points
- User controls movement toy via an interface, toy integrated with motors
- User controls static movement of the toy by using an interface (toy integrated with flexible body)

- User selects a new facial expression to be shown on a tablet integrated into the toy
- User draws a new facial expression to be shown on a tablet integrated into the toy
- User changes included, tangible facial masks and attached the new mask to the toy's face

- User pretends toy is speaking by using own voice
- User selects a new speech fragment out of set of fragments on an interface
- User types sentence to be spoken using an interface, text-to-speech unit converts text into speech
- User types sentence to be spoken using an interface, sentence shown in a speech bubble, as text
- User records speech using a microphone

- User pretends toy produces sound by using own voice
- User selects a new sound fragment out of set of fragments on an interface
- User types in sentence to be spoken using an interface, text-to-speech unit converts text into speech
- User types sentence to be spoken using an interface, sentence shown as text
- User records sound using a microphone

- User picks up toy and places toy at another position (and in another rotation)
- User controls movement and rotation of the toy by using an interface (toy integrated with motor-controlled wheels)

A3 Observations Pilot Study

NR	START STORY	ASK HELP	SILENCES	COMMUNICATION

1	No	No	Never	No, only about individual events, such as:
				• Robot actions:
				  • "Hij gaat naar de maan". *"He is going to the Moon".*
				  • "Hij gaat de poppetjes hier ontmoeten" [wijst hutje aan]. *"He is going to meet the characters here" [points at shed].*
				  • "Nee, kijk, hier, hier op de aarde, plaats hem op de aarde". *"No look, here, here at earth, place him at Earth"*
				  • "Kijk, zet hem op de ster". *"Look, put him on the star".*
				  • "Kijk, hij gaat van de maan afvallen". *"Look he is going to fall of the Moon".*
				• Character actions:
				  • "Kijk wat er gebeurd als er een poppetje van de planeet valt". *"Look what happens when a doll falls of the planet".*
				• Object actions:
				  • "Wacht eens even, het huisje gaat nu hier naar toe verplaatsen" [verplaatst hutje van de aarde naar de planeet waar alle poppetje zijn]. *"Wait a minute, the house is going to move towards here" [shifts the shed from the earth to the planet where all the dolls are positioned].*

2	Yes	No	Never	No, only about individual events, such as:
				• Which character to put in front of the robot next:
				  • "En die dan?" *"What about that one?"*
				• Character actions:
				  • "Hij moet in de boerderij". *"He needs to go into the farm".*
				• Robot actions:
				  • "Wat zou er gebeuren met de astronaut en de robot?" --> "Ja, laten we het proberen". *"What about the astronaut with the robot?" --> "Yes, lets try".*

3	No, only playing. Story created when researcher asked what is next.	No	No	No, one child creates the story, the other one mainly observes
4	No	No	No	No
5	No	No	No	No, only about individual events, such as: • Robot actions: • "Laten we hem op de maan zetten". *"Lets place him on the Moon."*

Table A4 Observations pilot study the creation of stories. The second column answers the question: *Do the children start creating a story within a minute after the introduction finished?* The third column answers the question: *Do the children ask for inspirational help?* The fourth column answers the question: *How often is there a silence during the playing? (i.e. time spans longer than twenty seconds).* The last column answers the question: *Do the children communicate with each other about the story?*

NR	START PLAYING IMMEDIATELY	ASK WHAT TO DO	COMMUNICATION
1	Yes	No	No
2	Yes	Not related to the storytelling task, but one child asked: "Hoe maken we hem weer blij?" [laten astronaut zien]. *"How do we make him happy again?" [shows astronaut].* Children had the idea the goal of the playing was to make all characters happy. The researcher answered not knowing this and encouraged them to explore it themselves.	No
3	No, have to be pushed a little, the researcher encouraged the children to pick up the robot and to explore how the robot would respond.	No, only asks what will all be displayed on the tablet.	No
4	Yes	No	No
5	No, have to be pushed a little, the researcher encouraged the children to pick up the robot and to explore how the robot would respond.	Yes, one child: "Ik snap niet hoe we hier een verhaaltje mee moeten maken?" *"I don't understand how to create a story with this?"*	No

Table A5 Observations pilot study concerning the children's understanding of the storytelling task. Second column answers the question: *Do the children start playing within a minute after the introduction finished?* The third column answers the question: *Do the children ask what they have to do?* The last column answers the question: *Do the children communicate with each other about what they have to do?*

NR	EXAMPLES REACTION ON ROBOT BEHAVIOUR	EXAMPLES COMMUNICATION MEANING BEHAVIOUR

1	• Sad, fear animation:
	  • "Ohoh, ik heb hem al weg" [verplaatst poppetje]. *"Ohoh, I removed him already" [moves doll].*
	  • Moves robot to other position.
	• Fear animation:
	  • Repeat robot: "Brrr"
	• Surprise animation:
	  • Repeat robot: "Hij zei: woooh". *"He said: woooh".*
	• Anger animation:
	  • "Do niet zo boos man" [kijkt Cozmo in zijn gezicht aan]. *"Don't be so angry man!" [looks at Cozmo's face].*
	• Happy, anger animation (wild movements):
	  • "Woooh, waah, cool" [laughing].
		• Character in front of robot:
		  • "Wat zou hij doen?" *"What will he do?"*
		• Recognition emotion per character:
		  • "Nee, kijk, doe de hond weer". *"No, look, lets do the dog again".*
		• Anger animation:
		  • "Kijk, hij is boos". *"Look, he is angry".*
		  • "Hij is boos". --> "Nee, nee, nee, nee". --> "Zet hem op zo'n kleine ster". *"He is angry"* --> *"No, no, no, no".* --> *"Place hem on such a small star".*
		• Placing doll in front of robot:
		  • "Kijk". *"Look".*

NR	EXAMPLES REACTION ON ROBOT BEHAVIOUR	EXAMPLES COMMUNICATION MEANING BEHAVIOUR

1	• Happy, anger animation (when doll placed on robot, robot moves arms up and doll falls off robot):
	  • "Wooooh"
	• Robot pick up:
	  • "Woooh"
	  • Laughing
	• Robot at location:
	  • Placing characters on planet next to the robot: "Welkom". *"Welcome".*
		• "Kijk, dan ziet hij dat meisje en kan hij deze optillen". *"Look, then he sees that girl and he can pick her up".*
		• Happy animation:
		  • Dancing robot: "Kijk, hij is aan het dansen, tutututu". *"Look he is dancing: tutututu".*

2	• Anger animation:
	  • "Ohohoh, hij gaat wel weer weg" [doet hond weg]. *"Ohohoh, he will leave [removes dog].*
	• Anger animation (wild movements):
	  • Child talks to robot: "Oh, niet omver rijden, wat doe je nou!" [boze stem]. *"Oh, do not override, what are you doing!" [angry voice].*
	• Surprise animation:
	  • Repeats Cozmo: "Ooooh".
	• Anger animation:
	  • Talks to face robot: "Niet doen!" *"Do not do that!"*
	• Happy animation:
	  • Behaviour robot confirms what children saw on the tablet: "Ja!" *"Yes!"*
		• Fear animation:
		  • "Nou is hij helemaal boos, we gaan mooi weg" [rijdt robot weg]. *"Now he is completely angry, we go" [drives robot away].*
		• Anger animation:
		  • "Hij is boos". *"He is angry".*
		• Sad animation:
		  • "Ze zijn allemaal droevig". --> "Hij gaat mooi weg [haalt Cozmo weg van poppetjes]. *"They are all sad". --> "He will leave" [takes Cozmo away from dolls].*

3	• Robot pick up:
	  • Children smile
	• Happy animation:
	  • "Wooh" [smiling]
		x

4	• First time a doll in front of Cozmo:
	  • Children completely surprised, asks researcher: "Hoe vindt hij hem?" *What does he think about him?"* Researchers says to look at tablet.
	• Fear animation:
	  • "Woowh, cool"
	• Anger animation:
	  • Children laugh, smile
	• Surprise animation:
	  • Children repeat what he said: "Wooh"
	• Anger animation (Cozmo becomes wild and knocks down dog):
	  • Several times: look specifically at Cozmo's face: "goh, oh" [laughing, smiling]
		• Surprise animation:
		  • "Daar is hij niet zo bang voor". *"He is not that scared for this one".*
		• Disgust animation:
		  • "Dat is saai" [pakt poppetje weg]. *"That is boring" [Removes doll].*
		  • "Hij huilt van een kindje". *"He cries because of a child".*
		• Fear animation:
		  • "Hij is bang" --> "Ja, hij is bang". *"He is afraid" --> "Yes, he is afraid".*

5	x [video data lost]	x [video data lost]

Table A6 Observations pilot study concerning the children's understanding of the robot behaviour. The second columns provides examples of answers to the question: *How do children react when the robot changes its behaviour?* The last column provides the question: *What do children communicate with each other about the meaning of the behaviour?*

NR	EXAMPLES REACTION ON TABLET CONTENT	EXAMPLES COMMUNICATION MEANING CONTENT

1	• Astronaut:
	  • "Ohohoh"
	• Dog:
	  • Add sounds to anger smile: "Grr"
		• First doll:
		  • "Hij zegt wat, hij zegt wat" [stoot ander kind aan]. *"He says something, he says something" [pushes other child].*
		• Dog:
		  • "Hij is boos op de hond". *"He is angry at the dog".*
		• Child:
		  • Child guesses emotion upfront: "Hij wordt blij, kijk" [wijst tablet aan]. *"He becomes happy, look [points at tablet].*
		• Moon:
		  • "Ja, hij is vrolijk, de maan maakt hem vrolijk". *"Yes, he is happy, the Moon makes him happy".*
		• Planet:
		  • "Ja kijk, hier is hij blij mee". *"Yes look, he is happy with this".*

2	• Earth [bug prototype, no image earth, only smiley]:
	  • Child moves head in front of face robot and asks: "Waarom ben jij verdrietig?" *"Why are you sad?"*
	• When the robot did not show any happy behaviour for a while, the children got more nonchalant: "Ah, jij ook weg" [gooit poppetje weg]. *"Ah, you go as well" [throws away doll]. --> Other child laughs*
		• Dog:
		  • "De hond is ook boos". *"The dog is also angry".*
		• Woman:
		  • "Dit is dit poppetje, hij is verdrietig" [wijst poppetje aan]. *"That is this doll, he is sad" [points at doll].*
		  • "Hij is verdrietig, kijk" [wijst tablet aan]. *"He is sad, look". [points at tablet].*
		  • "Oh, deze is nou een beetje droevig". *"Oh, this one is a bit sad now".*
		• Astronaut):
		  • "Hij schrikt, de astronaut schrikt". *"He is scared, the astronaut is scared".*
		• Child:
		  • "De baby is niet blij" [kijkt naar tablet]. *"The baby is not happy" [looks at tablet].*
		• Man/Woman:
		  • "Hij vindt hem leuk, de robot vindt hem leuk, misschien zij ook?" [laat vrouwtje zien aan robot]. Geen vrolijke lach op tablet. "Ohnee, zij moet weg" [zet poppetje weg]. *"He likes him, de robot likes him, maybe her as well?" [shows woman to robot]. No happy smile displayed on tablet: "Oh no, she has to go" [removes doll].*
		• Man:
		  • "Deze vind je aardig". *"This one you like".*
		  • Several times: "Ja hij is blij" [wijst tablet aan]. *"Yes, he is happy" [points at tablet].*
		  • "Oh, hij is blij" --> "Kijk" [wijst naar tablet] --> "Die is blij" [wijst poppetje aan]. *"Oh, he is happy" --> "Look" [points at tablet] --> "That one is happy" [points at doll]*
		  • "Deze is blij [lacht] en misschien de baby ook?" --> Geen vrolijke lach op tablet: "Nee, jij gaat weg, doei" [gooit poppetje weg]. "En de hond dan?" --> Geen vrolijke lach op tablet: "Aagh, ook weg". *"This one is happy [laughs] and maybe the baby as well? --> No happy smile on tablet: "No, you go, bye [throws away doll]. "What about the dog?" --> No happy smile on tablet: "Aagh, you go as well".*
		• After many "not happy" smiles:
		  • "Hij is overal boos op, hij vindt niemand aardig". *"He is angry at everyone, he does not like anyone".* Finally [move robot away from characters]

NR	EXAMPLES REACTION ON TABLET CONTENT	EXAMPLES COMMUNICATION MEANING CONTENT

3	x	• Man:
		  • "Dat is dit poppetje" [wijst poppetje aan]. *"That is this doll" [points at doll].* --> "Ja, dat zie ik". *"Yes, I see".*
		• Alien:
		  • "Kijk hij ziet dit robotje". *"Look he sees this robot".*
		• Child:
		  • Children start laughing, since in the story the girl and Cozmo get a long quite well, whereas on the tablet a disgust smiley is shown: "Nee, kan niet goed met robot, omdat hij er boos van wordt". *"No, cannot get along with the robot, since he becomes angry of it".*

4	x	• First doll (alien):
		  • "Hij zegt...". *"He says...".* --> "Hij is bang". *"He is scared".*
		• Woman:
		  • Kijk dat ziet hij [wijst smiley aan]. Look that is what he is seeing [points at smiley]
		• Astronaut:
		  • "Wooh, zei hij". *"Wooh, he said".*

5	x [video data lost]	x [video data lost]

Table A7 Observations pilot study concerning the children's understanding of the tablet content. The second column provides examples of answers to the question: *How do children react when the content on the tablet changes?* The last column provides examples of answers to the question: *What do children communicate with each other about the meaning of the content?*

NR	OTHER NOTES
1	• Already start playing with the dolls before they are introduced to the activity • Before introduced to the activity, one child says: "Zijn ze in de ruimte? Dit is de aarde... [wijst de aarde aan], dit is de maan [wijst de maan aan], de aarde draait zo [roteert armen]. *"Are they in space? This is earth… [points at earth], this is the moon [points at the moon], the earth turns like this [rotates arms].* • Researcher explains that the robot cannot drive, one child says: "Maar het is een auto?" *"But it is a car?"* • Greet Cozmo: "Hallo" [zwaait naar Cozmo en kijkt hem aan]. *"Hello" [waves to Cozmo and looks into his eyes].* • Children wave to Cozmo, reaction: "Hij zegt niks". *"He does not say anything".* • In the beginning the children instruct Cozmo where he has to move to and what he has to do, children believe the robot can hear them • Children place robot on shed
2	• Try to see what happens when placing different characters in front of the robot: "Die dan, en deze dan?" *"What about this one, and that one?"* • One of the children specifically looks at the face of the robot to see what he feels • The other child mainly looks at the tablet. • Produce character sound when placing character in front of the robot: "Hoooi". *"Hai".* • Place whole family in front of the robot to see what happens • Place Cozmo into the shed and tell him he is not allowed to go out [laugh] • Place shed in front of Cozmo to see if he reacts • Think that the message on the tablet means how the character feels about the robot instead of the other way around

NR	OTHER NOTES
2	• See it the playing as a puzzle: try to make characters happy, for example by guessing the man should be placed in the farms and the astronaut should be placed in space. • Then: mainly look at the tablet smilies, since the tablet reacts faster to their actions, and, therefore, they can speed up the "puzzling process" • Try to make the characters happy again • One child instructs Cozmo he needs to talk: "Jij moet praten". *"You must to talk".* • Once mentioned about Cozmo: "En dit is hun auto". *"And this is their car".* • Child in front of Cozmo, late wOZ: "Daar doet hij niks... " [kijkt bewust naar gezicht robot] . *"There he does not do anything" [specifically look at Cozmo's face].* • "Wat is hij toch allemaal aan het doen? Ik snap er niks van". *"What is he doing all the time? I don't get it".*
3	• One child shifts tablet towards the other child and instructs this child to look at the tablet whereas she is going to pick up the robot • Girl is really focused on creating her own story, she does not notice the robot behaviour interfering with her story, since she is not using the robot as character in her story at that moment • Boy mostly listens to story made by the girl, and watches the responses of the robot and images on the tablet • Children are quite calm • Interview, some confusion in guessing emotions, since Cozmo showed neutral mode (humming) in between, which was seen the robot feeling happy
4	• Before introduced to activity: boys wave to Cozmo and look at his face, gently move robot arms • Boys are really focused and concentrated during the whole session • Continuously change their attention from the tablet to Cozmo and back • Fiddling with dolls during play continuously • Often specifically turn their heads to be really in front of Cozmo's face • Put only the straps of the alien in front of the robot to see if he also reacts on this • Change a few times several dolls in front of the robot without really reacting to it, busy with observing what happens, however, smile at faces • Place multiple dolls together in front of Cozmo to see what happens • When it takes a while before Cozmo shows an animation, children look at the tablet to see if tablet provides a message • Alternately place a doll in front of Cozmo, without really communicating about it • During the start of the interview, the children do not really pay attention to the researcher, they are still focused on the robot and the dolls • When said robot is turned off during interviews, children still keep on fiddling with the dolls during the interview • The humming of the idle animation can follow quickly on another animation, this might be confusing • Pickup animation might be confusing, since nothing is shown on the tablet, children might think the animation belongs to previous content on tablet • No story created, only look at what happens when placing robot at different location or showing different character
5	• Youngest child does understand the robot behaviour better than the older child • Half way the playing the tablet application was changed towards normal tablet screen, however, children continued playing by only looking at Cozmo's behaviour • Children place Cozmo onto the house • Tablet image planet did not show when pressing the planet wOZ button, therefore only the sad smiley was shown on the tablet, however, the children understand from this smiley that the robot did not like Earth • The youngest child understands the emotion also changes based on location • No story created, only look at what happens when placing robot at different location or showing different character

Table A8 Other remarks observations pilot study

A4 Interview Results Pilot Study

GENERAL QUESTIONS

NR	AGE & GENDER	STORY SUMMARY	EMOTIONS ROBOT IN STORY
1	M(8) & M(8)	Over dat Cozmo nieuwe vriendjes leert kennen. En deze vond hij een beetje stom [pakt aliën]. En hij reisde naar allemaal planeten. *About that Cozmo gets to know new friends. And this one he found a bit stupid [grasps alien]. And he travelled to all kind of planets.*	Vrolijk, boos, bang. *Cheerful, angry, scared.*
2	M(10) & M(10)	Dat hij deze mensen alleen maar mocht [wijst mannetje aan] en hun niet [wijst alien aan], en deze ook [laat vrouwtje zien]. *That he did like these people [points at man], but did not like them [points at alien] and this one as well [shows woman].*	Not asked, see story summary.
3	M(6) & F(8)	Over een astronautje dat de robot ontdekte en dat verkocht aan wat mensen en toen ontdekte hij heel veel planeten en op een planeet was een huis en toen kwam hij twee keer in de krant te staan en toen was hij beroemd. *About an astronaut that discovered the robot and sold this to some people and then he discovered many planets and on one planet was a house and then he ended up in the paper twice and then he was famous.*	• Bij het astronautje doet hij zo: "wat is dat ofzo" [imiteert Cozmo met open mond]. *When seeing the astronaut he does like this: "what is that or so?" [imitates Cozmo with open mouth].* • Bij de hond was hij boos [imiteert wilde arm bewegingen robot]. *When seeing the dog he was angry [imitates wild arm movements robot].* • En bij deze [pakt mannetje op en trekt een glimlach]. *And for this one [grasps male doll and portrays a smile].* • En bij deze werd hij verdrietig [pakt kindje op]. *And for this one he got sad [grasps child doll].*
4	M(5) & M(6)	Asked, but no answer [no story created].	Eng, blij, boos. *Scared, happy, angry.*
5	F(5) & F(8)	Not asked [no story created].	Verdrietig, blij, boos. *Sad, happy, angry.*

Table A9 Results interviews pilot study

SIGNAL	TABLET MESSAGE
Tablet: Dat zag je hier met een smiley [wijst tablet aan]. *You saw this here with a smiley [points at tablet].* **Robot:** Hij rijdt achteruit en ging met dat ding zo [imiteert arm beweging robot]. *He drives backwards and did with that thing like this [imitates arm movement robot].*	Not specifically asked, see signal.
Tablet: Omdat hij dat laat zien [wijst tablet aan]. *Because he shows that [points at tablet].* **Robot:** Liet niks zien, alleen tablet. *Did not show any response, only tablet did.*	Not specifically asked, see signal.
Tablet: Een zielige smiley. *A sad smiley.* **Robot:** Ja volgens mij, uit zijn ogen kwamen een soort van tranen ofzo, tenminste zo leek het: allemaal kleine spikkeltjes. *Yes, I think, out of his eyes came sort of tears, at least, that is how it looked like: all kind of small speckles.*	Not specifically asked, see signal.
Tablet: Allemaal dingen op de iPad. *All kind of things on the iPad.* **Robot:** Ja, blij, heel blij. *Yes, happy, very happy.*	Not specifically asked, see signal.
Tablet: Smiley's en gezichtjes. *Smilies and faces.* **Robot:** Aan zijn gezicht, geluidjes, bewegingen en lampjes. *By his face, sound, movements and lights.*	

QUESTION ROBOT EMOTION

NR	EMOTION	GUESSED EMOTION CHILD 1	GUESSED EMOTION CHILD 2	REMARKS
1	Happy	Vrolijk. *Cheerful.*	Super vrolijk. *Super cheerful.*	
	Sad	Verdrietig. *Sad.*	Verdrietig. *Sad.*	
	Anger	Boos. *Angry.*	Boos. *Angry.*	"Dat gebeurde ook". *"That happened too".*
	Fear	Bang. *Scared.*	Bang. *Scared.*	"Dat deed hij ook toe hij deze zag" [laat astronaut zien]. *"That did he too when he saw this one [Shows astronaut].*
	Surprise	Verbaasd. *Surprised.*	Verbaasd. *Surprised.*	"Woowh".
	Disgust	Streng. *Strict.*	Boos-achtig. *Anger-like.*	
2	Happy	Blij. *Happy.*	x	"Hij lacht". *"He smiles".*
	Sad	x	Eenzaam. *Lonely.*	
	Anger	Boos. *Angry.*	x	
	Fear	Bang. *Scared.*	Heel boos. *Very angry.*	
	Surprise	Verbaasd. *Surprised.*	Mooi, dat hij iemand mooi vindt. *Beautiful, that he thinks someone is beautiful.*	
	Disgust	Boos. *Angry.*	Dat hij iets niet leuk vindt. *That he does not like something*	
3	Happy	Not asked	Not asked	
	Sad	*Sad*	Weet ik niet, verdrietig of iets, misschien heel erg geschrokken en dat hij dan verdrietig wordt, omdat hij ergens van geschrokken is. *I don't know, sad or something like that, very shocked and then he gets sad, because he is shocked.*	

NR	EMOTION	GUESSED EMOTION CHILD 1	GUESSED EMOTION CHILD 2	REMARKS
3	Anger	Boos. *Angry.*	Boos. *Angry.*	"Want hij deed zo" [imiteert wilde armbeweging Cozmo]. *"Because he did like this" [imitates wild arm movement Cozmo].*
	Fear	Verdrietig. *Sad.*	Verdrietig. *Sad.*	"En hij deed zo" [imiteert Cozmo met ogen dicht]. *"And he did like this" [imitates Cozmo with closed eyes]*
	Surprise	Geschrokken. *Shocked.*	Geschrokken. *Shocked.*	
	Disgust	Not asked	Not asked	
4	Happy	Blij. *Happy.*	Boos. *Angry.*	
	Sad	Verdrietig. *Sad.*	x	
	Anger	Boos. *Angry.*	Boos. *Angry.*	
	Fear	Bang. *Scared.*	x	
	Surprise	Weet ik niet. *I don't know.*	x	
	Disgust	Weet ik niet. *I don't know.*	x	
5	Happy	Heel erg blij. *Very happy.*	Blij. *Happy.*	
	Sad	Verdrietig. *Sad.*	Verdrietig. *Sad.*	
	Anger	Boos. *Angry.*	Boos. *Angry.*	
	Fear	Bang. *Scared.*	Bang. *Scared.*	
	Surprise	Mooi. *Nice.*	Blij. *Happy.*	
	Disgust	Boos. *Angry.*	Blij. *Happy.*	

Table A10 Guessed emotions in the pilot study

A5 Interview Results Second Study

CONDITION NE

NR	AGE & GENDER	TELL AT HOME	APPRECIATION STORYTELLING	APPRECIATION ROBOT
NE1	F(7) & F(7)	Dat we met de robot hebben gespeeld. *That we played with the robot.*	😊😊	😊😊
NE2	F(7) & F(8)	Ik heb met een robot gespeeld. En die heet Cozmo. *I played with a robot. And his name is Cozmo.*	😊😊	😊😊
NE3	M(8) & M(8)	Dat ik de robot heb geholpen en met hem heb gespeeld. En dat de school heel, heel leuk is. En dat de robot er leuk uit ziet. *That I helped the robot and played with him. And that school is really, really nice. And that the robot looks really nice.*	😊😊	😊😊
NE4	M(8) & M(8)	Dat we Cozmo hebben geholpen. *That we helped Cozmo.*	😊😐	😊😊
NE5	M(7) & M(7)	Uhm, dat er allemaal soort van plaatjes zijn van een wereld. En dat [naam ander kind] mocht uitkiezen naar de maan of naar Saturnus of naar de echte wereld. Hij koos voor de maan en de robot ging er naar toe. En dat ik ook een echte robot heb gezien. *Uhm, that there were all kind of images of the world. And that [name other child] could choose to go to the moon, Saturnus or the real world. He chose the moon and the robot went there. And that I saw a real robot.*	😊😊	😊😊
NE6	F(6) & F(7)	Ik had een spelletje gedaan, dat ging met de robot. En daar waren ook poppetjes. En daar gingen we mee spelen. Toen hadden we een tablet. De robot stond ergens, toen moest hij naar de maan, hij zei: “ik wil hil graag naar maan”. Toen hadden we hem gebracht: eerst naar de wolken, land en toen was hij bij de maan. *I played a game, with the robot. And there were figures too. We played with them. Then,we had a tablet. The robot was standing somewhere and had to go to the moon, he said: “I would like to go to the moon”. Then we brought him, first to the clouds and to the land and then he was at the moon.*	😊😊	😊😊

STORY SUMMARY	FEELINGS ROBOT	ADAPTATION STORY
Het ging over een robot. Ik weet het niet. *It was about a robot. I don't know.*	Heel erg blij. Ze voelde zich echt blij met ons, omdat wij hebben haar naar de maan hebben gebracht. *Really happy. She felt really happy with us, since we brought her to the moon.*	No answer.
Over een robotje die speelde op de maan. En dat hij avonturen ging meemaken. *About a little robot that played on the moon. And about him making adventures.*	Blij. Omdat de tablet zei: "Joepie, eindelijk op de maan". *Happy. Because the tablet said: "Joehoe, finally on the moon".*	No answer.
Over dat de robot naar de maan wou en dat hij een schild wou. Ja, dan kan de robot zich beschermen. En dat iemand hem moest helpen. *About a robot that wanted to go to the moon and wanted a shield. Yes, then he can protect himself. And someone needed to help him.*	Deze [wijst naar meest blije smiley op smiley schaal]. Heel leuk. Waarom?: Omdat dat op de iPad stond en ik kon het zien aan zijn gezicht. *This one [points at most happy smile at smiley scale]. Really nice. Why?: Because that was shown on the iPad and I could see it at his face.*	Yes, "Why-question": no answer
We moesten Cozmo helpen om naar de maan te gaan. Eerst ging hij een racket regelen en een ruimteschip om naar de maan te vliegen. *We had to help Cozmo to get to the Moon. First, he arranged a rocket and a space ship to fly to the moon.*	Ik denk wel leuk. Omdat hij heel graag naar de maan wilde en hij is er. *I think he liked it, because he wanted to go to the moon and he is at the moon now.*	Gedaan wat we zelf wouden. *Done what we wanted ourselves.*
Dat hij volgens mij... nou ik weet het nou niet meer. *That he, I think... well, I don't know.*	Wel leuk. En hij vond het ook leuk om hier naar toe te gaan [wijst maan aan]. *Quite nice. And he also liked to go here [points at moon].*	Ja. Hij was een beetje verdrietg en boos en hij was heel erg blij. *Yes. He was a bit sad and angry and he was very happy.*
Not asked, see question "tell at home".	Leuk [geen uitleg]. *Nice [no explanation].*	Not asked.

NR	AGE & GENDER	TELL AT HOME	APPRECIATION STORYTELLING	APPRECIATION ROBOT
NE7	F(7) & F(6)	Het was leuk. En dat, die robot [wijst naar robot], dat je die op de maan kan zetten. En dat hij grappig is en dat hij een rare naam heeft. En die popptjes zijn grappig. *It was fun. And that one could place that robot [points at robot] at the moon. And that he is funny and that he has a strange name. And the figures are funny.*	😊😊	😊😐
NE8	M(6) & F(7)	Dat je met een robotje hebt gespeeld. En zeggen hoe het was. En dan zeg je dat je op de computer hebt gespeeld en wat je dan moest doen. *That one played with a little robot. And then one tells how it went. And then one tells one plays on a computer and what one had to do.*	😊😊	😊😊
NE9	M(7) & M(6)	Ruimte gezien, en we gingen Cozmo helpen door de blokjes en poppetjes te geven. *Saw space, and we were helping Cozmo by providing him with blocks and figures.*	😊😊	😊😐
E1	M(9) & F(8)	Ik heb met een robot gewerkt. We mochten hem naar verschillende landen brengen. *I worked with a robot. We could bring him to several countries.*	😊😊	😊😊
E2	F(7) & F(7)	Vertellen hoe je met de robot omgaat. Dat je er voorzichtig mee moet zijn. *How you should take care of the robot. That you have to be careful with it.*	😊😊	😊😐
E3	M(6) & M(8)	Met de robot spelen. *Playing with the robot.*	😊😐	😊😊
E4	F(8) & F(7)	Dat we Cozmo hebben geholpen. En dat we dingen met hem mochten doen en dat we gingen spelen met Cozmo. En dat we het leuk vonden. *That we helped Cozmo. And that we were allowed to do things with him and that we went playing with Cozmo. And that we liked it.*	😊😊	😊😊

STORY SUMMARY	FEELINGS ROBOT	ADAPTATION STORY
Leuk. Het verhaaltje ging over dat hij heel veel mensen tegen kwam. Hij kwam ook een aliën tegen en een hondje en een astronaut. En een kindje en een mama en een papa. *Nice. The story was about that he met a lot of people. He also met an alien, and a dog and an astronaut. And a little child and a mum and a dad.*	Ik denk goed. Grappig, hij vindt het grappig. Omdat hij het denk ik leuk vond, omdat hij nu eindelijk bij de maan is. *I think good. Funny, he thinks it is funny. Because, I think, he liked it, because he is finally at the moon.*	Wat we zelf al wilden doen. *What we already thought of ourselves.*
Dat weet ik niet meer. *I don't know anymore.*	Leuk. Omdat ik het ook leuk vond. Ja, ik ook. *Nice. Because I liked it too. Yes, me too.*	Ik probeerde dat zelf. *I tried myself.*
Weet ik niet meer. *I don't know anymore.*	Heel blij, omdat wij hem hielpen. En moe, anders kon hij wel rijden. *Very happy, because we helped him. And tired, otherwise he would have been able to drive.*	Zelf bedacht. *Thought of ourselves.*
Cozmo moest naar de maan. *Cozmo had to go to the moon.*	Blij. Omdat hij "ja" ging schudden. Omdat je dat ook kon zien aan de ogen, dan kan je zien of hij boos is of blij. Happy. *Because he was nodding "yes". You could see it at his eyes, you can see if he is angry or happy.*	Gewoon doen. *Just done.*
Nee, dat lijkt me een beetje lastig. *No, that is a bit difficult.*	Not asked.	Doorgegaan met wat we al bedacht hadden. *Continued with what we already thought of.*
Over de robot. Hij moest ergens naar kijken. *About the robot. He had to look at something.*	Een beetje boos en een beetje bang. En heel leuk. Hij was heel blij. *A bit angry and a bit scared. And really nice. He was really happy.*	Ja [Geen uitleg]. *Yes. [No explanation]*
Over Cozmo die naar de maan wilde en ging reizen. Hij had eerst een raket nodig en een kaart en hij wou naar de maan. Hij had een raket en eten en drinken en hij zag de ruimte en een astronaut. De astronaut vertelde de dingen over de maan. *About Cozmo who wanted to go to the moon and started travelling. He needed a rocket first and a map and he wanted to go to the moon. He had a rocket and some food and drinks and he saw the space and an astronaut. The astronaut told things about the moon.*	Heel leuk. Hij vond het heel leuk dat hij op de maan was. *Hij was heel blij. Very nice. He liked it very much that he was on the moon. He was very happy.*	Iets bedacht. *Thought of something.*

NR	AGE & GENDER	TELL AT HOME	APPRECIATION STORYTELLING	APPRECIATION ROBOT
E5	M(6) & M(7)	Dat we naar de maan zijn geweest. Samen met [naam andere leerling] naar de maan. *That we went to the moon. Together with [name other child] to the moon.*	😊😊	😊😊
E6	F(6) & F(6)	Ik heb met de robot gewerkt. En ik vond het leuk. *I worked with the robot. And I liked it.*	😊😐	😊😊
E7	M(7) & M(6)	Niks. Ik ga zeggen dat ik met robots heb gewerkt, met een kleine baby robot. *Nothing. I will tell that I worked with robots, with a little baby robot.*	😊😐	😊😐
E8	M(6) & **M(6)**	Met de robot gewerkt en naar de maan gegaan. *Worked with the robot and travelled to the moon.*	😊	😊

Table A11 Results interviews second study

STORY SUMMARY	FEELINGS ROBOT	ADAPTATION STORY
Over de maan. Drie vrienden gingen mee, en ook eten mee, een kaart, een schild en een cadeau en een ruimteschip maken en een ruimtepak en gereedschap. En de maan. En de hond. About the moon. *Three friends went with him, and also food and a map, and a shield and a present and building a space ship and space suit and tools. And the moon. And the dog.*	Blij. Soms een beetje boos en soms niet een beetje boos. *Happy. Sometimes a bit angry and sometimes not a bit angry.*	Gedaan wat we al bedacht hadden. *Done what we already thought of.*
No answer	Blij. Omdat we hem wat hebben geleerd. *Happy. Because we taught him something.*	Gedaan wat we zelf hebben bedacht. *Done what we already thought of ourselves.*
Over de robot, die je niet kon besturen. *About the robot, that you could not control.*	Not asked [children flew away]	Not asked [children flew away]
Over Cozmo die kwam een astronaut tegen. *About Cozmo, he met an astronaut.*	Blij en verdrietig en boos: hij wilde geen gereedschap. Happy and sad and angry: *he did not want to have the tools.*	Gedaan wat ik zelf wilde. *Done what I thought of myself.*

A6 Observations Second Study

NR	AGE & GENDER	UNDERSTANDING TABLET INTERACTION	COMMUNICATION SELECTIONS	QUALITY STORY LOG
NE1	F(7) & F(7)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Koopt". *"Buys"*, "Een poppetje". *"A figure"*, "Krijgt misschien?". *"Recieves maybe?"*, "Cadeautje". *"Present"*. • Indirectly mention selection aloud (e.g. "Uhm, volgens mij wil hij deze". *"Uhm, I think he wants this one"*, "Die?" *"That one?* • Press buttons without telling anything aloud	• Robot at charger: already recognised flag of Africa before children moved him there. Therefore, tablet application was restarted to show children again. Previous actions not stored in log. • Really small story (one action).
NE2	F(7) & F(8)	Correctly select elements on tablet.	• Indirectly mention selection aloud (e.g. "Doe maar". *"Go ahead"*, "Deze". *"This one"*, "Hier". *"Here")*	• Okay, story saved is story created. • Really small story (one action).
NE3	M(8) & M(8)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Een racket". *"A rocket"*, "Een kaart". *"A map"*, "Schild, nee hamburger". *"Shield, no hamburger"*, "Koopt". *"Buys"*) • Indirectly mention selection aloud (e.g. "Uhm, dit". *"Uhm, this"*, "Die, niet deze". *"That one, not this one"* , "Deze". *"This one")*	• Accidentally pressed wrong button, therefore, the tablet application closed and had to be restarted. Previous actions not stored in log. • First time: really small story (one action).

UNDERSTANDING PLACEMENT OBJECT BLOCKS & FIGURES	UNDERSTANDING MOVEMENT COZMO	CHILD REMARKS ABOUT ROBOT	OTHER NOTES

x	After the researcher explains they have to read the text on the help screen, they understand. Researcher encourages them to pick up the robot, since children were doubting if they were allowed to. Afterwards they correctly move the robot the another location	• When arriving:
		  • "Oh dat is een schatje". *"Oh that is a cute one".*
		  • "Oh die is leuk". *"Oh that one is nice".*
		  • "Is dat een echte robot?" *"Is that a real robot"*
		• "Kan hij ons horen?" *"Can he hear us"?*
		• "Kan hij rijden?" *"Can he drive?"*
			• After reading intro screen: "Maar hoe komt hij dan bij de maan?" *"But how does he reach the moon?"* --> Select action "go to", to go to the moon immediately, but the moon is not in the list, they ask: "is dit de maan?" [wijzen naar de zuidpool] *"is this the moon?"* [point at south pole] --> Researcher interferes and explains going to the moon is not possible yet. --> Child repeats: "Maar hoe komt hij dan bij de maan? *"But how does he go to the moon then?* --> The other child responses: "Vanaf Nederland met de racket naar de maan". *"From the Netherlands with a rocket to the moon".*

Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Not immediately. Children start with dragging over line on tablet; they think they have to move the image of the robot on the tablet. Researcher interferes and tells them to move robot physically. From then on: no need to read the help text, understand they have to move the robot.	• "Praat hij ook?" *"Does he talk?"* • Robot recognises location flag, researcher says: "Hij zag het". *He saw it".* Although no emotion animation, child says: "Zo te zien aan zijn ogen wel, ja". *"It seems like it from his eyes, yes".*	• Wave at Cozmo when entering
Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After reading the text on the help screen they immediately move Cozmo.	• "Kan je hem woedend maken?" *"Can you make him angry?"* • First time robot thought bubble on tablet, refer to robot: "Waarom doettie niks?" *"Why doesn't he do anything?* • "Waarom beweegt hij nooit?" *"Why doesn't he move?"*	• Wave at Cozmo when entering: "Hallo". *"Hello".* • One boy presses "yes" to bring the robot to the moon. --> Other child responses: "Neeee, hij moet nog een pak aan". *"Noooo, he should still wear his suit".* • One child continuously asks when they can play with the robot, the other child seems to like creating the story already. • When showing a new object to the robot, they refer to the robot's recognition: "Ja hij hebt hem, in een keer". *"Yes, he got him, in one time".*

NR	AGE & GENDER	UNDERSTANDING TABLET INTERACTION	COMMUNICATION SELECTIONS	QUALITY STORY LOG
NE4	M(8) & M(8)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Ik weet welke, de ruimteman". *"I know which one, the space man"*, "Ruimteschip". "*Rocket ship*", "Een cadeau". *"A present"*, "Doe maar, naar de maan". *"Go ahead, to the moon"*, "Kopen". *"To buy"*, "Wat maakt". *"What makes"*, "Praat met". *"Talks to"*, "Neemt mee". *"Takes with him*) • Indirectly mention selection aloud (e.g. "Ja, die". *"Yes, that one"*, "Die, niet deze". *"That one, not this one"*, "Doe maar". "*Go ahead)* • Press buttons without telling anything aloud	• Okay, story saved is story created.
NE5	M(7) & M(7)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Een cadeautje". *"A present"*, "De kaart". "The map", "Kopen". *"To buy"*) • Press buttons without telling anything aloud	• Okay, story saved is story created. • Really small story (one action).
NE6	F(6) & F(7)	Correctly select elements on tablet.	• Directly mention selection aloud(e.g. "Die, een kaart". *"That one, a map"*, "Hier naar toe". *'To here"*, *"Hier? "Here?"*, "Gaat naar". *"Travels to")* • Indirectly mention selection aloud (e.g. "Met die?". *"With this one?"* ,"Zullen we die doen?". "*Shall we do this one?"*, *"Die"*. *"That one"*)	• Okay, story saved correctly.

UNDERSTANDING PLACEMENT OBJECT BLOCKS & FIGURES	UNDERSTANDING MOVEMENT COZMO	CHILD REMARKS ABOUT ROBOT	OTHER NOTES
Do understand interaction. After looking at the help screen they immediately look for the object block / figure. Initially place icon rotated towards Cozmo, after researcher interferes and explains icon should be on top, they place it correctly rotated in front of Cozmo.	Do understand interaction. After the researcher explains they have to read the text on the help screen, they immediately move Cozmo.	• "Lieve Cozmo, hoor je me?" *Dear Cozmo, can you hear me?* • "Kan hij rijden?" *"Is he able to drive?"* • "Cozmo is grappig". *Cozmo is funny".*	• Talk to robot to meet him: "Hi Cozmo" • Stroke Cozmo • Before starting: "Ik vind dit leuk". *"I like this".* • Selected rocket: "Maar hoe komt hij er dan in?" *"But how does he get in?"* • Reasoning: "Hij wil meer vriendjes maken". *"He wants to make more friends".*
Initially think the robot would drive to the object block / figure. After researcher explains they have to look at the tablet, they understand they have to perform an action. Initially place icon rotated towards Cozmo, after researcher interferes and explains icon should be on top, they place it correctly rotated in front of Cozmo. When having an action including both a character and an object, they placed the figure in front of the robot instead of the object block.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	• About size robot: "Ik had groter verwacht". *"I expected it to be larger".* • "Hij kan ook zo zijn ogen klein maken. *"He can also make his eyes small".*	• One boy wants to presses "yes" to bring the robot to the moon. --> Other child responses: "Neeee, hij moet een pak". *"Noooo, he needs a suit".* • "Ik vond hem eigenlijk wel super leuk deze plaat". *"I actually did really like this mat".*
Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	x	• Press map icon, action "go to", because they think it means the robot uses a map. • Select "go to" to go to the moon • Let robot travel all around the map, when he is at the location closest to the moon they say he is ready to go to the moon.

NR	AGE & GENDER	UNDERSTANDING TABLET INTERACTION	COMMUNICATION SELECTIONS	QUALITY STORY LOG
NE7	F(7) & F(6)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Komt tegen". *"Meets"*, "En nu praat met". *"And now talks to"*, "Een plantje". *"A little plant"*, "Astronaut", "Praat met de hond", *"Talks to the dog"*) • Indirectly mention selection aloud (e.g. "Deze". "*This one*", "Die". *"That one"*, "Ja, doe die". *"Yes, do that one"*) • Press buttons without telling anything aloud	Okay, story saved correctly.
NE8	M(6) & F(7)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Een snack-je". *"A little snack")* • Press buttons without telling anything aloud	Okay, story saved correctly.
NE9	M(7) & M(6)	Correctly select elements on tablet.	Sound lost	Okay, story saved correctly.
E1	M(9) & F(8)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Raket". *"Rocket"*, "Kaart". *"Map"*, "Doe maar de raket". *"Do take the rocket"*, "Naar de noordpool". *"To the north pole"*, "Tropisch eiland". *"Tropical island"*, "Naar de bestemming gaan". "*Going to the destination*", "Gaan naar". *"Go to"*, "Vinden", *"Find"*) • Press buttons without telling anything aloud	Okay, story saved correctly.
E2	F(7) & F(7)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Ik denk wel dat hij wat mee moet nemen: in een raket". *"I do think he needs to take something: in a rocket"*, "Hij moet wel wat meenemen". *"He needs to take something"*, "Eten". *"Food"*, "Hij moet ook hulp meenemen". *"He also needs to take help with him"*) • Indirectly mention selection aloud (e.g. "Die en dit". *"That one and this"*)	• Okay, story saved is story created. • Really small story (one action).

UNDERSTANDING PLACEMENT OBJECT BLOCKS & FIGURES	UNDERSTANDING MOVEMENT COZMO	CHILD REMARKS ABOUT ROBOT	OTHER NOTES
Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	• When reading intro text: "Hij luistert". *"He listens".*	• Thought bubble on tablet: "Hij heeft hem gezien". *"He saw him".* • "Go to" screen on tablet: "Waar is de maan?" *"Where is the moon?"* • "Dit is echt heel leuk". *"This is really nice".*
Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	• "Hij knippert". *"He blinks"* • "Cozmo heeft blauwe ogen en vierkante". *"Cozmo has blue eyes and rectangular ones"*	• Meet Cozmo: "Hi Cozmo" • Children think icon receive and give action represents a present as an object, whereas it represents the action. • Thought bubble screen tablet: "Die heeft hij gezien". *"He saw that one".*
Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	Sound was lost	Sound was lost
Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	• "Oh, zijn ogen". "Oh, his eyes". • "Mijn robot thuis kan wel praten". *"My robot at home is able to talk"*	• Immediately press the *"goes to"* action to select the moon. Researcher asks the children if it is already possible to go to the Moon. When they understand this is not possible yet, they explain: "Nee, nog niet hij heeft nog een raket nodig". *"No not yet, he still needs a rocket".* • Randomness emotions: • Do not react differently to (varying) emotions for an item already used as an item used for the first time.

Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	x	• Reasoning:
			  • "Eten, dan kan hij niet dood gaan". *"Food, then he cannot die".*
			  • "Hij moet ook nog een raket mee, want anders kan hij niet naar de maan". *"He also needs to take a racket, otherwise he cannot go to the moon".*
			• Randomness emotions:
			  • Mainly explore all unused items
			  • Do not react differently to (varying) emotions for an item already used as an item used for the first time.

NR	AGE & GENDER	UNDERSTANDING TABLET INTERACTION	COMMUNICATION SELECTIONS	QUALITY STORY LOG
E3	M(6) & M(8)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Maakt eten". *"Makes food"*, "De raket". *"The rocket"*, "Maakt. *"Makes"*, "Hij moet iets kopen". *"He needs to buy something"*)	• Okay, story saved is story created.
E4	F(8) & F(7)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Een cadeautje". *"A present"*, "Van dit meisje". *"From this girl"*, "Eten en drinken". *"Food and drinks"*, "Iets krijgen". *"Receive something"*, "Vindt iets". *"Finds something"*, "Inpakken". *"Pack"*, "Maakt hij iets? Wat maakt hij?" *"Does he make something. What does he make?*, "Dan komt hij een astronaut tegen". "T*hen he meets an astronaut"*) • Indirectly mention selection aloud (e.g. "Die". *"That one"*, "Deze misschien?". *"Maybe this one?"*, "Ja, dit". *"Yes, this"*)	• Okay, story saved is story created.
E5	M(6) & M(7)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Welke gaan we doen?". *"Which one shall we do?"*, "Een raket". "A rocket", "Een cadeautje, nee gereedschap". *"A present, no tools"*, "Mars", "Eten en drinken". *"Food and drinks"*. "Ruimteman". *"Spaceman"*, "Koopt". *"Buys"*, "Kaart". *"Map"*, "Oke ik kies voor maken". *"Okay, I choose to make"*, "Vinden". *"To find"*, "Hondje, nee robot". *"Dog, no robot"*, "Wacht een schild". *"Wait, a shield"*, "Praat". *"Talks"*)	• Okay, story saved is story created.

UNDERSTANDING PLACEMENT OBJECT BLOCKS & FIGURES	UNDERSTANDING MOVEMENT COZMO	CHILD REMARKS ABOUT ROBOT	OTHER NOTES

First time drag the block over the line on the tablet. After researcher explains they have to place the object in front of the physical robot, they interact correctly.	Read the text on the help screen, but do not understand what they have to do. The researcher explains they have to pick up the robot and place him at the location. Afterwards, they understand.	• "Maar is die robot echt? *"But is the robot real?"*	• "Hi Cozmo"
			• Look at thought bubble on tablet: "Hij ziet hem". *"He sees him"*.
			• Ask: "Wat moeten we hiermee doen?" [wijzen naar poppetjes]. *"What do we have to do with these?" [point at figures].*
			• Randomness emotions:
			  • Mainly explore all unused items
			  • "Wat gebeurd er als we deze weer doen?" [wijst naar object blok] *"What happens if we do this one again?" [points at object block].* Question not followed by an action.
			  • Use the suit two times, the first time the robot reacts happy, the second time sad. Response child on second emotion robot: "Maar hij had een niet zo'n blij gezicht…". *"But he did not have such a happy face…".*

Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	x	• Ask: "Hoe moet je naar de maan eigenlijk?" *"How do you have to go to the moon actually?"*
			• Reasoning:
			  • "Hij maakt iets. Ja, dit" [selecteren raket] --> "Anders kan hij niet vliegen". *"He makes something. Yes, this". [select rocket] --> "Otherwise he cannot fly".*
			• Randomness emotions:
			  • First time: robot is happy seeing the astronaut and the woman. Second time: children start with only the astronaut, the robot is sad. Children's reaction: "Misschien meisje erbij?". *"Maybe also the girl?"*. The robot is still sad. Reaction: "Nog steeds verdrietig?!" *"Still sad?!"*, followed by: "Misschien hebben ze drinken nodig?". *"Maybe they need drinks?".*

First place the object block on the tablet. After the researcher explains they have to place the block in front of Cozmo, they correctly interact with the object blocks and figures.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	x	• "Is wel een leuk spel, ja". *"Is a ice game, yes".*
			• Reasoning:
			  • Ready?*:* "Nee nog meer spullen. Hij moet nog wat hebben". *"No, more stuff. He needs to have something more".*
			  • "Misschien moet hij een hond hebben?" *"Maybe he needs a dog?"*

NR	AGE & GENDER	UNDERSTANDING TABLET INTERACTION	COMMUNICATION SELECTIONS	QUALITY STORY LOG
E5	M(6) & M(7)		• Indirectly mention selection aloud (e.g. "Die". *"That one"*, "Dit". *"This"*, "We gaan die doen". *"We do that one"*) • Press buttons without telling anything aloud	
E6	F(6) & F(6)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Cadeautje". *"Present"*. "Uhm, een bubbel". *"Uhm, a bubble"*, "Uhm, hij moet echt iets kopen". *"Uhm, he really needs to buy something"*) • Indirectly mention selection aloud (e.g. "Uh, die". *"Uh, this one"*, "Ik denk deze". *"I think this one"*, "Deze, nee die". *"This one, no that one"*) • Press buttons without telling anything aloud	• Okay, story saved is story created.

UNDERSTANDING PLACEMENT OBJECT BLOCKS & FIGURES	UNDERSTANDING MOVEMENT COZMO	CHILD REMARKS ABOUT ROBOT	OTHER NOTES

			• Explain Cozmo's emotion:
			  • "Hij is bang daarvoor". *"He is afraid of that"*.
			  • Negative emotion: "Nee hij wil met iemand anders praten. Misschien een mens?" *"No he wants to talk with someone else. Maybe a human?"*
			  • Sad animation robot: "Hij is verdrietig, maar waarom dan?" *"He is sad, but why?"*. Accept it and continue.
			  • Happy emotion: "Ja, hij zei ja. Oke dit is goed, dit is goed. Hij moet vriend als ruimteman". *"Yes, he said yes. Okay, this is good, this is good. He needs the friend as a space man."*
			• Talk to Cozmo:
			  • "Kaart voor jou". *"Map for you"*.
			  • "Ben je bang?" *"Are you afraid?"*
			  • "Dankje voor het cadeau", *"Thanks for the present"*.
			• Repeat Cozmo:
			  • "Waaauw, zegtie". *"Waaauw, he says"*.
			  • "Hij zei: ja". *"He said: yes"*
			• Randomness emotions:
			  • Reuse dog more often. Children do not react to the robot responding differently. When the robot doesn't like another item they use the dog.

Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	x	• Repeat Cozmo:
			  • "Waaauw"
			  • "Nananana..." (Cozmo humming)
			• React on emotion:
			  • Happy emotion: "Hij is blij". *"He is happy"*
			  • Sad emotion: "Nee", *"No"*.
			• Randomness emotions:
			  • The reuse of items does not occur often: children have difficulties with reading, therefore, less time is left to select actions.
			  • Mainly explore all unused items
			  • If so, they do not always notice that the robot responses differently: see each action as a different one.
			  • Reuse suit, first time robot is afraid, second time angry. Reaction children: "Toen was hij bang". *"Then he was afraid"*. Recognise different emotion, but just accept it.

NR	AGE & GENDER	UNDERSTANDING TABLET INTERACTION	COMMUNICATION SELECTIONS	QUALITY STORY LOG
E7	M(7) & M(6)	Correctly select elements on tablet.	• Directly mention selection aloud (e.g. "Zullen we maken doen? Ja oke, maken". *"Shall we do to make? Yes okay, to make"*, "Cadeautje uitpakken". *"Unwrapping present"*) • Press buttons without telling anything aloud	• Okay, story saved is story created.
E8	M(6) & **M(6)**	Correctly select elements on tablet.	Sound lost	• Okay, story saved is story created.

Table A12 Observations second study. The third column contains the observations concerning the children's understanding of the tablet interaction. The fourth column describes the communication of the children about the selection of actions, characters, objects and locations on the tablet. The column of the quality of the logs indicates in which way the story created matches the story saved in the log. The sixth column contains the observations describing the children's understanding of how to place the object blocks and figures in front of Cozmo. The next column explains if the children understand they have to place Cozmo at a specific location. The final two columns describe children's remarks about robot characteristics and other notes.

UNDERSTANDING PLACEMENT OBJECT BLOCKS & FIGURES	UNDERSTANDING MOVEMENT COZMO	CHILD REMARKS ABOUT ROBOT	OTHER NOTES

Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo.	Do understand interaction. After looking at the help screen they immediately move Cozmo.	• Robot is still turned off: "Waarom doet de robot niks?" *"Why doesn't the robot do anything?"*
		• "Kan hij ook rijden?" *"Is he able to drive?"*
		• "Maar waarom gaat hij niet rijden?" *"But why doesn't he drive?"*
		• "Waarom kan hij niks zeggen?" *"Why isn't he able to talk?"*
			• Talk to robot after anger animation robot: "Hoi". *"Hi"*.
			• Randomness emotions:
			  • Mainly explore all unused items
			  • If so, they do not always notice that the robot responses differently: see each action as a different one.
			  • Tendency not to reuse items if robot responded negatively the first time.
			  • Child selects the present, robot is afraid. Other child again selects the present, robot turns happy. First child is indignant and upset robot is happy now. Children tend to see activity as a competitive game.

Do understand interaction. After looking at help screen they immediately look for the object block / figure and place it correctly rotated in front of Cozmo (Note: one of the children already played before).	Do understand interaction. After looking at the help screen they immediately move Cozmo (Note: one of the children already played before).	Sound lost	• Children stroke the robot
			• Children remove robot from the planet when he reacts anxiously
			• React on emotion:
			  • Robot reacts happy on a figure: "Oke dit poppetje zit in jouw team". *"Okay, this figure is in your team"*.
			  • Surprise animation: "Dat wil jij". *"That is what you want"*.
			• Look at storyline, see they already placed the dog nine times in front of Cozmo: "Negen honden" . *"Nine dogs!"*

A7 Tablet Selections and Reasoning Final Study

NE CONDITION

STORY ELEMENT	NE1	NE2	NE3	NE4
Action 1	Finds [rocket]	Brings [shield]	Goes to [planet]	Makes [suit]
Reason Action 1 (a1)	"Om te gaan vliegen". *"To go flying".*	"Voor de zon". *"For the sun".*	"Naar de planeet". *"To the planet".*	"Omdat hij naar de maan wil". *"Because he wants to go to the moon".*
Reason Emotion 1 (e1)	"Fijn". *"Nice".*	"Blij goed". *"Happy good".*	"Omdat hij leuk is op de planeet". *"Because he is nice at the planet".*	"Hij voelt zich blij". *"He feels happy".*
Action 2	Buys [telescope]	Gives [food and drink] to [alien]	Gives [present] to [dog]	Goes to [planet]
Reason Action 2 (a2)	"Hij vind dat leuk om te gaan kopen". *"He likes to buy that".*	"Dat hij de mensen op wil eten". *"That he wants to eat humans".*	"Omdat iemand van hondjes houdt". *"Because someone loves dogs".*	"Om aliens te ontmoeten". *"To meet aliens".*
Reason Emotion 2 (e2)	"Fijn". *"Nice".*	"Blij goed". *"Happy good".*	"Omdat hij een cadeautje heeft". *"Because he has a present".*	"Blij". *"Happy".* --> Too short: "Blij, hij kan Nederland zien". *"Happy, he can see the Netherlands".*
Action 3	Receives [present] from [man]	Finds [suit]	Talks to [woman]	Talks to [dog]
Reason Action3 (a3)	"Omdat hij dat leuk vond". *"Because he liked that".*	"Om de hondje op te eten". *"To eat the little dog".*	"Omdat hij dat wil". *"Because he wants to".*	"Woef zeggen". *"Saying woof".*
Reason Emotion 3 (e3)	"Leuk". *"Nice".*	"Blij goed". *"Happy good".*	"Omdat hij haar vertrouwt". *"Because he trusts her".*	"Samen adopteren". *"Adopt together".*

Table A13 Story elements selected and typed in by the children in the NE condition of the final study. The action rows refer to selections on the tablet, the reason action rows refer to answers on the "why-question" after an action selection and the reason emotion rows refer to the answers on"why-question" after the robot response.

NE5	NE6	NE7	NE8
Goes to [Madagascar]	Meets [alien]	Finds [present]	Goes to [planet]
"Omdat het daar mooi weer is". *"Because it is nice weather over there".*	"Raket". *"Rocket".*	"Omdat hij dat wil". *"Because he wants to".* [the present]	"Omdat hij daar ergens een raket ziet". *"Because he sees a rocket somewhere over there".*
"Hij is blij omdat hij er is". *"He is happy because he got there".*	"Blij". *"Happy".* [space, space, space].	"Heel blij". *"Very happy".*	"Blij". *"Happy".* --> Too short: "Blij omdat hij een raket ziet". *"Happy because he sees a rocket".*
Brings [telescope]	Talks to [dog]	Makes [rocket]	Finds [suit]
"Omdat hij naar de sterren wilt kijken". *"Because he wants to look at the stars".*	"Omdat hij hem lief vindt". *"Because he thinks he is sweet".*	"Naar de maan". *"To the moon".*	"Omdat hij anders geen zuurstof heeft". *"Because he does not have oxygen otherwise".*
"Verdrietig want hij mist zijn mam". *"Sad because he misses his mum".*	"Heel blij". *"Very happy".*	"Heel blij". *"Very happy".*	"Blij omdat hij nu bij de maan is". *"Happy because he is at the moon now".*
Buys [rocket]	Talks to [woman]	n.a.	n.a.
"Omdat hij naar de maan wil reizen". *"Because he likes to travel to the moon".*	"Omdat hij je lief vindt". *"Because he things you are sweet".*	n.a.	n.a.
"Hij is blij omdat hij net genoeg geld heeft". *"He is happy because he has just enough money".*	"Blij omdat hij leuk vindt". *"Happy because he likes".*	n.a.	n.a.

E CONDITION

STORY ELEMENT	E1	E2	E3
Action 1	Brings [suit]	Goes to [South pole]	Goes to [South pole]
Reason Action 1 (a1)	"Heeft hij nodig om te ademen". *"He needs it to breath.*	"Hij vindt dat misschien leuk op die landje". *"He maybe likes it on that little land".*	"Omdat hij nog niet naar de maan kan". *"Because he cannot go to the moon yet".*
Emotion	Surprise	Happy	Happy
Reason Emotion 1 (e1)	"Omdat hij dat wil". *"Because he wants to".*	"Om die vlaggetjes te zien". *"To see the little flags".*	"Omdat het daar warm is". *"Because it is warm over there".*
Action 2	Goes to [Europe]	Finds [present]	Meets [woman]
Reason Action 2 (a2)	"Daar kan hij nieuwe vriendjes maken". *"There he can make new friends".*	"O is dat van mij". *"O is that mine".*	"Omdat ze lief is". *"Because she is sweet".*
Emotion	Fear	Happy	Fear
Reason Emotion 2 (e2)	"Alleen is". *"Is alone".*	"Omdat hij denkt ik heb een cadeautje". *"Because he thinks I have a present".*	"Omdat hij haar niet kent". *"Because he does not know her".*
Action 3	Meets [dog]	Receives [telescope] from [astronaut]	Brings [suit]
Reason Action3 (a3)	"Omdat die hondje zijn baasje zoekt". *"Because that dog searches for his owner".*	"Om ver mee te kijken". *"To look far with".*	"Omdat hij naar de maan gaat". *"Because he goes to the moon".*
Emotion	Happy	Happy	Sad
Reason Emotion 3 (e3)	"Omdat hij eindelijk iemand hebt gevonden". *"Because he finally found someone".*	"Oh is die van mij". *"Oh is that mine".*	"Omdat hij niet naar de maan wilt". *"Because he does not want to go to the moon".*

Table A14 Story elements selected and typed in by the children in the E condition of the final study. The action rows refer to selections on the tablet, the reason action rows refer to answers on the "why-question" after an action selection and the reason emotion rows refer to the answers on"why-question" after the robot responded with behaviour according to the generated emotion..

E4	E5	E6	E7
Buys [suit]	Buys [rocket]	Goes to [south pole]	Buys [rocket]
"Niet ademen op de maan". *"Not breathing on the moon".*	"Omdat hij naar de maan wilde". *"Because he wanted to go to the moon".*	"Omdat 1 van zijn vrienden daar is". *"Because one of his friends is there".*	"Raket en astronautenpak". *"Rocket and astronaut suit".*
Sad	Angry	Sad	Anger
"Dat hij niet in de raket wilt". *"That he does not want to go into the rocket".*	"Omdat hij het nog niet kan". *"Because he cannot yet".*	"Omdat we hem verkeerd hebben gebracht"."*Because we brought him to the wrong place*". [not to the moon]	"Hij wil niet in de raket". *"He does not want to go into the rocket".*
Brings [food and drink]	Buys [suit]	Finds [map]	Talks to [dog]
"Anders heb je geen eten in de raket en dat moet wel". *"Otherwise you do not have any food in the rocket and you must have".* [to go to the moon]	"Omdat hij niet kan ademen". *"Because he cannot breath".*	"Om naar de maan te kunnen". *"To be able to go to the moon".*	"Omdat hij een robot is". *"Because he is a robot".*
Sad	Angry	Sad	Fear
"Hij wil geen eten". *"He does not want food".*	"Hij wil geen pak aan". *"He does not want to wear a suit".*	"Omdat hij nog steeds niet bij de maan is". *"Because he is still not at the moon".*	"Hij is bang". *"He is afraid".*
Meets [alien]	Meets [astronaut]	Brings [rocket]	Gives [suit] to [alien]
"Maan". "Moon". --> Too short: "Maan, raket, eten en ruimtepak". *"Moon, rocket, food and space suit".*	"Omdat hij weet hoe die het schip bestuurt". *"Because he knows how to steer the ship".*	"Om naar de maan te kunnen". *"In order to go to the moon".*	"Omdat hij ervan houdt daarom". *"Because he likes it, therefore".*
Sad	Angry	Fear	Happy
"Omdat er is geen ruimtemannetje". *"Because there is no little space man".*	"Omdat hij geen mens heeft gezien". *"Because he did not see any human".*	"Hij is bang dat hij in het vuur gaat". *"He is afraid he will go into the fire".* [of the rocket]	"Omdat hij durft niet alleen". *"Because he is afraid to go alone".* [to the moon]

A8 Observations Final Study

STORY GRAMMAR

NR	GROUP & GENDER	ACTION 1	ACTION 2	ACTION 3	TOTAL ACTIONS
NE1	F(3) & F(3)	1	1	1	*3*
NE2	F(3) & M(3)	1	1	0	*2*
NE3	F(4) & F(4)	0	0	0	*0*
NE4	M(4) & M(4)	2	1	0	*3*
NE5	F(4) & F(4)	1	2	2	*5*
NE6	F(3) & F(3)	0	1	1	*2*
NE7	F(3) & F(3)	1	2	n.a.	*3*
NE8	M(3) & M(3)	1	2	n.a.	*3*
E1	F(3) & M(3)	2	1	1	*4*
E2	F(3) & F(3)	1	0	1	*2*
E3	F(3) & M(3)	1	1	2	*4*
E4	M(3) & M(3)	2	2	0	*4*
E5	M(4) & M(4)	2	2	2	*6*
E6	M(4) & M (4)	1	2	2	*5*
E7	M(4) & M(4)	0	0	0	*0*

Table A15 Story grammar scores per trial. The action columns describe the score for the quality of the reason children came up with why the action takes place (connection reasoning and selected action). The emotion columns describe the score for the quality of the reasons children came up with how or why the robot feels in response to an action (connection reasoning emotion and selected action). The total actions column sums the score of the three actions columns, the total emotions column sums the score of the three emotion columns and the last column sums the score of all action and emotion columns. A score can either be 0, 1 or 2, resulting in a total maximum score of 12 per trial. If no casual relation exist between the action reasoning and the action, children receive 0 points. If only a local causal relation exists (i.e. the global goal is not taken into account), they earn 1 point and if a global causal relation exist (i.e. the global goal is taken into account) they earn 2 points. For the emotion the following scoring applies: children receive 0 points if no emotion is given, 1 points if either an emotion or reasoning is given and 2 points if an emotion with reasoning is given (NE condition) and 0 points for only an emotion, 1 point for a reasoning including a local causal relation and 2 points for a reason including a global causal relation (E condition).

EMOTION 1	EMOTION 2	EMOTION 3	TOTAL EMOTIONS	TOTAL
1	1	1	*3*	**6**
1	1	1	*3*	**5**
0	1	1	*2*	**2**
1	2	0	*3*	**6**
2	2	2	*6*	**11**
1	1	1	*3*	**5**
1	1	n.a.	*2*	**5**
2	2	n.a.	*4*	**7**
1	1	1	*3*	**7**
1	0	0	*1*	**3**
1	1	2	*4*	**8**
2	1	1	*4*	**8**
2	1	1	*4*	**10**
2	2	1	*5*	**10**
1	0	2	*3*	**3**

OTHER OBSERVATIONS

NR	GROUP & GENDER	REMARKS QUESTIONING

NE1	F(3) & F(3)	• Spelling:
		  • Spell checker is on, this annoys the children and takes up even more time for typing, since the children always have to correct what they typed in. Children react: "Echt heel irritant". *"Seriously, very annoying"* .
		  • Correct each other on spelling: "Zo schrijf je dat niet...". *"That is not how you write that"*.
		• Reasoning:
		  • Immediately after reading Cozmo's request: "Met de raket!" *"With the rocket!"*
		  • Sometimes the children look at the researcher after coming up with an answer on the question to see if what they came up with is allowed, they seek for approval.
		  • Sometimes children distracted from typing on tablet, researcher had to point them at the fact they were typing.
		• Reasoning & Collaboration:
		  • Children collaborate, often the person that came up with a reason typed it in on the tablet.

NE2	F(3) & M(3)	• Spelling:
		  • Girl doubts spelling: "Welke ij? *"Which y?"*
		• Reasoning:
		  • Directly after reading intro text: "Rijden?" *"Drive?"*.
		  • First time children doubt a bit if what the reason they came up with was okay, researcher had to encourage them they could come up with everything they want.
		• Reasoning & Collaboration:
		  • Mainly the boy types on the tablet.

NE3	F(4) & F(4)	• Spelling:
		  • "Hoe schrijf je 'huilt'?" *How do you write 'cries'?"*
		  • One child: "Cadeautje, ik weet niet hoe je dat schrijft"."*Present, I don't know how to write that"*. --> Other child laughs at what is written at the moment: "CadAUtje haha".
		  • Child helps other child with spelling, other child responses: "Ik weet wel hoe je het schrijft hoor". *"I do know how you write this"*.
		  • One child to the other: "Jij weet toch niet hoe je dat in moet typen, zal ik doen?" --> "Nee ik kan het zelf". *"You don't have a clue how to type it in anyway, shall I do it?"* --> *"No, I can do it myself"*.
		• Reasoning & Collaboration:
		  • Select "talks to woman", why-question action: "Bedenk jij maar, ik weet het ook niet". *"You can come up with something, I don't know anything either"*.
		  • Why-question emotion: "Wil jij deze doen? Ik wil deze ook een keer doen". *"Do you want to do this one? I want to do this one once as well"*.

NE4	M(4) & M(4)	• Spelling:
		  • One child types, other child: "Hooooh" [pointing at the fact the words should be one word].
		  • Child asks researcher: "Heb ik al een spatie gedaan?" *"Did I already type a space?"*
		  • Second time, other child types, when ready: "Klaar". *"Ready"*, Indicating he was faster.
		  • "Hoe schrijf je 'aliëns'?" *"How do you write 'aliens'?"*
		  • "Dat weet ik niet hoe je dat schrijft". "That, I don't know how to write" --> Researcher dictates.

OTHER REMARKS

- Collaboration:
  - When one child takes some time to type on the tablet the other child looks around.
- Characteristics Cozmo:
  - "Kan Cozmo echt alleen een beetje praten? Maar hij praat niet? *"Is Cozmo really only able to talk a little? But he does not talk?"*
  - "Kan Cozmo een handje geven?" *"Is Cozmo able to give a hand?"*
  - "Zijn ogen gaan steeds naar beneden en dan omhoog, hij knippert ook wel". *"His eyes continuously go up and down, he also blinks a bit".*
- "Dit is echt heel leuk, ik vind dit leuk". *"This is really fun, I think this is fun".*

- Collaboration:
  - When one child takes some time to type on the tablet the other child looks around.
  - "Mag ik lezen, mag ik lezen?" *"Can I read, can I read?".*
  - When placing an object in front of Cozmo: "Mag ik, mag ik?" *"May I, may I?"* "Nee, ik mag". *"No, it is my turn".*
- Characteristics Cozmo:
  - The boy: "Wanneer gaat Cozmo rijden? *"When starts Cozmo with driving?"* (5x) --> Becomes more irritated over time.
  - "Hij is zo schattig. Ja, zo klein". *"He is so cute. Yes, so small".*
- Help screen: drag virtual object block over line on tablet instead of reading the text and placing blocks in front of Cozmo in physical world.
- Select "finds": "We gaan die poppetje en deze hondje verstoppen en dan moet hij die vinden". "*We will hide this figure and this dog and they he needs to search for them".*

- Collaboration:
  - Selection actions on the tablet: "Oke, nu mag ik. *"Okay, now it is my turn".*
  - Placing object block for Cozmo: "En daarna ben ik". *"And then it is my turn".*
- Thought screen tablet:
  - Select "give present to the dog", then thought screen appears on tablet: "Hij weet wat er in zit". *"He knows what is in it".*
- Characteristics Cozmo:
  - "Gaan we straks ook nog iets met de robot doen, dat hij gaat rijden?" *"Are we also going to do something with the robot, that he is going to drive?"*
  - "Is zo grappig hoe hij met de ogen zo doet". *"It is funny what he does with his eyes".*

- Thought screen tablet:
  - "Yeah, een raketje". *"Yeah, a little rocket".*
  - "Ja hij heeft hem gezien". *"Yes, he saw him".*
  - "Wooh, hij ziet hem". *"Wooh, he sees him".*
- "Goes to" action:
  - "Oh misschien 'gaat naar', dan gaat hij een beetje lopen toch?" *"Oh maybe 'goes to', then he will walk a little, right?*
  - Children search for the moon, which is not there yet.
- After help screen help Cozmo to planet: "Maar hoe zetten we hem dan op de planeet?" "*But how do we place him on the planet then?"*

NR	GROUP & GENDER	REMARKS QUESTIONING

NE4	M(4) & M(4)	• Reasoning:
		  • Immediately after reading Cozmo's request: One child "I denk dat hij een ruimteschip moet maken". *"I think he needs to make a rocket ship"*. Other child: puts finger in the air: "Ik heb een tip, eerst moet hij wat trainen, dan gaat hij naar de oefenruimte". *"I have a hint, he first needs to train a bit, he goes to the exercise room"*.
		  • Select "goes to planet", why question action: "Oh deze weet ik ook niet, alleen omdat hij het leuk vindt". *"Oh, this one I don't know either, only because he likes it"*. --> Other child comes up with a reason, on which the first child replies: "Die vind ik wel heel bijzonder". *"That one I think is really special"*.
		  • Select "talk to alien", why-question action: "Aaaugh, omdat hij het leuk vindt". *"Aaaugh, because he likes it"*.This child gets more irritated by the questions over.
		• Reasoning & Collaboration:
		  • "Ja, type jij maar". *"Yes, you can type"*.
		  • Mainly one child always comes up with reasons and types them.

NE5	F(4) & F(4)	• Spelling:
		  • Help each other with spelling.
		  • Dictate each other sometimes.
		  • "Wacht, is dat verkeerd?" *"Wait, is that wrong?"*
		  • Non-typing child says: "Fout!" *Wrong!"*
		• Reasoning:
		  • Why-question after selecting location: "Maar wat moeten we nu doen?" *"But what do we have to do now?"*
		  • Why-question "Wat nu?" *"What now?"*.
		  • One child laughed about the reason she came up with.
		• Reasoning & Collaboration:
		  • Child gets annoyed by typing: "Waarom moet ik de hele tijd opschrijven? Wil jij niet een keer?" *"Why do I have to write all the time? Don't you want to do it once?"* --> "Ja is goed". *"Yes, that is okay"*.
		  • One of the two children would like to play with the robot, does not like answering questions. Other child always comes up with the reasons.

NE6	F(3) & F(3)	• Spelling:
		  • "Hoe schrijf je blij?" *"How do you write happy?"*
		• Reasoning:
		  • Why-question "meets alien": "Oh dit is lastig". "*Oh, this is difficult*".
		  • Why-question "talks to woman": "Ah, moeilijk". *"Ah difficult"*.
		• Reasoning & Collaboration:
		  • When they do not know an answer on a question: "Jij mag". *"It is your turn"*.
		  • "Mag ik nu typen?" "*Is it now my turn to type?*"
		  • Why-question emotion: "Mag ik een keer blij doen?" *"May I do happy once?"*
		  • Only once asks researcher: "Kan jij het voor mij opschrijven, want jij kan sneller typen". *"Can you type for me, since you can type faster"*.

OTHER REMARKS

- Thought screen tablet:
  - "Ja, wat nou?" *"Yes, what?"*
  - "Ja hij hebt het". *"Yes, he got it".*
- Characteristics Cozmo:
  - "Ik wil graag weten hoe hij praat. Wat moeten we dan doen?" *"I would like to know how he talks. What do we have to do then?"* --> other child reacts: "Misschien moet hij eerst een kaart maken om te weten waar de ruimte precies is". *"Maybe he needs to make a map first in order to know where the space is exactly".* --> But then they select something else: goes to planet.
  - "Praattie niet of rijdtie niet?" *"Doesn't he talk or doesn't he drive?*
- When selecting objects: "Nee, die hebben we al gehad". *"No, that one we have had already".*

- Collaboration:
  - One child continuously walks around, other child calmly stays on her place.
  - "Mag ik nu?" *"Is it now my turn?"*
  - "Nu ben ik" *"Now it is my turn".*
  - "Nee, ik mag lezen". *"No, it is my turn to read".*
  - About object blocks: "Dan leg ik ze hier even neer, zodat jij ze nog niet kan pakken als ik nog aan het typen ben". *"Then I place them here for a moment, to ensure you cannot grab them already before I finished typing".*
- Thought screen tablet:
  - "Hij heeft hem gezien". *"He saw him".*
- Characteristics Cozmo:
  - "Wanneer gaat hij eigenlijk rijden? *"When does he start driving actually?"*
  - "Gaat hij niet met dat bewegen?" [wijst naar armen]. *"Doesn't he move with that?" [points at arms].*
  - One child: "Kan hij ook lopen?" *"Can he walk as well?"* --> Other child: "Nee, hij kan niet lopen, alleen rijden". *"No, he cannot walk, he can only drive".* --> First child: "Kan hij ook rijden? "Can he also drive?
  - "Is hij een jongen?" *"Is he a boy?*
  - Stroke robot: "Oh hij voelt lekker". *"Oh he feels nice".*
  - Talk to Cozmo: "Oke Cozmo, nog een poppetje en dan ga jij lekker rondrijden". *"Okay Cozmo, one more figure and then you start driving around".*
  - "Hoe gaat hij lachen?" *"How doe he laugh?"*
- Action selection: "Maar die hadden we net ook al". *"But we had that one before already".*

NR	GROUP & GENDER	REMARKS QUESTIONING

NE7	F(3) & F(3)	• Reasoning:
		  • After a few why-questions: "Oke, dat zinnetje heb ik nu al heel vaak gehoord". *"Oke, I have heard that little sentence quite often now".*
		• Reasoning & Collaboration:
		  • "Nu moet jij wat bedenken, ik heb al de hele tijd wat gedaan. *"Now you have to come up with something, I did already do something all the time".*
		  • Basically one child creates the story and types on the tablet, the other child observes what this child is doing and mainly observes Cozmo.

NE8	M(3) & M(3)	• Spelling:
		  • "Waar is 'i'?" *"Where is 'i'"* --> Other child points at correct place.
		• Reasoning:
		  • One child takes much time for typing on tablet, other child: "Wacht. Je moet dit doen." *"Wait. You have to do this".* --> "Weet ik"."*I know".*
		• Reasoning & Collaboration:
		  • "Mag ik nu typen?" *"Can I type now?"*
		  • Typing on tablet: "Ik ga". *"I go" [picks tablet].*
		  • One time researcher types in answer on the tablet.

E1	F(3) & M(3)	• Spelling:
		  • Help each other with spelling.
		  • "Eigenlijk die niet" [wijst letter aan]. *"Actually, not that one" [points at character].*
		• Reasoning:
		  • Why-question after emotion robot to Europe: researcher has to provide children with some suggestions.
		• Reasoning & Collaboration:
		  • Type in turns some characters on the tablet.

E2	F(3) & F(3)	Spelling: • Help each other with spelling. • Help each other by selecting next letter, by pointing at next letters. • "Hoe schrijf je 'misschien'?" How do you write 'maybe'?

E3	F(3) & M(3)	• Spelling:
		  • Help each other with spelling.
		  • Help each other by selecting next letter, by pointing at next letters.
		  • "Nee, omdat moet altijd aan elkaar!". *"No, because should always be written as one word!".*
		  • Child accidentally pressed wrong button: "Neeee, wat doe je! *"Nooo, what are you doing!*
		• Reasoning:
		  • Why-question location: "Oooooh"
		  • Select 'meet the woman', why-question: "Ik weet niks om in te vullen". *"I don't know anything to fill in".*
		• Reasoning & Collaboration:
		  • Why-question: "Nu moet jij even wat doen". *"Now, you have to do something".*
		  • "Jij mag typen"."*You may type"* (other child dictates).
		  • Typing on tablet: "Ik ben". *"It is my turn".*

OTHER REMARKS

- Characteristics Cozmo:
  - "Kan Cozmo ook zelf rijden?" *"Is Cozmo able to drive by himself?"*
  - "Cozmo doet met een oogje groter dan de andere". *"Cozmo does with one eye larger than the other".*
- First selection: children stare at tablet for long time, they need to be encouraged by the researcher to select something.

- Collaboration:
  - One boy that is not typing is quite calm, observing what the other boy is doing.
  - The other boy mainly plays with the alien figure when other child types on tablet.
- Characteristics Cozmo:
  - "Waarom doet hij zo met die ogen?" *"Why does he do like this with his eyes?"*
  - "Waarom doettie niks?" "*Why doesn't he do aything?"*
- Select "goes to" to go to the moon immediately.

- Robot behaviour:
  - Children smile when Cozmo responses by showing different behaviour.
  - Happy animation: "Hij is blij". *"He is happy".*

- Collaboration:
  - Both children focused and concentrated.
  - One child is more the assistant, she is quite calm, helps the other child with getting the correct object blocks, helps with spelling. The other child thinks of the story, talks and reads aloud.
- Robot behaviour:
  - Look at Cozmo's face: "Hij denkt 'oh'". *"He thinks 'oh'"*
  - Children laugh when Cozmo responses by showing happy behaviour.
- Select "goes to" to go to the moon immediately.

- Collaboration:
  - "Straks mag ik weer wat kiezen". *"Later, I can selected something again".*
- Robot behaviour:
  - Children laugh when Cozmo responses by showing happy behaviour.
  - Sad animation Cozmo: "Hij is niet blij met die". *"He is not happy with that one".*
- Select "goes to" to go to the moon immediately.
- "Mag ik hem een keer aaien?" *"May I stroke him once?"*

NR	GROUP & GENDER	REMARKS QUESTIONING

E4	M(3) & M(3)	• Spelling:
		  • Help each other with spelling.
		  • Dictate each other.
		  • "Nee eerst de 'm'!" *"No first the 'm'!"*
		• Reasoning:
		  • Halfway the sentence they are distracted by the blocks and figures and have to start over with the reasoning.
		  • Child thinks he solved the problem: "Nu weet ik het!" *"Now I know!"*.
		• Reasoning & Collaboration:
		  • "Oh schrijf jij maar op, jij hebt het verzint". *"Oh, you can write, you did came up with it"*.
		  • Why-question: "Jij bent aan de beurt". *"Now it is your turn"*.
		  • Type in turns some characters on the tablet.
		  • "Ik ga 'maan' op schrijven. Nee ik wil 'maan' doen." *"I am going to write 'moon'. No I want to do 'moon'"*.
		  • "Jij doet 'hij'". *"You do 'he'"*.
		  • Typing takes much time, halfway the playing the researcher starts typing.

E5	M(4) & M(4)	• Spelling:
		  • Hoe schrijf je dat 'ademen'? *"How do you write that 'breathing'?"* --> Other child dictates
		  • "Hij geen pak... Hij WILT geen pak". *"No suit, he WANTS no suit"*.
		  • "Tss ik begin elke keer met omdat". *"Tss, I always start wtih because"*.
		• Reasoning:
		  • Why-question on anger animation when buying a rocket: "Ik snap echt niet waarom hij boos is". *"I really don't get why he is angry"*.

E6	M(4) & M (4)	• Spelling:
		  • "Niet zo 'misschien' schrijven! *"Not like that writing 'maybe'!"*
		• Reasoning:
		  • "We moeten naar de maan dus we hebben iets logisch nodig" --> "Ik weet er wel eentje: die koffer" (neemt mee). *"We need to go to the moon, so we need something logical"* --> *"I know one: the suitcase" (takes with).*
		  • Fear animation robot in response to rocket, why-question: "Weet ik niet" --> "Ik wel". *"I don't know"* --> *"I do!"*.
		• Reasoning & Collaboration:
		  • Type a reasoning in turns.
		  • Why-question: "Dat mag jij doen". *"You may do this"*
		  • "Ben ik nu of ben jij? Jij hebt net getypt". *"Is it my turn or yours? You just typed"*.

E7	M(4) & M(4)	• Spelling:
		  • Help each other with spelling.
		  • Nee "d". *No "d"*.
		• Reasoning & Collaboration:
		  • Collaboratively type sentences.

Table A16 Observations concerning the questions asked and other observations during the final study.

OTHER REMARKS

- Characteristics Cozmo:
  - "Kan die ook rijden? *"Can he also drive?"*
  - "Hij is zo schattig". *"He is so cute"*.
- Robot behaviour:
  - Sad animation robot on taking food: "Nu is hij zielig". "*Now he is sad*".
  - Humming Cozmo: "Rustig maar, wat zeg je nou?" *"Relax, what are you saying?"*
  - Sad animation robot on meeting alien: *"Huh"*.
- "Hoe komt hij dan naar de maan? *"How does he get to the moon then?"*

- Collaboration:
  - While one child is typing on the tablet the other one plays with the figures and object blocks
- Robot behaviour:
  - Angry animation robot: laughing, "Hij is boos". *"He is angry"*.
  - Second and third angry animation "Hij is alweer boos". "*He is again angry*".
  - Third angry animation: "Wat, waarom wil die niks?" *"What, why doesn't he want anything?"*

- Robot behaviour:
  - Fear animation robot in response to rocket: *"Huh"*.
- Select "goes to" to go to the moon immediately.
- "Dit is best wel leuk". *"This is quite fun"*.
- "Die hebben we net al gedaan". *"That one we already had just before"*.

- Collaboration:
  - Do rarely talk aloud, mainly whisper.
- Robot behaviour:
  - Angry animation robot: Smile
  - Happy animation robot: "Hij is blij". *"He is happy"*.

A9 Interview Results Final Study

CONDITION NE

NR	GROUP & GENDER	DIFFICULTY CREATION STORY	STORY SUMMARY
NE1	F(3) & F(3)	😊😊	"Over de maan en over een verjaardag en over vakantie. En dat hij heel veel dingen heeft gegeten". *"About the moon and about a birthday and about holidays. And that he eat many things".*
NE2	F(3) & M(3)	😊😊	"Uuhm". No answer.
NE3	F(4) & F(4)	😐😐	"Dat Cozmo naar de maan ging en dat hij honger had en dat hij iemand kende en zag en dat hij een cadeautje wou geven en hij had honger". *"That Cozmo went to the moon and that he was hungry and that he knew someone and saw and that he wanted to give a present and he was hungry".*
NE4	M(4) & M(4)	😐😐	"Over de ruimte, ja over de ruimte. Dat de hond in de ruimte ging". *"About space, yes about space. That the dog went in space".*
NE5	F(4) & F(4)	😊😊	"Over eten, over een raket, over de telescoop, en over met de raket en over dat hij naar de maan reist". *"About food, about a rocket, about a telescope, and about with the rocket, and about that he travelled to the moon".*
NE6	F(3) & F(3)	😐☹	"Oh dat weet ik niet. Het verhaaltje gaat over dat jij in een park ging wandelen en toen had je trek en je naar de maan wou" [praten tegen Cozmo]. *"Oh I don't know. The story was about that you went for a walk in a park and then you were hungry and you wanted to go to the moon". [talk to Cozmo].*
NE7	F(3) & F(3)	😊😐	"Over de maan". *"About the moon".*
NE8	M(3) & M(3)	😐😐	"De maan". *"The moon".*

Table A17 Results interviews final study - NE condition

FEELINGS ROBOT	HELP QUESTIONS	DIFFICULTY QUESTIONS
"Leuk, heel leuk, omdat hij dat fijn vond". *"Nice, very nice, because he liked that".*		
"Blij, omdat zijn ogen zijn blij." *"Happy, because his eyes are happy".*		
"Leuk, blij, omdat hij het leuk vond om naar de maan te gaan". *"Nice, happy, because he liked it to go to the moon".*		
"Heel leuk en heel blij, omdat hij is nog nooit in de ruimte geweest en we hebben hem geholpen". *"Very nice and very happy, because he has never been in space before and we helped him".*		
"Soms verdrietig en soms ook blij. Omdat... soms was hij heel blij met de spullen wat hij had en soms was hij ook verdrietig, omdat hij zijn mama miste". *"Sometimes sad and sometimes also happy. Because... sometimes he was happy with the stuff he had and sometimes he was sad, because he missed his mum".*		
"Blij, heel blij. Elke keer toen blij, toen wouden we gewoon blij doen. Want niet erg blij is niet erg vrolijk. Omdat wij hem wilden helpen naar de maan te doen. *"Happy, very happy. Every time then happy, we just wanted to do happy. Since not very happy is not very cheerful. Because we wanted to help him to go to the moon".*	Not answered.	
"Heel blij. Omdat hij het heel leuk vindt, om naar het blokje te kijken". *"Very happy. Because he liked it very much, to watch the block".*		
"Blij, omdat hij naar de maan wil en dat wij hem daar hadden gestuurd". *"Happy, because he wanted to go to the moon and we sent him there".*		

CONDITION E

NR	GROUP & GENDER	DIFFICULTY CREATION STORY	STORY SUMMARY
E1	F(3) & M(3)		"Over op reis. Naar de maan". *"About going on a journey . To the moon".*
E2	F(3) & F(3)		"Dat hij naar de maan wou". *"That he wanted to go to the moon".*
E3	F(3) & M(3)		"Hij ging naar de maan. Cozmo gaat naar de maan en dat vond hij leuk en hij ontmoet al zijn vrienden en straks komen nog meer vrienden." *"He went to the moon. Cozmo goes to the moon and he liked that and he meets al his friends and later on there will be even more friends".*
E4	M(3) & M(3)		"Over de maan. Met de ruimteman en de aliën. En toen ging hij naar de maan met de raket en toen zocht hij ook de aliën en de ruimteman". *"About the moon. With the space man and the alien. And then he went to the moon with the rocket and then he searched also for the alien and the space man".*
E5	M(4) & M(4)		"Over dat Cozmo naar de winkel ging om een kostuum en een raket te kopen, hij was boos. Toen kwam een man die wou helpen hoe hij naar de maan ging. Toen was Cozmo boos geworden, toen wou hij naar de maan. en toen ging die naar de maan met een schip". *"About that Cozmo went to the shop to buy a suit and a rocket, he was angry. Then there was a man that wanted to help how to go to the moon. Then Cozmo was angry, then he wanted to go to the moon and then he went to the moon with a ship".*
E6	M(4) & M (4)		"Dat hij niet naar de maan kon gaan en wij hadden hem geholpen". *"That he was not able to go to the moon and we helped him".*
E7	M(4) & M(4)		"Over Cozmo die naar de maan wilt en astronauten". *"About Cozmo that wanted to go to the moon and astronauts".*

Table A18 Results interviews final study - E condition

FEELINGS ROBOT	HELP QUESTIONS	DIFFICULTY QUESTIONS
"Een klein beetje blij, twee keer blij. Omdat hij eerst even een hondje tegen kwam en nu is hij op de maan". *"A little happy, twice happy. Because he first met a dog for a little while and now he is on the moon".*		
"Leuk, omdat...". *"Nice, because....".*		
"Niet echt heel blij, hij keek zo [doet vinger horizontaal voor mond] en zo verdrietig was hij en hij is een beetje bang voor die" [wijst meisje aan]. "Omdat hij haar zag was hij verdrietig [pakt meisje op]. *"Not really very happy, he looked like this [places finger horizontally in front of mouth] and so sad was he and he is a bit afraid for that one [points at girl]. Because he saw here he was sad" [picks up girl].*		
Not asked		
"Niet leuk. Hij ging de hele tijd boos worden". *"Not nice. He went angry the whole time".*		
"Hij voelde zich een beetje bang en verdrietig. Omdat hij dat zei op de tablet". "*He felt a bit anxious and sad. Because he said that on the tablet".*		
"Ja, soms was die bang, zeker bang en soms was hij wel een beetje boos. Blij". *"Yes, sometimes he was afraid, defintiely afraid and sometimes he was a bit angry. Happy".* Angry? --> "Van de hond". *"Of the dog".* Afraid? --> "Van de raket". *"Of the rocket".* Happy? --> "Van de astronaut. *"Of the astronaut".*		

DESIGNING AN INTERACTIVE STORYTELLING SYSTEM FOR CHILDREN USING A SMART TOY

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