Designing a smart toy interactive setting for creating stories

From free play to story structure and reflection support

Silke ter Stal[1,2], Alejandro Catala[3], Mariët Theune[4], and Dennis Reidsma[4]

[1] Roessingh Research and Development, Enschede, The Netherlands
s.terstal@rrd.nl
[2] Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, The Netherlands
[3] Centro Singular de Investigación en Tecnoloxías Intelixentes (CiTIUS), Universidade de Santiago de Compostela, Spain
alejandro.catala@usc.es
[4] Human Media Interaction, University of Twente, Enschede, The Netherlands
{m.theune, d.reidsma}@utwente.nl

Abstract. Smart and robotic toys introduce more possibilities than ever for building interactive settings for playful learning. Here we explore their use for supporting the development of storytelling skills in children. Previous research on interactive storytelling prototypes has already shown their potential to this end. However, the focus has often been set on technical implementation issues or using very specialized hardware that may limit their potential to go outside the lab. The lack of a general and integrated application with off-the-shelf affordable components has encouraged our research on how to combine a tablet application with an existing smart robotic toy, so that it supports the creation of structured stories and children's reflection on them. Thus, this paper reports on the design and development of a multimedia storytelling application that includes a smart robotic toy, adopting a user-centric approach with iterative design and user-testing cycles.

Keywords: Interactive Digital Storytelling · Smart Toys and Robots · Structured Narrative Support · Application for Primary School Children

1 Introduction

Nowadays toys enhanced with animated behavior are becoming more advanced and ubiquitous by including digital capacities and embedded electronics. Intelligent or smart toys exhibit autonomous believable responses to changes in their environment [1]. An emerging strand of smart toys are programmable robot toys [3], fueled by their increase in popularity and suitability to STEM[5] activities both at school and home. However, as largely discussed in [19], the range of

[5] STEM stands for Science, Technology, Engineering and Mathematics

skills expected to be developed by children far exceeds a strict interpretation of STEM education. Skills such as creativity, communication, and collaboration are consistent across frameworks for 21st century competence. When considering activities with smart toys that can be used for strengthening and supporting development of these skills, we focus on *storytelling* as it has been presented as a suitable new media approach for learning (see [5], [16]-p.300).

During primary school, children's narratives are expected to move from very linear and chronological to something more coherent and evaluative, by including a clearer resolution or conclusion, connectives (e.g., *so, then, next, finally*) and comments about thoughts, feelings and intentions based on memories and critical thinking. This transition, however, is not homogeneous in all children and is affected by individual differences [4] (p.390). For this reason, having tools and activities supporting the construction of stories interactively can be beneficial, to learn by interacting in small groups and reflecting on the process. Our research aims to start filling this gap. As most interactive digital storytelling systems for children (see [9]) typically involve *ad hoc* or very specialized technical developments, which are not easily adopted outside the research lab, we used a commercially available smart robot and affordable toys to create an interactive story world. Our contribution lies in the iterative design of a tablet app that integrates interaction with the robot and guides children to create coherent narratives. Specifically we try to support children's inclusion of structurally important narrative elements such as causal links between actions, references to goals and to internal states of characters [18].

2 Related work

Much of the existing related work combines a sort of display providing a visual story world representation with tangibles as input devices, which children can use to influence the on-going narrative [10,13]. Some projects have used a tabletop display, coupling in this way both input and output to provide a more direct manipulation [2,12]; tablets have also been used to represent the state of the story world [21]. Regardless of the underlying technology, tangibles are used to encode assets, behaviors for the characters and props that have an effect on the unfolding of the story.

Sometimes children are allowed to expand the available assets by creating drawings, either digital [12] or paper-based [20]. Some storytelling systems rely on pre-scripted stories, although variation is still possible by means of plot choices [2,11]. These systems restrict children in the stories that can be created, but in turn, they define relationships between story assets, which can be useful to develop higher quality stories by linking the assets together in the narrative.

Besides tangibles, more active devices have been incorporated, such as small robots. The work in [17] uses a turtle toy capable of moving, which is driven by means of handheld projectors. The system in [20] can record the movements of the robotic tangible to be played afterwards. The small robot in [12] can move by using tangible cards on a digital tabletop, whereas the robot in [6] can be tele-operated using a tablet app with digital assets and motion controls, as part of the narrative being created. A dinosaur robot is used for storytelling in [15], but it is more focused on programming sequences of behaviors linked to tangible cards than their narrative value. Advanced humanoid robots have also been used as storytellers with pre-recorded behavior [8] or fluffy robots as companions in supportive storytelling activities [21].

Overall, most systems focused on how innovative technology can be used to enable storytelling, but less attention has been paid to encouraging the development of narrative structure, besides organizing assets by scenes, episodes or programs. This observation motivated our research presented below.

3 Iterative design: rationale and implementation

We followed an iterative approach, in which three design cycles were carried out with both implementation and testing stages. They are briefly summarized next.

3.1 First design: free-play setting with emotions

Playing with toys is a common activity in childhood, but how children use them to create stories is complex, since it might involve a mix of pretend play, free play and some narrative. Similar to the approach in Davis et al. [7], we created a setting to observe children's free-play with a smart robot toy as shown in Figure 1-Left. The toy we used was the Cozmo robot designed by Anki [6]. Its physical size and features, such as the possibility to change its speech and facial expressions, made it suitable for use as the main character in the storytelling activity.

A map of the story world was printed on an A0-sized play mat to be placed onto a table. We gave it a space theme, with the earth, the moon and a planet positioned in space. We added simple tangible figures to the setting, since related work suggested that these can help shaping the story world, giving context to the storytelling activity. For this we used Playmobil figures, which also fit the space theme and, besides, they are robust and match the size of the robot. Finally, a tablet was included. The first version of the tablet interface only displayed the robot's mood reactions visually. Depending on the character in front of the robot, or its location, the robot showed a different emotion as a way to introduce reactions and trigger a sort of meaning making process in children.

Evaluation Ten children (4 female, 6 male; aged from 5 to 10 y/o) participated [7] in the evaluation in this stage. The children played in groups of two, resulting in five trials. They were invited to freely play with the setting and tell a story

[6] https://www.anki.com/en-us/cozmo

[7] Previous to their participation, ethical approval from the University was acquired and informed consent forms were signed by the legal tutors of every child participating in any design stage reported in this paper.

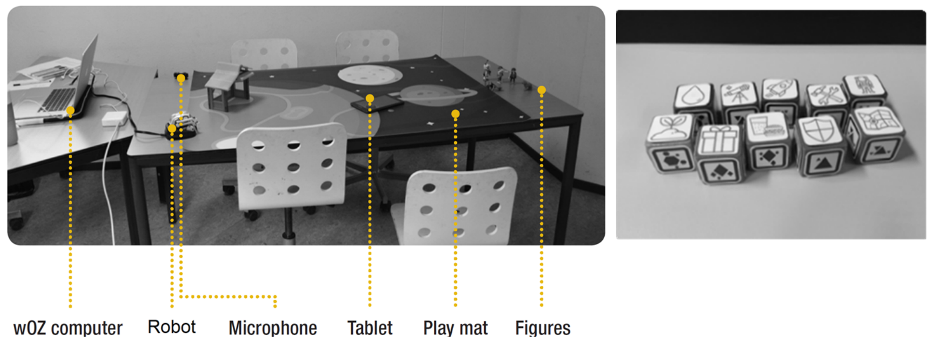


Fig. 1. Left) Set up for the free play setting. Right) Picture blocks used as prop in the revised assisted settings with autonomous functions in designs 2 and 3.

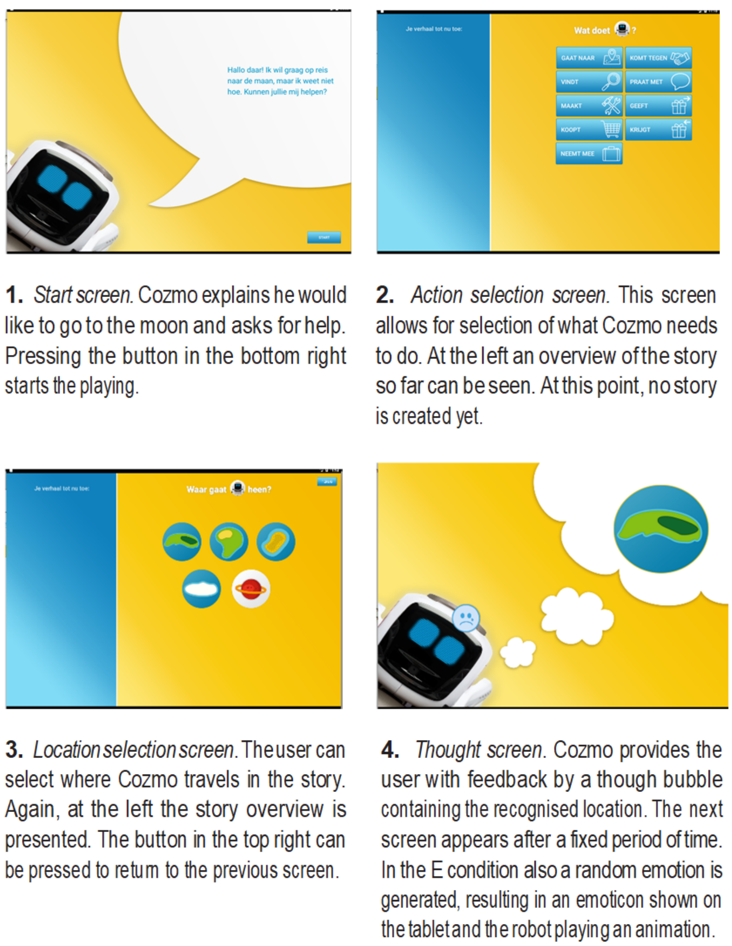
within the space theme with the robot as the main character. The researcher used a Wizard-of-Oz (wOZ) computer interface, which at this stage of development showed the emotional responses of the robot to the children's play.

In all trials children played continuously without having pauses longer than twenty seconds. However, in most trials children mainly played to explore the robot behaviour. This can (at best) be seen as a primitive form of emergent storytelling rather than as creating a coherent narrative. Communication between children was mainly based on individual events, such as explanations of the robot's actions, e.g. “He needs to go into the farm” or “What about that?” while pointing at a figure to be placed in front of the robot. In all trials the children said aloud how they thought the robot was feeling. Sometimes they specifically referred to the character or location shown on the tablet or made exclamations representing the emotion being shown. The trial made clear that the children did see the robot as a character and recognized its emotions (except for disgust, which we left out in the following designs). However, the design did not invite them to create structured stories.

3.2 Second design: interaction mediated by tablet

In order to support the transition from free play to creating structured stories, we decided to constrain the storytelling task in a number of ways. First, we introduced a goal for the main character (wanting to go to the moon) to encourage the construction of goal-directed narratives [18]. Second, we provided a set of actions for the children to choose from, and changed the tablet app to mediate the interaction, making the storytelling process more controllable by forcing the children to take some necessary steps in order to progress in the construction of the story. Via the tablet, the children had to select an action from a predefined general set. After each action, the robot responded. Then, the children could again select an action. This sequence continued until the children believed the story to be finished (the robot could depart for the moon). A selection of the designed screens can be seen in Figure 2.

Actions were displayed as verbs on the tablet screen. They are general actions that could be valid for many different themes, supported by the following action taxonomy: Social-entity [*meets, talks to*], Social-object [*gives, receives*], Location [*goes to, finds, brings*], and Generation [*makes, buys*]. These actions were chosen as they could be easily linked to each other and the robot's goal, and combined with many of the locations, objects and characters in the setting. General tangible objects in the shape of picture blocks were introduced as props that could be used in the actions, for example, a rocket, a telescope and a map. In short, the children were guided in the storytelling process by forcing them to select actions from a predefined set, but this set was still sufficiently open for the children to use their creativity.



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. *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.

Fig. 2. Selection of tablet screens used in the second and third design.

The features previously enacted through wOZ were now actually implemented, so that the computer software was handling the sensing and the corresponding autonomic responses of the robot. That required the inclusion of fiducial tags in objects, figures and flags placed in the locations that were recognized by the built-in robot camera (see Figure 1-Right).

Evaluation Thirty-three children (15 female, 18 male; aged 6 to 9 y/o) played in pairs with the second design (one child took part twice). In many trials, some story content was present. Children included causality by describing reasons for the occurrence of actions or emotions. They mentioned goal-directed arguments, such as: "he wants to make more friends", "he should wear his suit", "he needs food, otherwise he dies", and "he needs a rocket to go to the moon".

Nevertheless, we observed in the interviews we held afterwards with each pair that most children had difficulties with telling a summary of the story they had created. This indicates that the children still needed some extra scaffolding to structure their narratives and foster connection between story elements. Only a few children specifically mentioned connections between story actions, such as the robot wanting a shield to protect himself, arranging a rocket or map to go to moon, or meeting with an astronaut to get information about space.

3.3 Third design: supporting story structure and reflection

In previous steps we learned that interaction in the physical setting could successfully be mediated through the tablet so that there is some order and sequence in the story actions. Giving the robot a goal, having a range of objects to be used in the actions and emotional responses can stimulate children to find links between story elements and make meaning of events that contribute to a certain narrative structure. There were still some issues such as a lack of explicit causal relationships between story elements. This is particularly important, because children at this stage need to develop skills in structuring stories by giving coherence and causal links and increase digital literacy (writing) skills, as emphasized in conversations with primary school teachers involved in the project.

For the final design step, we evolved the tablet app to include questions that would make children reflect on the robot's emotional state and why they selected certain actions in their story. After each action selection step (screen 2 in Figure 2) and each robot thought screen (screen 4 in Figure 2), the children were shown a new screen with the question "Why does the robot *action*" , with *action* being the previously selected action for the robot. The children had to type their answers on the tablet. In the E condition of the user study (see below), the children were asked a similar question after each emotional response of the robot shown on the 'thought screen'(screen 4 in Figure 2): "Why does the robot feel *emotion*?", with *emotion* being the previously selected action or emotion shown by the robot. In the NE condition, they were asked "How does the robot feel?" instead. The purpose of the questions was to help the children to work with the concepts in the story world and make connections between them.

The second change we made was that at least three action sequences were required before the children could take the robot to the moon to finish the story. The rest of the tablet app functions and setting remained unchanged. [8]

Evaluation Thirty children (15 females, 15 males; aged from 6 to 8 y/o) participated in testing the third design. They were all in the third and fourth grade of a Dutch elementary school that did not participate in any of the two previous design step evaluations.

We tested two conditions that differed on whether or not the robotic character showed emotional responses on the thought screen (Figure 2, screen 4) and in its behavior. The condition with no emotions (NE) implied that the robot was mostly a regular toy, whereas the condition with emotional robot responses (E) implied a smarter toy with autonomous reactions. We focused on the emotional responses because they can be a source of feedback and introduce conflicts to the children's stories, with the potential to assess how such responsiveness might affect the storytelling process. The children were spread over fifteen trials, eight for the NE condition (n = 16) and seven (n = 14) for the E condition.

Based on the answers given by children during the storytelling activity, we assessed some aspects of story quality. Inspired by the story grammar scoring scheme of the Index of Narrative Complexity (INC) created by Petersen, Gillam & Gillam [14], our criteria related to two aspects: Action reasoning and Emotion reasoning. For the first one, we assigned 0 points if there was no causal relation between motivation (answer to the 'why'question) and action, and 1 or 2 points depending on whether a local or a global causal relation was given, respectively. Unlike local causal relations, global causal relations link the action to the main goal of the robot (going to the moon), and thus they are signs of goal-directed storytelling. Examples are: "no breathing on the moon" as a reason for buying a space suit (global) and "to meet aliens" as a reason for going to the planet (local). An example lacking any causal relation (0 pt) is "saying woof" as a reason for talking to the dog. Emotion reasoning was scored similarly, but to prevent an unfair advantage for the E condition (where emotions were given by the system), the scoring system differentiated between the two conditions. In the E condition, 0 points were assigned if an emotion was mentioned but no reason for it; 1 point for a local reason (sad, because "there is no little space man") and 2 points for a global reason (angry, because "he does not want to wear a space suit"). In the NE condition, 1 point was assigned if an emotion was mentioned but no reason, and 2 points if also a reason was given (either local or global).

All stories were annotated by two annotators, leading to a substantial interrater agreement (Cohen's Weighted Kappa of 0.67). Differences between the annotators were resolved by discussion when giving the final score for stories. Table 1 presents the results of the annotations. It shows a slight trend in favour of the E condition. However, we must be cautious because larger samples would be needed as the scores largely varied across the different trials, ranging between two and eleven points with similar variability in both conditions. Children in the

[8] Video: https://www.youtube.com/watch?v=TfrfhNtuqHs

	Condition NE		Condition E	
	M	SD	M	SD
Total score	5.83, median(5.5)	2.93	7, median(8)	2.94
Actions score	2.5	1.64	3.57	1.99
Emotions score	3.33	1.37	3.43	1.27

Table 1. Story annotation scores.

NE condition almost exclusively mentioned the happy emotion; they did so in all trials except one. In the E condition, emotions were more varied, as they were randomly generated by the system. The children mainly took the randomness of the robot emotions for granted, but the 'why' questions did trigger them to come up with reasons to match the emotions with the story. They also included more emotions (happy, angry, sad, surprise) in their story summaries when retelling the story they had created. Also, their summaries more often centred around the robot as a protagonist, and explicitly referred to its goal.

It is worth mentioning that many children had problems with spelling and typing, which may have caused their answers to be more limited than if they could have provided them in some other way. Sometimes the question answering was a source of discussion because one child was telling the other that they were wrong or criticising their language skills. We also observed a child saying he was impressed by the reason the other child came up with, and a child laughing about what she had come up with herself. A child specifically mentioned the need to come up "with something logical" in order to go to the moon. This kind of reasoning and skills are to be trained and these reactions show that the structure of the task and app is supporting the process.

4 Conclusion and future work

In this paper, we have reported the iterative design of a multimedia application and tangible setting that includes a smart robotic toy in a storytelling activity. Giving the deserved importance to user-centred methods, the design process consisted of several steps, empirically evaluating the various prototypes involving seventy-three children in total.

To support children in moving from free play with toys to more coherent and structured story-based play, the final version of the app included additional why-questions to be completed during the storytelling, in order to let the children reflect and externalize links between elements in the story. The final prototype was tested in two versions, one in which the robotic toy expressed emotions in response to events (condition E), and another without such responses (condition NE). The results showed that introducing emotional responses by the robot led to differences in the way children incorporated emotions in their stories. The E version encouraged children to explore different emotions and reflect on them, linking them to possible causes and consequences. Children managed to create stories around the robot responses, suggesting that the tool can be evolved to support emotional development through stories in future work. We observed that typing the answers to the reflection questions was sometimes an issue. Hence, input can be improved by considering audio recording or using a speech recognizer specialized for children . This would also speed up the pace of interaction and story steps, hopefully leading to longer stories with more possibilities for children to explore different connections between elements in their story. As the prototype design evolved children's storytelling improved, but even in the final study the created stories were somewhat lacking in global coherence. Possibilities to improve the prototype to further encourage the creation of structured stories include extending the tablet app with a goal reminder, content specific questions from the main character's perspective, and story suggestions, to be tested in new follow-up studies with children.

Overall, the research indicates the designed prototype can be used as a starting point for an interactive storytelling system. It also raised many new issues, such as the relationship between play, creativity and storytelling, and how to measure the quality of stories produced. It is future work to research these issues and, in addition, perform brainstorm sessions with elementary school teachers, parents and caregivers on how the technology could best be used in practice.

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