Fabula: A Storytelling Robot for Motivating and Engaging Children in Primary Education

Summary

In recent years, concerns have been raised regarding the motivation and engagement of students in primary education; in school, students display decreased interest in topics such as history, science and technology, often due to the use of uninteresting materials and lack of involvement by educators [2,12,16]. As student motivation and engagement greatly affect learning performance [1], it is important to explore alternative educational methods to actively engage children with school material and stimulate them to learn. In this research project, an educational storytelling robot, called *Fabula*, has been developed to educate children on topics such as history, science and technology in a manner that promotes engagement and motivates children to learn. To this end, Fabula implements various forms of quizzing and a question answering (QA) system to actively engage children in the storytelling session. Furthermore, Fabula implements numerous didactic techniques, from encouragements to non-verbal immediacy, to stimulate participation and motivate children to learn.

This document is structured as follows: In the first section, *Foundation*, the problem statement is provided and relevant stakeholders and human factors principles are identified. In section *Interaction Design*, the application context and design principles underlying the design of the robot are explained, after which, in *Implementation*, details of the robot software are provided. Lastly, in the *Evaluation* section, a study is described in which users were asked to evaluate the design features of the robot with regard to their motivation and engagement during storytelling; results showed that the encouragements provided by the robot contributed to the motivation of the users and that the incorporation of quizzing greatly improved engagement; despite this, gestures showed minimal influence on motivation.

Link to video presentation: Final Video Presentation of Fabula

Foundation

Problem statement

Primary education is of fundamental importance to the personal development of children as it provides the basic skills and knowledge necessary to function in society. In primary school, children are taught numerous lifelong skills, such as reading, writing and arithmetic, and are educated on a multitude of topics from history and geography to science and technology [11]. As children benefit from having an understanding of history, science and technology later in life, it is crucial that these subjects are given to an acceptable standard; however, it has been widely acknowledged that in the current educational climate, these subjects are often not properly implemented in school curricula [2,11]. To educate children on history, science and technology, educators commonly use standardized materials, such as text- and workbooks and e-learning platforms [2,4].[1] Common practice when working with these materials is to let children read a story in a textbook, look at relevant illustrations and answer questions in a workbook, either individually or in groups; however, it has been shown that working as such may not elicit interest on part of the child, affecting the motivation and engagement of the child and his or her ability to recall information on the subject [2,8].

In order to improve the motivation and engagement of students, didactically-proven methods (e.g. storytelling sessions, excursions and guided-exploratory learning) are often necessary to complement the use of textbook materials [2,3]; however, as classrooms commonly contain many students, these methods can be difficult for educators to organize on a regular basis [2]. As a result, educators are stuck using traditional methods with little appeal to children, affecting the motivation and engagement of the children in class.

We believe that social storytelling robots, capable of telling stories on history, science and technology in a manner that provides an engaging and motivating experience for children, can be beneficial to support educators in providing didactically-sound education and increase children's motivation to learn about history, science and technology in school.

Problem scenario

Mike is an eight y.o. boy from the Netherlands who is currently enrolled in an international primary school in Amsterdam. As this year marks a change in the curriculum of primary education, Mike has to follow classes on history, science and technology for the first time. Even though Mike enjoyed the classes given by his teacher in the previous year and likes to learn about new topics, he has a hard time remaining motivated to work in class as he is required to work mostly out of his workbook and do so relatively independently. In addition, the assignments in his workbook are all very similar and not very appealing to him, affecting his engagement with the material and his motivation to continue to work on the assignments.

To help Mike, his teacher tries to organize after-school tutoring sessions for them to work on the material together; however, due to after-school obligations and the high workload of teaching a class of more than thirty children during the day, his teacher has limited time to help Mike and cannot sufficiently provide him individual education on a daily basis. As a result, Mike does not get the engagement he desires and does poorly on his assignments.

Target Audience

A number of direct stakeholders have been identified that would be affected by the presence of the robot at school. For one, primary school children (group 5 to 8;[2] aged 8 to 12 y.o.) are the primary stakeholder as they have the central role for any school activity, being the main beneficiary of the educational curriculum. Children aged between 8 and 12 are often very active and curious, yet may lose attention quickly. One of the needs of the child is an educational method that keeps him/her engaged with the material and is enjoyable to work with. In addition, children require an educational method that is semi-adaptable to their learning abilities and speed of progression.

The second direct stakeholder is the educator; teachers move in sync with the children, guiding them and managing the learning channels of their education. Apart from the 21st century characteristics an educator should meet, there may be complications that affect the aforementioned problem, like being overwhelmed by the number of tasks (leading to stress) and the number of children to manage in class. Their needs revolve around having enough

1 Educational methods such as *Wijzer!* and *Oxford International Primary* being prime examples.

2 History, science and technology education most commonly starts in year 5 of primary education.

time to plan and organize class and having access to sufficient facilities and class support.

Personas

Human-factors knowledge

Research has shown that interactive forms of teaching which emphasize teacher immediacy, positively affect student motivation, attention and cognitive learning ability (i.e. recall) [8]. Teacher immediacy, described as communicative actions that send positive messages towards students, can be divided into verbal and non-verbal components; the former associated with use of pronouns (e.g. "you"), encouragements, praise, personal names and humor; while the latter includes eye contact, use of positive gestures and a relaxed posture.[3] In [8], Frymier researched the extent to which a teachers' use of verbal and non-verbal immediacy affected students' reported motivation to study for class. In the study, immediacy had shown to have a profound influence on motivation, in particular, when students felt demotivated; Frymier found that students who initially scored low on the motivational scale showed considerable growth in state motivation when immediacy had been implemented.

The interactive nature of the robot underlies why the robot is suitable for our storytelling purposes; the robot can offer students an interactive educational story, incorporating various forms of both verbal and non-verbal immediacy; for example, by referring to the student's name and by sustaining eye contact during storytelling. Moreover, since a humanoid robot is used (see Social robot), non-verbal immediacy can be incorporated by means of positive gestures. Lastly, students will be tested for their knowledge of the story, to see to which extent they have understood the material and can recall it (see Design ideas); as the robot has the ability to question pupils about the story, it has the opportunity to verbally congratulate them when their answer is correct. Using these, and other methods of immediacy, students are actively engaged with the story by the robot and remain motivated.

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[3] Not all forms of immediacy are mentioned in [8]; a semi-exhaustive list of actions related to verbal and non-verbal immediacy can be found in [10, 15].

Interaction Design

Design scenario

Let's get back to Mike, the eight-year-old boy who has trouble remaining motivated to work in class. Mike's lack of engagement and motivation is noticed by his teacher, who takes him to a room outside the classroom, where the Fabula robot is waiting for him. The teacher asks a class intern to watch over Mike and explain the robot to him, while she goes back to her class. The intern introduces Mike to Fabula; "This is Fabula, he will help you with the assignment." Mike sits down in front of the robot and when Fabula recognizes him, it starts talking. After a short introduction in which Mike and Fabula get acquainted, the robot tells Mike a story related to his assignment; *the story of Talos; the first robot*. Mike is fascinated by the robot and patiently listens to the story. A few times, the robot asks Mike a question and Mike answers enthusiastically; he had it right and the robot congratulates him. The robot continues the story and at the end Mike has a question; he interrupts the robot to ask it; the robot answers it perfectly. Mike has no further questions. He enjoyed the story and is able to recall it. Meanwhile, the teacher was able to help other children and do some work that she would otherwise not be able to get to. The robot makes it easier for her to handle her class.

Application context

Physical environment

As mentioned in the design scenario, the target application context is a primary school environment. As the main communication channel between the child and the robot is speech, it is important that the room in which the interaction takes place is not too noisy. In particular, the robot needs to be audible and able to understand the child, and not pick up background conversations. To achieve this, the robot would be placed on the floor[4] in a separate room, where noise levels can be controlled (e.g. a hallway or playroom), as shown in Fig. 1. Playrooms and hallways are ideal as these rooms often have large open areas, allowing the robot to be placed where there is sufficient space for it to move freely.
In addition, as vision-based systems, such as face and emotion recognition, are used by the robot to identify the child and is/her emotional state (see Vision), the environment needs to be well-illuminated; primary schools are required to have artificial lighting,[5] hence this requirement is met. To use the robot, a laptop will need to be available capable of connec- ting to the robot over Wi-Fi and run its software. For this, a stable Wi-Fi connection will need to be present and, depending on the frequency of use, a charging port may need to be available in the room as well to charge the laptop and robot. As many modern schools use digital devices to educate their students, Wi-Fi and power outlets are likely to be available.

[4] Or any other stable surface (e.g. a large table) as long as the robot cannot fall from height.

[5] As per *Arbeidsomstandighedenbesluit, Artikel 6.3*.

Social environment

The robot will be introduced to students who struggle with the current manner of teaching, as exemplified by the design scenario; these include, students who feel disengaged with the material or have trouble with study motivation. The robot can be used after class, or during class hours when other students are working independently. It is preferred that few people are near the robot; however, it is essential that a supervisor (e.g. a class intern) is present to keep an eye on the child and robot and prevent any accidents (e.g. robot falling over). The interaction with the robot will be done by students themselves. However, on the first encounter, the supervisor should provide a brief introduction to explain what the robot can do and how they can interact with it. The intern will be there to switch the robot on and off.

Organizational environment

In terms of the organizational setting, some changes are required to implement the robot; if the robot is used during regular school hours, a separate room needs to be made available and the supervisor needs to be present to monitor the interaction and give technical support when needed. Alternatively, in an after-class scenario, when the teacher does administrative work, some students may choose to stay a bit longer to work under supervision with the robot. In this scenario, the robot could be used in the classroom and no additional room or supervisor is required. As with the supervisor in the during-school scenario, the teacher should be able to resolve issues with the robot, such as charging it or restarting it if needed.

Design ideas and principles

In the following sections, the design ideas and principles underlying the robot design are discussed. In the first section, *Social robot*, the use of the NAO robot is argued for, after which the storytelling approach of the robot is described in *Story & Storytelling* and *Conversational interaction*. In the final sections, the non-verbal behaviors of the robot are discussed along with its vision, personalization and question answering capabilities.

Social robot

This project aims to provide a storytelling platform to educate children in a manner that promotes engagement and improves their motivation to learn. The platform of choice is the NAO robot by Softbank Robotics (see Fig. 3.); a versatile humanoid robot used in numerous child-robot interaction (CRI) studies [4,5]. Due to its hardware capabilities (i.e. speakers and microphone) and its embodiment, the NAO is capable of both verbal and non-verbal communication. As described in the section on Human-factors knowledge, gestures, which are a natural way of non-verbal communication, are often perceived as stimulating and motivating by children [6,8,11]; hence the NAO robot, which is capable of performing gestures, is highly appropriate to engage and motivate the target audience. Furthemore, research has shown a moderate degree of human likeness improves children's acceptability of a robot [7], making the semi-humanoid form of the NAO ideal in the context of primary education. Lastly, as the robot is small and not very strong or heavy, it is safe to use around children.

Story & Storytelling

Despite the ability to narrate stories about numerous topics from history to technology, the number of stories has been limited to two due to time constraints. These stories, *Talos the* *first robot*[6] and *Da Vinci's Mechanical Knight*[7], concern the history of robotics and are as such examples of integrated history, science and technology education.[8]

To ensure children remain engaged, stories are not told in a passive manner in which the child listens patiently to the story being told; to engage its audience, the storyteller will involve the child by telling parts of the story and intermittently asking the child questions about the story. To add variety to the questions, several types of questions may be asked, including factoid (e.g. *Do you know who Leonardo Da Vinci is?*), inventive (e.g. *Do you think he created Talos to be a nice robot?*), and open questions (e.g. *Can you explain what ichor is?*). The structure of the *story of Talos* is shown graphically in the interaction diagram.

In addition, to engage the child further in the storytelling experience and improve his/her agentic engagement, the child will be able to ask questions to the robot at any point during the storytelling session. This feature is further described in the section Question answering.

Conversational Interaction

As the robot is aimed to be motivational, the robot interaction has been designed to allow several additional opportunities to be created to motivate the child prior to and after story-telling sessions. This is done by means of a pre-story *introduction* and a post-story *quiz*.

Introduction

On the first contact between the user and robot an introduction is given to allow the child and the robot to get acquainted. After greeting the child, the robot tells its name and asks the child to introduce him/herself. After the child responds, the robot will ask how the child is doing and asks whether he/she would like to agree upon a personal greeting (all of which remain optional). At the end of the introduction, the robot proposes to tell a story and starts the storytelling session, which is described in more detail in Story & Storytelling.

After the first contact with the robot, a lengthy introduction is not necessary; hence, on subsequent encounters, the robot will fall back to a shortened introduction. In this case, the robot greets the child with his/her personal greeting and quickly recaps the results of the previous session. Depending on previous results, the robot will suggest redoing the previous story or will recommend a new story; when the child did well, the robot congratulates the child; in case results were poor, the robot motivates the child to try again and suggests re-doing the previous story. After a choice is made by the child, the storytelling session begins.

Quiz

Once the story has been told, the child is asked whether he/she enjoyed the story and would like to take a short quiz. The quiz allows the opportunity for additional encouragement to be given to the child. In the quiz, the robot will do a small recap with questions from facts told in the story. After a question has been answered, the robot will give a compliment when it was answered correctly or give feedback when the answer given was incorrect. When correcting the child, care is taken to ensure the robot has a positive and encouraging attitude.

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[6] Apollonius, Rhodius. (1961). The Argonautica. Cambridge, Mass. Harvard University Press.

[7] Moran, Michael E. (December 2006). "The da Vinci robot". *Journal of Endourology*.

[8] As described in [2], subjects taught in school are often integrated in primary education.

Non-verbal behavior

As described in the Human-factors knowledge section, non-verbal behavior is an essential component to successfully motivate and engage children in an educational context [3]; hence, it is important to incorporate non-verbal communication into the storytelling robot. To this end, several gesture-based features have been incorporated; for one, the emotions of the robot will be shown through pre-recorded gestures. Such gestures can be, for example, a waving gesture when saying “Hello”, a happy dance or throwing its arms up to praise the child for a correct answer on a quiz question. In addition, several personal gestures have been recorded that children can select in the introduction. This open attitude of the robot ensures that it is approachable and accessible to the child.

In addition, as maintaining eye contact during a dialog is a common form of non-verbal immediacy, the robot will try to maintain eye contact with the child during the interaction.

Lastly, the robot is equipped with multi-color LEDs, designated to the ears, eyes and button locations. The NAO will use these lights to signal turn-taking and discourse structure; that is, the lights indicate when the robot is in a listening state, so the child knows that he/she can speak. By default, the robot uses blue to indicate its listening state.

Vision

Several vision-based capabilities have been incorporated in the robot software to allow the robot to be aware of its surroundings and monitor the state of the user. For one, the cameras are used to monitor the emotional state of the child and act in case the child signals a bad mood; when a bad mood is detected for a sufficient period of time,[9] the robot interrupts its story and tells a joke to boost morale and stimulate the child to continue to pay attention; by interrupting its story and telling a joke, the robot can thus ensure the child remains engaged.

Furthermore, the camera of the robot is used in conjunction with a face recognition system to identify the child with which the robot is interacting. On the first encounter, when the child is unknown to the robot, the face recognition system is used to compute an identifier for the child, which can be used on later encounters to re-identify the child from memory (see implementation), speeding up the formalities of subsequent introductions and allowing the robot to maintain information regarding user progress (see Personalization).

Personalization

As described in the Vision section, the robot is capable of recognizing children using face recognition, allowing the robot to keep a personal record of an interaction and track various statistics. Fabula keeps track of user progress and quiz results, which allows the robot to alter its introduction on subsequent encounters depending on story progress and quiz results from last time. For example, in case the user did not perform well on the quiz or the last story was not been completed, the robot may suggest to the child to redo the story and quiz from last time. In case the quiz went well, the robot can suggest to move on to the next story.

These personalizations have been implemented as they increase the effectiveness and productivity of the robot and have the potential to increase the student’s satisfaction of working with the robot. Additionally, the extra rehearsal for students who had difficulty with the material ensures that they too obtain full knowledge of what they are being taught. Lastly, the extra encouragement for the students who have to repeat something, because they did not get a good result last time, ensures that the self-confidence of the student is boosted and that they remain motivated to work with the robot.

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[9] The system has been calibrated to trigger the emotion interrupt after 20 seconds.

Question answering

In order to further engage the child during a storytelling session and improve his/her agentic engagement [14], a system has been developed to allow children to ask questions about the story at any point during the interaction by pressing one of the robot's foot bumpers. When the bumper is pressed, the robot will ask the child what it can do for him/her. The child may then indicate its intent to ask a question (e.g. *"Can I ask a question?"*) or ask a question directly (e.g. *"Who is Talos?"*).[10] When a question is posed to the robot, the robot attempts to answer it using the question-answering (QA) system described in Implementation. After an answer is given, the story is resumed using a repair phrase (e.g. by "But, as I was saying.").

The main rationale for using a button press as opposed to a speech-based interruption is that the robot cannot discriminate between the child's voice and its own. As a result, continually listening for interruptions using speech may cause many interruption failures to occur due to its own speaking; a button press mitigates this issue as a different channel of communication is used to signal the interruption.

Reflection

To gain further insight into the design specifications, two peer-review sessions were organized; one with a group of peers from the Vrije Universiteit (VU) and one with theater students from the University of Utrecht (UU). During the first session with VU students and a teaching assistant, feedback was given regarding the non-verbal cues by which to communicate turn-taking, in particular by incorporating different LED colors to indicate the user's dialog turn. It was decided to use a neutral blue color for the LEDs to indicate that the robot is waiting for a response from the user. This color was chosen since it is distinctive from the standard white color of the eyes, yet did not distract nor carried a strong association with a particular emotion, such as sadness [17].
Another observation concerned the nature of the questions asked during the stories and quizzes; it was agreed that binary "Yes/No" responses may get repetitive after frequent use. As a result of the feedback received, it was decided to incorporate multiple-choice and more open-ended, keyword-based questions in the stories and quizzes.

The multidisciplinary collaboration with the theater students provided interesting and unique insights into the design specifications. The students provided a moodboard, which was later explained during an online meeting. One of the most interesting suggestions was to emphasize the fact that Fabula is not human; that is, its power might lie precisely in its robotic nature. Instead of masking its non-humanity, it was advised to embrace its robotic movements. The collaboration with both groups of students was insightful, the time allocated for the sessions was sufficient and it helped gain a different perspective on the problem.

[10] A question related to stopping the interaction may be used to stop the storytelling session prematurely (e.g. by *"Can we stop? I have to go."*).

Use case

Title	UC01 - First time contact between the child and robot.		
Objectives	1. Familiarize the child with the robot (and vice versa). 2. Start the teaching process. 3. Motivate the child to use the robot again	**Actors**	Child (primary user and active participant of the learning process). Robot (starts teaching by telling a story and asking questions).
Pre-condition	1. A room is available for the interaction to take place in. 2. The robot has sufficient charge. 3. The robot has no previous recollection of the child.	**Post-condition**	The first step in the teaching process has been made. The child is aware of the robot's availability and feels motivated to use it. The robot is familiar with the user to the extent that it has stored the child's name, facial features and story progress for future interactions.
Happy Flow	1. The child is led into the room by the supervisor. 2. The child is asked by the supervisor to sit on the floor. 3. The child sits down. 4. The supervisor places the Fabula robot on the floor, in front of the child. 5. The supervisor briefly introduces Fabula and its capabilities to the child. 6. The supervisor switches the robot on. 7. The robot attempts to recognize the child. 8. The robot introduces itself by telling its name and its role as an educational storytelling robot. 9. Fabula asks the child to introduce him/herself by stating his/her name. 10. The child tells his/her name. 11. Fabula says it's nice to meet the child and calls the child by name. 12. Fabula asks how the child is doing that day. a. The child indicates doing great: Fabula makes a happy gesture. b. The child indicates doing poorly: Fabula tells the child it has something that might cheer him/her up. 13. Fabula asks if the childs wants to agree upon a personal greeting.	19. Fabula narrates a part of the story. 20. Fabula asks a question related to the storyline. 21. The child responds to the question. a. The child answers correctly: Fabula reacts happily. b. The child answers incorrectly: Fabula reassures the child and gives the correct answer. 22. Fabula repeats steps 19-21 until the end of the story. 23. Fabula asks if he/she liked the story. a. The child confirms: Fabula reacts happily. b. The child disconfirms: Fabula accepts answer. 24. Fabula asks if the child would like to take a small quiz. 25. The child agrees. 26. The robot asks a question. 27. The child answers the question. 28. The robot indicates whether the child answered correctly.	

Alternative Flow 1	Alternative Flow 2	Alternative Flow 3
There may be moments when the child would like to interrupt the story to ask a question: a1. Child presses the bumper button on Fabula's feet. a2. Fabula acknowledges the request. a3. Child asks a question. a3-success: Fabula knows the answer and replies.	The child might not wish to tell its name or agree on a personal gesture: b1. Child states his/her desire not to answer. b2. The robot accepts the child's intent to not answer the question. b3. Fabula returns gracefully to the	When a question is asked during the story or quiz, a child may state he/she does not know the answer. c1. The robot will reassure the child it is okay. c2. The robot will give the correct answer. c3. Fabula returns gracefully to the happy flow.

Another use case to highlight is the Practice session on previous lessons, which is provided in [Appendix 1.2](#).

Requirements and claims

UC Step	Requirement	Upside	Downside
7	The robot can use face detection to identify the child and maintain eye contact during storytelling	The child appreciates the personalized, face-to-face interaction, improving engagement during storytelling.	The child feels overwhelmed by how the robot looks at him/her. This could damage the engagement during storytelling.
11	Fabula is able to recall the name of the child.	The child feels listened to and taken seriously.	The robot might misidentify the child, which leads to disappointment.
a3 - success	Fabula is able to respond to the child's question.	The child appreciates the feeling of having an actual impact on the story, improving their engagement.	The child is frightened by the idea that a non-human is able to have a conversation.
26	Fabula asks questions for each part of the story told.	The child feels a higher level of engagement in the story and becomes more motivated to learn about the subject.	The child gets bored by being questioned after each small part of the story.
12-a & 15	Fabula is able to perform gestures.	The gestures are seen as fun to the child and engages the child further during storytelling.	The child expects the robot to do fun things, such as dances all the time, distracting the child from learning.

Interaction diagram

The interaction diagram can be found on diagrams.net. As the interaction is inherently dynamic the interaction flow could not be represented by a fixed visualization; the diagram has therefore been restricted to the introduction given by the robot, the main story (i.e. the story of Talos) and its associated quiz. The question-answering mode of the robot can be enabled at any point during the interaction, hence it has been represented as a separate component.

Implementation

To realize the aforementioned design ideas, robot control software has been implemented. The software consists of four components: an *interaction manager* to track the state of the interaction, a *user model* to store and retrieve user information, a *question answering* (QA) system to answer user queries and a *connector* to put these components together and interface with robot hardware. An overview of the software architecture is shown in Appendix 2.

First, to incorporate the design ideas described in Story & Storytelling and Conversational Interaction, an *interaction manager* has been implemented to run interaction designs[11] as the one shown in Fig. 2. Interaction designs take the form of a finite-state machine (FSM) in which each state represents a conversational turn by the robot. In each state the FSM specifies what the robot should say, what gestures it should perform and how it should transition to the next state. Transitions are governed by the results of *Action* functions (e.g. skip, listen_for_keywords, recognize_user); after running the *Speech* and *Gesture* commands of a state, the Action function is evaluated and its return value (e.g. 'confirm') is used to determine which branch is taken.[12] Tags are used in *Speech* commands to incorporate personal information (e.g. <name> can be used to add a child's name to Speech commands).

[11] As designing and maintaining interaction designs in plain text can be a time-consuming and error prone task, conversion software has been written to convert diagrams.net designs to the desired JSON format.

[12] A complete list of Action transitions and intents supported by the robot is provided in Appendix 3.

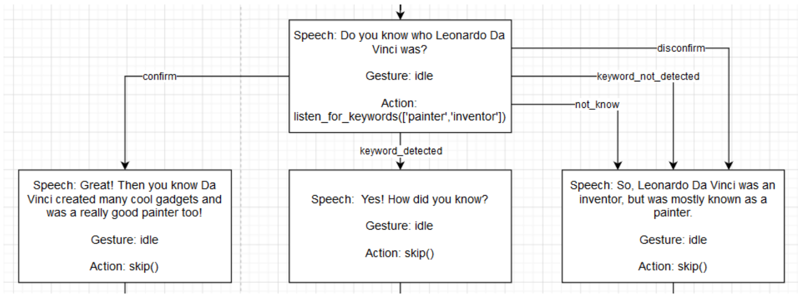


Fig. 2. *A snippet from Da Vinci's Mechanical Knight. Boxes represent interaction states with Speech and Gesture commands. The transition labels confirm, disconfirm, and not_know are intents extracted from user responses using Dialogflow. The Action listen_for_keywords is used to determine whether a keyword was used in a response transcript.*

The manager implements methods to get Speech and Gesture commands of the current state (*get_state*) to send to the robot and to perform state transitions (*update_state*). This way, the FSM allows the robot to maintain a strict agenda and enables the robot to track the state of the introduction, story and quiz with little computational overhead.

The second component, the *user model*, interfaces with an SQL database to store and retrieve information obtained during interactions (e.g. the child's name). If the robot interacts with the user for the first time, a new record is created in the database table for the user, which allows his or her name, age, face identifier, and personal greeting to be stored. In addition, the table allows the progress of the user to be recorded in terms of which stories have been completed, which story was told last and how well the user did on quizzes.

The final subcomponent is the *question answering (QA)* system which allows users to ask questions about the story at any point in the interaction. QA implements a semantics-based approach to NLU and question answering. It uses a CSV file with question-answer pairs and computes which question in the file is semantically most related to a user query. The answer associated with this question is returned as the answer to the user query. When the system has limited confidence in its answer, it refrains from answering and falls back to an apology.

The *connector* is the final component that puts all other components together. As the name implies, the main purpose of the connector is to interface with the hardware using the *Social Interaction Cloud* (SIC), and integrate the interaction manager, question answering system and *user model*. The connector contains all methods needed to run interactions (i.e. *listen, recognize_user, answer_question,* etc.). The main method of the connector is *run* which implements an *interaction loop* to repeatedly query the interaction manager and so progress through the story. During execution, there may be cases in which the interaction fails, for example, when the user is misunderstood or when the user interrupts the robot to enable QA mode. For the former, the loop implements a fallback strategy, in which the failure to understand the user is signaled back to the user (e.g. by *"Don't think I understand."*). In the case QA is enabled, the robot interrupts itself, runs its *answer_question* method, and continues from the current state, repeating what was previously said to repair the dialog and re-engage the user in the story. A similar interruption is used for emotion detection as well.

Evaluation

Research question

As described in the problem statement, the main aim of this project has been to provide an educational storytelling robot to educate children on topics such as history and technology in a manner that promotes their engagement with the material and improves their motivation to learn. An important part to achieve this goal is to evaluate whether the implemented features of the robot contribute to this design objectives; that is, whether the features improve the motivation and engagement experienced by users compared to traditional teaching materials (i.e. textbooks). To this end, the following research question has been formulated:

Q: How do the verbal and non-verbal characteristics and features of the Fabula robot contribute to the engagement and motivation experienced by users during story learning compared to a plain textual medium?

To address this research question, a user study has been conducted; participants were given a textual version of the story of Talos to read, after which the story was retold in an interactive manner by the robot. After the interaction, participants filled out a questionnaire about their experiences with the robot and how the features of the robot impacted their motivation and engagement during storytelling.

Method

Participants

Due to concerns regarding the COVID-19 pandemic, the user study has been conducted with adult participants, as opposed to the primary target group of children. A small group of participants (N=5) was predesignated by the university as the only group to take part in the study. Participants consisted of students following the master Artificial Intelligence from the Vrije Universiteit, aged between 22 and 26 (M=23.8, SD=1.8). Care was taken to ensure participants had minimal prior knowledge regarding the content of the story told in the study. Participation was voluntary and participants received complete information regarding the purpose of the study. All participants were asked for informed consent. Lastly, care was taken to ensure participants could participate while adhering to COVID-19 guidelines.[13]

Ideally, primary school children would have been recruited to participate in the study as they are the primary demographic of the robot, which would allow more representative findings to be obtained. A larger number of participants would have been recruited (n>30) from a sufficient number of English-speaking international primary schools in the area of Amsterdam; in particular, children aged between 8 and 12 y.o., enrolled in group 5 to 8, would have been asked to participate, ensuring an equal ratio between boys and girls. In this situation, parental consent would have been acquired prior to performing the study.

Design

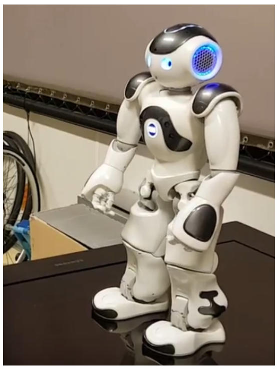
A qualitative study was set up with two conditions; the independent variable varied between conditions being the medium type. In the *textual condition*, participants were provided with a plain text version of *the story of Talos* to read on their own. This version did not include intermediate questions within the story, nor did it contain any form of feedback or interaction; the text version of the story hence functioned similar to textbook story. In the *robot condition*, the story was told in an interactive manner by the robot, which contained all features implemented, including an introduction, intermediate story questions, a quiz, etc. A number of factors were measured including self-reported engagement during storytelling and the experienced motivation with respect to each of the features implemented.

As only a limited number of participants could be recruited, a within-subjects design was used in which all participants (N=5) were exposed to each of the experimental conditions.

[13] An ethics self-check was performed to verify no additional evaluation was required by the Research Ethics Review Committee.

Materials

Due to concerns regarding COVID-19, the study was set up to allow participants to perform the study themselves. To this end, an evaluation procedure was specified prior to the evaluation session, which can be found in Appendix 4. The study was conducted in a room at the university which permitted a semi-controlled environment to be created in which confounding factors, such as noise, lighting and distractions, could be controlled.[14] The lab was set up as shown in Fig. 3; the robot was placed on a table and put in a standing position (when in use), facing the direction the participant would be sitting. As per the requirements of the study setup imposed by the university, the robot was connected to the laptop of the participant which in turn was used to run the robot software.



To obtain insight into the engagement of users during storytelling and obtain qualitative insights regarding experienced motivation of participants, a questionnaire was created which included open-ended questions regarding motivation and engagement. The questionnaire can be found in Appendix 6. In addition, an observation scheme had been created to obtain objective measurements regarding user behavior, which is found in Appendix 5. The text version of the story of Talos used in the textual condition can be found in Appendix 8.

Procedure

During the evaluation session, participants were instructed to follow the provided procedure; first, participants filled out the consent form, after which they set up the lab as described in the Materials section. Once set up, participants were let into the lab one at a time. Participants were instructed to sit at the designated location in front of the robot and were asked to perform the text condition of the study; the participant read the story from his/her laptop and, after having read the story, the story was put away. The participant was then exposed to the *robot condition*, where he/she was told the story by the robot. At two points in the interaction, the participant was asked by the robot whether he/she would want to continue; participants were instructed to agree. After the interaction with the robot, the robot put itself in 'rest' position and the participant filled out the questionnaire. The participant was then thanked for his/her participation and left the lab. The conditions were reset and a new participant was let into the lab. The study lasted approximately 12 minutes per participant.

During the study, a member of the research group was present to record notes using the observation scheme; these observations were used as support material for the resulting analysis. The researcher positioned himself behind the participant, out of sight of both the robot and participant, as to not influence the interaction.

Results

In this section, the results of the user study are described. A summary of the questionnaire responses can be found in Appendix 9. In the questionnaire, all participants stated to have felt comfortable during the interaction with the robot and to have enjoyed the session. In terms of engagement, all participants noted an increase in engagement in the robot condition over the textual condition, in part due to the use of gestures by the robot and the constant involvement it provided through asking questions; participants stated to have experienced an increased drive to stay focussed and pay attention to the story when the

[14] The trade-off being that practical subtleties, such as user distractions, were not considered in the evaluation.

robot was there to actively involve them in the interaction. One participant did note a decrease in engagement in the robot condition, as he/she felt distracted by certain gestures.

In terms of motivation, all participants reported an increase in motivation in the robot condition, often attributing this to the verbal appreciation and encouragement received after answering quiz questions. The responses given by the robot when a correct answer was given were mentioned by four participants to be a contributing factor influencing their motivation and satisfaction. Encouragement and consolation when an incorrect answer was given was noted by a participant as providing '*energy to continue'* and made one '*feel less bad'* and *'reassured'*. The gestures performed by the robot, though appreciated as a feature, were not deemed impactful to all participants' willingness to continue the story.

In the final section of the questionnaire, participants provided notes regarding the interaction. Technical complications encountered during the interaction were associated with speech recognition failures, low speech volume or not knowing the right time to speak. Looking at loss of focus and the sensation of boredom, all participants stated they had experienced both when reading the story, while two participants mentioned that even with the robot they felt a bit underwhelmed as its pace was slower than expected. None of the participants reported feeling disappointed with any part of the story or the robot's responses and the joke told upon detecting sadness was well received by one participant (see Appendix 9). Finally, considering the suggestions made, specific animations and eye colors for characters were mentioned as well as additional sound effects.

Discussion

The results of the study demonstrate how the features implemented by the robot may contribute to the motivation and engagement experienced by users when learning material by storytelling. The results indicate that, by incorporating non-verbal immediacy using gestures, users feel more comfortable and feel an increased drive to pay attention to the story. In addition, results show that the encouragements provided by the robot contributed to the motivation of the users and that the incorporation of quizzing greatly improved engagement. The results thus support the idea that the incorporation of immediacy into the robot aids the ability of the robot to serve as an effective educational tool to motivate and engage students.

Nonetheless, due to the circumstances in which the study was performed, care has to be taken regarding the conclusions drawn from these results. Due to the COVID-19 circumstances we were unable to perform the study on our actual target group of children, limiting the validity of the results obtained. Because of the limited possibility to test it out on a larger group, it was not possible to perform a quantitative study as initially designed and were thus restricted to do a strictly qualitative evaluation approach. A quantitative study would have allowed more objective data to be gathered which could have provided more insight on how the robot impacted the learning process. In addition, validated tools would have been available to measure the motivation and engagement of the participants more precisely.

Regarding the hardware of the robot, the study was performed in a room at the VU where complete silence was not feasible; it was found that in situations with background noise, speech recognition sometimes did not succeed, with speech recognition failures during the evaluation study. This finding has potential consequences for the applicability in schools, if a noise-free room cannot be made available. In addition, it was noticed that in conditions with severe backlighting, the robot was unable to identify the user with the face recognition mechanism, necessitating the camera to be turned off in the evaluation session.

Regarding the feedback from the respondents, there remain possibilities to improve the communication of the robot. Since problems arose for some users, in particular in terms of timing of dialog turns, the speaking and listening states of the robot may need emphasis; in addition to the visual cues that are given by the robot (e.g. Fabula changing eye-color when transitioning from a talking to a listening state) aural cues, like a short tone, could be added to stress when exactly Fabula requires input from the user. Moreover, as there was some discrepancy between the users with regard to the effect of the gestures on their motivation, it is useful to conduct a separate analysis on the effect of specific gestures on the motivation of the students; Gestures that turn out to increase the motivation and concentration of users may then be selected, while the gestures that seem to elicit inattentional behaviour can be removed. Lastly, given that students have different learning rates, it is important that each student is able to adjust the talking speed of the robot so that it suits their tempo best.

Conclusion

In this research project, the use of educational storytelling robots in primary education has been explored. A storytelling robot, called Fabula, was developed to educate children on history and technology in a manner that promotes engagement and motivates children to learn. Previous research had shown that interactive forms of teaching which emphasize teacher immediacy, positively affect student motivation, attention and cognitive learning ability; hence, Fabula was implemented to utilize various forms of verbal and non-verbal immediacy to stimulate participation and motivate children to learn. Furthermore, Fabula implemented quizzing and question answering to actively engage children in storytelling.

A qualitative user study was performed to validate the design features of the robot. The results showed that the motivation of subjects was influenced positively by the encouragements provided by the robot and that engagement was significantly enhanced by the quizzing mechanism in place; however, not all gestures showed to equally augment motivation, as some subjects noted them as being distracting.n

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Appendices

Appendix 1.1: Use case 1

Title	UC01 - First time contact between the child and robot.
Objective	1. Familiarize the child with the Fabula robot (and vice versa). 2. Start the teaching process. 3. Motivate the child to use the robot again.
Actors	Child (primary user and active participant of the learning process). Robot (starts teaching by telling a story and asking questions). Supervisor (introduces robot and keeps an eye on the interaction).
Precondition	1. A room is available for the interaction to take place in. 2. The robot has sufficient charge. 3. The robot has no previous recollection of the child.
Postcondition	The first step in the teaching process has been made. The child knows about the robot's availability and feels motivated to continue to use it. The robot is familiar with the user to the extent that it has stored the child's name, facial features and story progress for future interactions.

Happy Flow	1. The child is led into the room by the supervisor.
	2. The child is asked by the supervisor to sit on the floor.
	3. The child sits down.
	4. The supervisor places the Fabula robot on the floor, in front of the child.
	5. The supervisor briefly introduces Fabula and its capabilities to the child.
	6. The supervisor switches the robot on.
	7. The robot attempts to recognize the child.
	8. The robot introduces itself by telling its name and its role as an educational storytelling robot.
	9. Fabula asks the child to introduce him/herself by stating his/her name.
	10. The child tells his/her name.
	11. Fabula says its nice to meet the child and calls the child by name.
	12. Fabula asks how the child is doing that day.
	    a. The child indicates doing great: Fabula makes a happy gesture.
	    b. The child indicates doing poorly: Fabula tells child it has something that might cheer him/her up.
	13. Fabula asks if the childs wants to agree upon a personal greeting.
	14. The child confirms.
	15. Fabula shows several greetings.
	16. The child chooses a greeting.
	17. Fabula asks the child if he/she would like to hear a story.
	18. The child responds affirmatively.
	19. Fabula narrates a part of the story.
	20. Fabula asks a question related to the storyline.
	21. The child responds to the question.
	    a. The child answers correctly: Fabula reacts happily.
	    b. The child answers incorrectly: Fabula reassures the child and gives the correct answer.
	22. Fabula repeats steps 19-21 until the end of the story.
	23. Fabula asks if he/she liked the story.
	    a. The child confirms: Fabula reacts happily.
	    b. The child disconfirms: Fabula accepts answer.
	24. Fabula asks if the child would like to take a small quiz.
	25. The child agrees.
	26. The robot asks a question.
	27. The child answers the question.
	28. The robot indicates whether the child answered correctly:
	    a. Answered correctly: Fabula congratulates child.
	    b. Answered incorrectly: Fabula reassures the child.
	29. Fabula repeats steps 26 and 28 until the end of the quiz.
	30. Fabula says it had a good time and that the child did well.

Alternative Flow 1	There may be moments when the child would like to interrupt the story to ask a question:
	
	a1. Child presses the bumper button.
	a2. Fabula acknowledges request to ask a question.
	a3. Child asks a question.
	    a3-success: Fabula knows the answer and replies.
	    a3-failure: Fabula apologizes for not knowing.
	a5. Fabula returns gracefully to the happy flow.

Alternative Flow 2	The child might not wish to tell its name or agree on a personal gesture: b1. Child states his/her desire not to answer. b2. The robot accepts the child's intent to not answer the question. b3. Fabula returns gracefully to the happy flow.
Alternative Flow 3	When the robot asks a question during the story or quiz, a child may indicate he/she does not know the answer. c1. The robot will reassure the child it is fine. c2. The robot will give the correct answer. c3. Fabula returns gracefully to the happy flow.

Appendix 1.2: Use case 2

Title	UC02 - Practice session on previous/next lessons.
Objective	Objective 1: Continue the teaching process between the child and robot. Objective 2: Asses / Re-assess child's learning capabilities.
Actors	1. Child (primary user and participant of the teaching-learning process) 2. Robot (continues teaching by telling a story and asking questions) 3. Supervisor (keeps a close eye on the situation)
Precondition	The child has already interacted with the robot and knows how it works. It feels comfortable interacting with the robot.
Postcondition	The child has become more familiar with working with the robot and has managed to recall the reviewed material better.
Happy Flow	1. Child enters the room accompanied by the supervisor. 2. The supervisor places the robot on the floor in front of the child. 3. The child sits down near the robot. 4. The child adjusts his position to be closer to the robot and on the same level. 5. The supervisor powers on the robot. 6. Fabula recognizes the child. 7. Fabula greets the child. 8. Fabula asks how the child is doing that day. a. The child indicates doing well: Fabula makes a happy gesture. b. The child indicates doing poorly: Fabula tells child it has something that might cheer him/her up. 9. Fabula checks progress of previous story and quiz score. a. Completed & sufficient quiz score: Proposes to move on to next story. b. Incomplete or Insufficient score: Fabula proposes to redo previous story. 10. Child accepts. 11. Fabula narrates a part of the story. 12. Fabula asks a question related to the storyline. 13. The child responds to the question. a. The child answers correctly: Fabula reacts happily. b. The child answers incorrectly: Fabula reassures the child and gives the correct answer. 14. Fabula repeats steps 19-21 until the end of the story. 15. Fabula asks if he/she liked the story. a. The child confirms: Fabula reacts happily. b. The child disconfirms: Fabula accepts answer. 16. Fabula asks if the child would like to take a small quiz. 17. The child agrees. 18. The robot asks a question. 19. The child answers the question. 20. The robot indicates whether the child answered correctly: a. Answered correctly: Fabula congratulates child. b. Answered incorrectly: Fabula reassures the child. 21. Fabula repeats steps 26 and 28 until the end of the quiz. 22. Fabula says it had a good time and that the child did well. 23. Fabula proposes to continue another time. 24. Fabula says goodbye. 25. The child says goodbye.

Appendix 2: Control software architecture

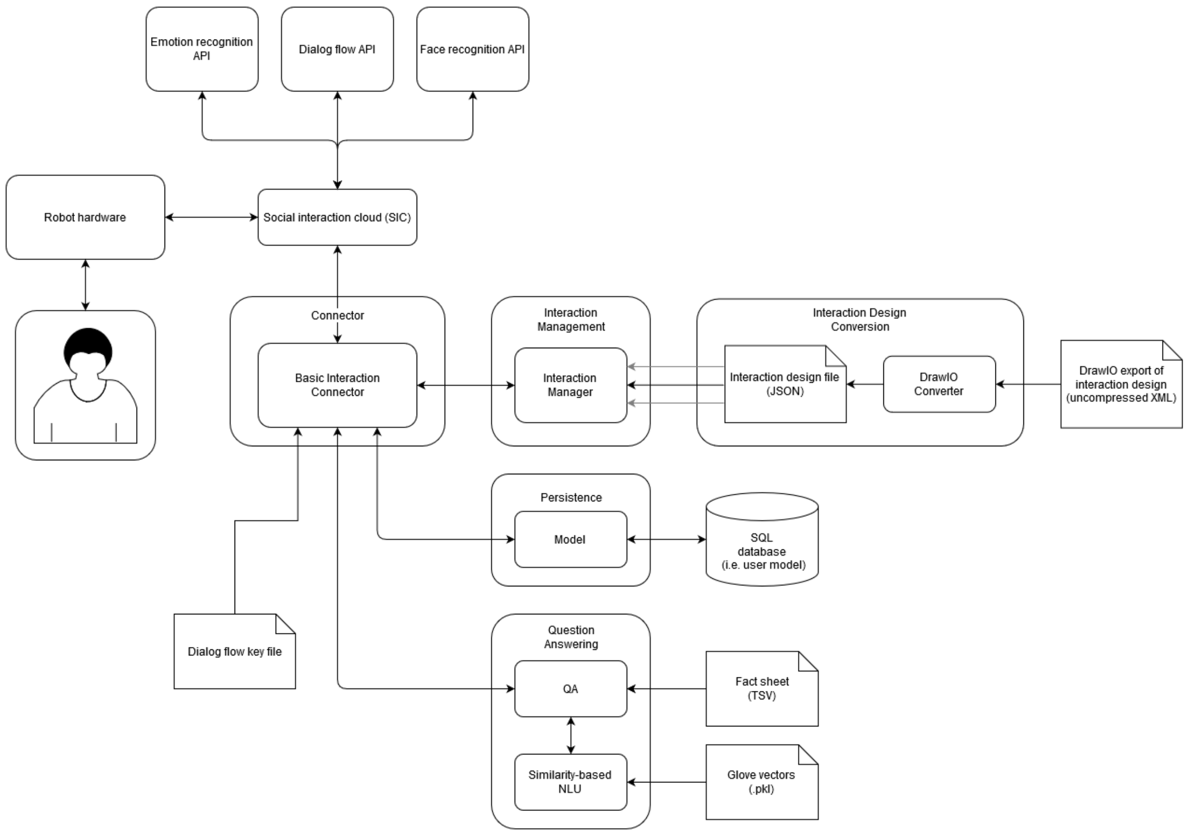

Fig. 4. *High-level visualization of the control software architecture. The central component interfacing with the robot hardware is the connector, which connects with the hardware through the Social Interaction Cloud software. The connector interfaces with peripheral components, such as the user model (Model), question answering system (QA) and interaction manager, to perform various tasks related to the interaction as described in [Implementation](#) and [Design ideas and principles](#).*

Appendix 3: Dialogflow intents

As described in Implementation, Dialogflow intents may be used to label state transi- tions in an interaction design. The following intents can be recognized when using the *listen() Action*:

Intent name	Description	Example usage
asks_question	Asks a question.	*"Who was King Minos?"*
has_question	Requests to ask a question.	*"Can I ask a question?"*
confirm	Confirms statement from Fabula.	*"Yes please."*
disconfirm	Disconfirms statement from Fabula.	*"No thank you."*
not_know	Indicates he/she does not know.	*"I don't know."*
feeling_bad	Indicates feeling bad.	*"I feel horrible."*
feeling_good	Indicates feeling good.	*"I feel amazing today."*
likes	Indicates he/she liked something.	*"I loved that story."*
not_likes	Indicates he/she did not like	*"I don't like that."*
name	Provides name to Fabula.	*"I'm Thomas."*
wants	Indicates he/she desires something.	*"Yes, I want that."*
not_wants	Indicates he/she does not desire something.	*"I don't want a personal greeting."*
quit	Indicates to the robot that he/she wants to stop the interaction / story.	*"I want to stop."*
Default Fallback Intent	Called in case no intent could be recognized by Dialogflow.	-

The table below shows the *Action* (i.e. transition) functions which have been implemented and can be used in interaction files, see Fig. 2.

Action function	Output intents	Optional arguments
recognize_user	'user_recognized', 'user_not_recognized'	-
listen	Any dialogflow intent.	intent_name: a Dialogflow
listen_for_keywords	'keyword_detected', 'keyword_not_detected', (optional; 'confirm', 'disconfirm' and	keywords: keywords to recognize allow_intent: boolean indicating whether to allow '*confirm*',
set_random_personal_gesture	'confirm', 'disconfirm', 'likes', 'not_know',	-
run_personal_gesture	-	-
skip	-	-
run_story	'reset'	offset: to indicate which story to run relative to the previous time; either 'first', 'last' or 'next'

end_story	-	-
completed_story	‘complete’, ‘incomplete’	-
run_quiz	reset	-
update_score	-	score: weight to give to a question
end_quiz	-	-
quiz_result	‘incomplete’, ‘good_result’, ‘bad_result’	thres: A threshold indicating the number of questions correct on the quiz to consider job well done
quit	-	-

Appendix 4: Evaluation procedure

Overview

First and foremost, **thank you** for performing the evaluation of our robot design!

The robot we have designed is an *educational storytelling robot* with its primary purpose being to educate primary school children on subjects like history and technology in a manner that promotes their *engagement* with the material and improves their *motivation* to learn. As such, various features have been implemented that aim to improve the motivation and engagement of the students, which we wish to evaluate in this study.

During the evaluation session each member of your group will run through two storytelling scenarios; the first being a *reading session* in which you will read a text version of the *story of Talos*; and the second being an *interactive session* in which the story is retold interactively by our robot. Afterwards, you are given a questionnaire to fill out about your experiences during these sessions and how the features of the robot affected your engagement and motivation to learn about the story material. Also, a member of our group will be present to obtain some more objective data (described below).

In order to perform the evaluation as intended, we have set up a procedure for you to follow during the session (see Instructions). The procedure should be fairly self-explanatory, but if there are questions regarding the procedure prior to, or during the evaluation, feel free to ask the group member present or contact us directly.

Contact information (or contact any of us via Slack):

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***Important**: Please read this document through before the evaluation session and run the instructions under Prerequisites (if time allows). The code provided requires some packages to be installed. So to avoid any complications during the session, it would be great if you could install them beforehand.*

Thank you for evaluating our robot and **good luck** during the session!

1. Prerequisites

1.1. Install Python packages

The code we have provided makes use of some additional Python packages that may not be installed by default. Please make sure that the following packages are installed on your system:

Standard packages:
os, glob, collections, random, time, ast, copy, sqlite3

Non-standard packages:
pickle-mixin, json, re, numpy

You can install missing packages using the following command in the terminal / command line (if *pip3* is not recognized, use *pip* instead):

pip3 install <PACKAGE_NAME>

1.2. Verify SIC compatibility

Verify that your laptop supports the services of the Social Interaction Cloud required to run the code. We assume you have Docker Desktop/Toolbox up-and-running and the *docker* repo cloned from here. Navigate to the *docker* folder (in the terminal) and execute the following command:

docker-compose up redis dialogflow

Note: The robot may also use *face_recognition* and *emotion_detection,* but, as specific hardware specs are required to run emotion_detection (e.g. AVX) and not all NAOs are fully functional, these features have been temporarily disabled for the evaluation.

Note: Due to the COVID-19 circumstances, it is not recommend you use the laptop of another group member during the evaluation. However, when redis or Dialogflow do not work and someone else's machine needs to be used, please follow COVID-19 guidelines.

You are now all set to evaluate the robot!

2. Instructions

2.1. Informed consent

Before participating in the evaluation, it is important you understand the purpose of the research and what it would involve for you. Therefore, it is necessary you have read and signed the *informed consent form* provided to you at the start of this experiment, before continuing with the experiment. The form will be provided by the present group member prior to the session.

2.2 Setup

Assuming the instructions under Prerequisites have been followed and everyone has filled out the informed consent form, you can set up the lab itself.

1. First, make sure all of your group members have received:
    a. the **questionnaire** as a link to Google forms.
    b. the **story** in pdf.
    c. the **code** provided as a zip (unzip this zip).
2. Take the NAO robot to a separate room. In S1.11 there is a small storage room to the left which would be the preferred place to perform the experiment.
3. Place the robot on the floor at the end of the room (as there is enough space there). Point the robot towards the end/back of the room, making sure you can still sit in front of the robot and that the robot cannot bump into things (to prevent it from damaging itself).
4. Make sure the robot has enough charge left; if not, plug the robot in.
5. Make sure the robot is stable and in its 'rest' mode (if not, double press the chest button).
6. Ideally, it should not be too loud in the room. In case it is, ask the people outside the room to be a bit more quiet and close the door. (Complete silence is not necessary of course; but the you should be able to hear the robot speak and the robot should be able to hear you as well).
7. Now, let all participants connect to the network the robot is on (e.g. NETGEAR40).
8. Make sure Docker Desktop is running (It should by default; but if not, run Docker Desktop).
9. Open a terminal and navigate to the *docker* repo. Then execute the following command:

   docker-compose up redis dialogflow

10. Leave the terminal running.

2.3 Experiment (repeat for each of your group members)

Please, read this section prior to doing the experiment. Perform these steps one by one. Once read, follow these steps:

1. Before entering the lab:
    a. Open the story in a pdf viewer (Adobe Acrobat or Google Chrome/Firefox), but do **not** read the story yet.
    b. Open the link to the questionnaire.
    c. Open the *BasicInteractionConnector.py* in your IDE of choice, but do **not** run it yet.
    d. Connect to the robot using the *robot-installer.jar/.bat/.sh* (under docker/cbsr-local) as usual. Press the button on its chest to get its IP-address. Password should be *nao*.

2. Enter the lab room with your laptop.
    a. A member of our group will be there to observe/log the interaction (he will be behind you and out of sight of the robot so as to not influence your interaction with the robot).

3. Take place in front of the NAO and make sure the robot has enough space so you can sit in front of it without it hitting you when it moves. For good communication it is important that the face of the robot is directed to you and that it is also on approximately the same level as you.

4. Read the text version of the story, then close the application.

5. Run the *BasicInteractionConnector.py*. This will start the session with the robot.

   Note: During this part of the session, you will be going through an introduction where the robot will introduce itself to you and ask you whether you want to hear a story (**Accept it**). After the story is told the robot will give you an opportunity to do a quiz, where questions about the story will be asked. **Accept the quiz.** After the quiz the interaction is finished.

   Note: the robot should put itself in rest mode when it is done. In case it does not, you can press the button on its chest twice to force it back into *rest* mode.

   Note: If there are any problems with running the code, see the troubleshooting instructions below. If problems arise that cannot be solved, contact someone of group 16.

   Troubleshooting:
   - When the terminal displays an error upon starting the code related to some missing attribute in the *BasicSICConnector*, run code again (likely an issue with the firmware).
   - In case the robot is unstable or you are unable to connect, you might want to use another robot. Robots with IP addresses ending with 4 and 27 are known to work.

6. Disconnect from the robot.

7. You may now fill out the questionnaire op your laptop. You can do that outside, allowing the next participant to come in.

When everyone has interacted with the robot, you can take the robot back to the main room.

Thank you for evaluating our robot!

Appendix 5: Observation Scheme - Digitized form

Appearance	Age	Additional notes: Any common characteristics for subjects interacting more?
	Gender	
Verbal communication	Tone of voice of child	Additional notes: Any observation after the interaction?
	Semantics (+, - neutral)	
	Any silence? What caused it?	
Nonverbal communication	Facial expressions	Additional notes: Encode the 2 observations in relation to affective behaviors depending on the nature of the emotion manifested (positive, negative, neutral).
	Body Posture	
Proxemics	Interaction range	Additional notes: For interaction range, we have 3 possible values: Short-range interaction (<0.5m); Medium-range interaction (<1m); Long-range interaction (>1m) For spatial data, some examples of data collected: Avoiding the robot Interacting with robot Near guardian Hiding from the robot
	Spatial Data	
History	Did the robot and the subject have repeated interactions?	
Overall behavior	Affectionate	
	Friendly	
	Neutral	

Appendix 6: Questionnaire

Thank you for participating in our research! We hope you enjoyed your time with the robot and learned something new.

This questionnaire is about the engagement and motivation experienced during the storytelling process with the robot compared to the text you have read previously. Please answer the following questions as detailed as possible.

At the bottom an empty field has been added; feel free to add any remarks or suggestions there for improving the robot.

Introduction

Question 1: How comfortable did you feel using Fabula, compared to the textbook (after having had a personal introduction to the robot)? Can you elaborate on that?

Story

Question 2: How engaged did you feel with the story, comparing the robot with the textbook?

Question 3: How did the **questions** asked by the robot affect the engagement you experienced?

Question 4: How do you think the non-verbal behavior (i.e. gestures) of the robot affected your motivation to continue?

Question 5: Was there a moment that you lost focus or felt bored during the storytelling? If so, could you explain when and how that happened?

With the text:

☐ Yes ☐ No

With the robot:

☐ Yes ☐ No

Question 6: The robot told you a story about the history of robots. After this, how confident are you about your knowledge on this subject? Is this different from when you just read the text, and why?

Question 7: Were there moments when you felt disappointed with any **technical** complications in the interaction with the robot? If so, can you elaborate?

☐ Yes ☐ No

Question 8: Were there moments when you felt disappointed in a **response** given by the robot? Which moments, and why were you disappointed?

☐ Yes ☐ No

Question 9: Do you think the attitude of the NAO contributed to your motivation? Why?

Quiz

Question 10: How did you perceive the difficulty level of the questions in the quiz, comparing when they were given by the robot or by text?

Question 11: How did the verbal appraisal after answering a question correctly (e.g. "Well done!") given by the robot affect your motivation to continue?

Question 12: When you had a question wrong during the quiz, how did you perceive the verbal consolation (e.g. "You will get it next time!") given by the robot?

Note: the following questions are optional.

(Optional) Question 13 : In case the robot was able to notice that you were sad, how did the response of the robot influence your mood?

(Optional) Question 14: Do you have any additional remarks/tips/improvements?

Appendix 8: The story of Talos

So, the story starts long long ago, on the island kingdom of Crete. On the island, there lived a god called Hephaestus, the god of technology, who was about to reveal one of his greatest inventions. Hephaestus had set out to build a robot which he called Talos. Talos was a giant robot cast from solid bronze and given life by the ichor of the gods. The Greeks believed ichor to be the life energy of their gods. With the ichor, Talos was unlike anything Hephaestus had built before. A giant robot with superhuman strength and a life of his own. A true masterpiece thought Hephaestus.

Talos was created to protect the island of Crete from invaders. To protect the island, he threw very big stones at ships to sink them and prevent them from getting close to the island. But, he didn't just attack bad guys. He also attacked other ships too, fishermen, traders, everyone really. So, Talos was kind of a meanie, actually. And so people set out to stop Talos and take him down.

Talos was not perfect. The giant robot had one weak spot, a loose bolt on his ankle. And this bolt turned out to be a problem for Talos. One day, a ship approached the island with an army, called the argonauts, who wanted to seek refuge at the island. And there was also a sorceress on the ship, called Medea. Medea wanted to go to the island to rest, she had been traveling for very long. But then, Medea and the argonauts were spotted by Talos! But before Talos could attack them, Medea noticed something. She noticed Talos' loose bolt and figured out a plan to take Talos down. While Talos was distracted by one of Medea's spells, the argonauts attacked Talos and pulled out the bolt from his ankle. The ichor poured out and Talos the robot was defeated. His bolt turned out to be his achilles' heel. And so the story ends, Talos was defeated and Medea and the argonauts were able to reach the island.

Appendix 9: Summary of questionnaire responses

Question ID	**Response** Participants are indicated using (P*).
1	*The interaction was very nice, with appropriate gestures that allowed to feel more connected to the story and the different characters. Overall I would say I was very comfortable, however I would have liked less pauses during the storytelling. (P2)*
2	*I felt a lot more engaged. Although the story was very well written, I feel like the interaction with the robot heightened even more the experience, bringing a voice and gestures into the scene. (P2)* *I felt a lot more engaged with the story when the robot told the story. But he told it a little slow. (P3)* *Very. I liked that the robot made some movements based on the story. (P4)*
3	*Questions helped recall the story I had just read previously, and at the same time also allowed to fix some details in the memory which I might forget (referred to the small quiz just after the story). (P1)* *The questions made sure I actually tried to remember the story (P3)* *It made me remember more, and more sharp. (P4)*
4	*Gestures were a nice addition to the storytelling, but I do not think they had a major impact on my willingness to continue with the story. (P1)* *They where very funny and a great asset to the story. (P2)* *Was really funny and nice to say, it toke my attention. (P5)*
5	*no not really exactly, so that is a good thing! (P5)* *Just before the argonauts came, I had the feeling that the storytelling was going a bit slowly, compared to what my expectations were. (P2)* *When I read the story myself I lost focus a lot (but that always happens) and when Nao told the story I listened better and tried to understand everything at once because I didn't want to miss part of the story (P3)*
6	*I feel that both the text and the robot helped me in strengthening my knowledge on the topic, and I definitely think that hearing a told story with a voice and gestures, while also being asked questions, will have a major impact on my future memories of this story (P1)* *I didn't know any of the information in the story so I learned a lot (P2)* *Well, I didnt know anything before. So, i learned some. I liked to hear it from*
7	*I had a bit of troubles at te beginning of the interaction to understand when I should answer the questions, but then, also thanks to the experimenter, I figured that I had to wait for the eyes to turn blue. (P1)* *I thought the sound was too low. (P4)* *no not at my experience. (P5)*

8	*When the robot aked me how I was feeling, I answered "I'm feeling good", but he understood "'I'm feeling sad" and so he performed the wrong following part of the interaction. Apart from this small thing, everything went well. (P1)* *No the responses Nao gave were very good (P2)* *no, I think you guys did a really good job. (P3)*
9	*Yes, because he was a[s]king questions constantly (P1)* *Yes. I liked his feedback, and the compliments (P3)* *yes, the gestures are very nice. (P4)*
10	*The difficulty of the questions was fair (P1)* *Quite difficult if i were to be a child. Maybe implement multiple choice questions instead. Especially if this is meant for kids of 8 (P2)* *questions are ok to answer and understandble. (P3)*
11	*I don't think it affected my motivation to continue in any way, I just felt satisfied whenever I gave a correct answer. (P1)* *I liked it, i wanted to hear more (P4)* *really nice, sometimes he used your name again, which is a very good implementation guys! (P5)*
12	*I felt reassured by the robot saying that, and I think that gave me extra energy to continue (P1)* *I didn't get any of the questions wrong (P2)* *I wanted to answer more questions to prove my smartness (P3)*
13	*The joke made me laugh (P1)* *This didnt work during our evaluation (P2) [Note: was not triggered during the session]* *I don't know, I did not notice. (P3) [Note: was not triggered during*
14	*I would suggest adding more specific animations/eye colours for every character present in the story (for example Hephaestus, Talos, and Meedea). (P1)* *The sound could be a bit louder. (P2)* *maybe some more sound effects would have been nice! and gestures, but I really liked how fluently the questions were going. (P4)*

Individual Project Summaries of Group Members

Thomas Bellucci

Over the course of the project I have contributed to all major deliverables; from the design and implementation of the robot to the design document and the presentations. In terms of design/implementation, I built the interaction manager and QA systems used by the robot and implemented many of the features in the connector, including the main interaction loop, its speech recognition/generation capabilities (incl. fallbacks), gestures, the story/quiz progress management and QA features. My contributions to the high-level design of the robot are that I suggested several design features (e.g. QA system) and wrote and implemented the *Introduction* and *Story of Talos* interaction designs; to do this, I wrote conversion software for draw.io (see implementation). In terms of design document, I wrote the following sections; Summary, Problem statement, Problem scenario, Conversational interaction, Question answering, Vision, Interaction diagram, Implementation, Participants, Design and Procedure (with smaller contributions to Human-factors knowledge, Application context, Research question and Results). For the use case presentation, I worked on the introduction and main aims. Some organizational tasks were done by me as well (e.g. zoom meetings; Github schedule). In terms of my role as a team member, I think I contributed a fair amount to the project and I believe that it went well. However, reflecting on the process, I do think that communication on my part could have been better as not everyone in the group was always equally aware of (large) changes made to the code or design document. In addition, when sections were not written (say a day before the Friday deadline) or code was not finished the evening before the practical session, I often took it upon myself to write it, failing to see other people have other schedules and may not have time to do it before that time (which I can imagine to be frustrating to them). I should have more trust that others will get their work done. Despite these remarks, I think the project and teamwork went fairly well.

Romy Vos

For the course Socially Intelligent Robots, I mostly focused on the non-technical aspect of the project. This means that I focused less on the technical implementation and more on the design (document) and presentations. For the design document, I contributed to several sections (Design scenario, Application context, Personalization, Non-verbal behavior Requirements & Claims, Research Question and Procedure) as well as finishing up the document as a whole. I also worked on the use-case presentation, specifically on the design scenario and the conversation starters. For the evaluation part, I contributed by making (a first draw) of the questionnaire and finishing it up with the group as well. Finally, I wrote the script of the final video and edited the final presentation video.

Overall, I think that the project went well. All group members were involved and communicative and no conflicts have arisen. Something that could have been improved is task-division: sometimes it was not completely clear who did what and we would just do something without clearly communicating that. For me, I could have taken more initiative (e.g. initiate meetings more, assigning tasks etc.) and get out of my comfort zone by trying to contribute more on the implementation part, since that is also an area that I want to improve on.

Wesley Sieraad

During the Socially Intelligent Robots course, I focused mostly on the non-technical aspect of the project, although I did write a small script which we used to capture the gestures of the NAO. Other group members took great initiative with regard to the writing of the script and the stories for which I am really grateful. Besides the small gestures script I wrote some parts in the design (document) and presentations and led the presentation during the VU and UU sessions. I had also made a quickstart for the ideas and shots that were needed for the final video that we shot during the tutorial sessions. Moreover, I was present during the observation and evaluation of our robot by another group (group 14). All other group members showed great initiative and it was a pleasure to have worked with them. I can learn from their work-ethic and programming skills. At future projects I will try to be more initiative and to work on the technical aspects of the project more, mostly because of the difference in skills I was too hesitant to do so during this project. But I learned a great deal of information during the course, both from fellow group members and from the course in general, which hopefully will prove to be very useful at later stages of my (academical) career.

Hidde van Oijen

During the project of the Social Intelligent Robotics course, I worked mainly on non-technical parts of the assignment. This means I did write multiple paragraphs of the design doc (Target Audience, Story and storytelling, Personalization, Non-verbal behaviour, Reflection and the design of the Method. Next to that I worked a part on the script (Mainly the intro and the outro). I also had a good contribution in the presentation with making multiple slides and presenting it to the UU students and the TA's. Besides that, I also helped with the final video by taking shots and doing the voice-over. Finally, I was present during the testing of our robot by group 14.
I thought the group had a great balance due to the different skills of the group members. Normally I find programming really exciting and want to help much on that part. This time I saw that others had more experience on this kind of programming, so I gave them more space to exploit that. But through looking at the code and discussing things to implement/do different, I learned quite a lot on this part. I saw my role in this project more as manager of the meetings, where I took the plunge for a couple of important decisions. I didn't really have a specialized role in the creation process, but I tried to jump in where I could on all of the different parts of the assignment. In future projects, I want to try and help more on the technical part. Although I learned a lot on that part from the work of the group members, I don't think I made the most of what the assignment had to offer in terms of technical development. In upcoming courses I want to take that opportunity.

Ouail Zogari

During this SIR project, I worked mostly on the non-technical part of the project. I have written different parts of the design document (Personas, Application context, Social robot, Interaction diagram, parts of the Method and the Discussion). Furthermore, I helped where needed in the design document, participated in shortening the text since we were exceeding the limit and also written the second story (Da Vinci robot). Besides working on the design document I also worked on the use case presentation, by contributing to multiple slides (Main aims, Application context and Use case). For the evaluation part I contributed partially in writing the Evaluation procedure and finishing up all parts for the evaluation.
Regarding my role as a team member, I think I contributed a fair amount to this project. The whole group was involved and communicative and we never had troubles with meetings or with non-responsive group members. The individual qualities of this group varied and I learned a lot from them all. Personally, I would like to do more regarding the programming part, since it was a goal for me to improve. I did not do as much as I could and wanted. But still I learned a lot from my group members as from the course.

Andreea Hazu

Over the course of this project I have tried to contribute to all the required deliverables. Starting with the design main ideas of where to guide the research, what kind of story to tell and for which audience, I continued implementing and testing different features from a coding point of view for Nao, like face detection, emotion recognition and database architecture for storing user-robot interaction attributes, later used in the main flow. I've contributed to multiple sections of the design document (Target Audience, Design Scenario, Design Principles, Use Case, Requirements and Claims, Research question, Method,

Results, etc.), either by starting from scratch, re-writing or improving different paragraphs upon discussions with my colleagues. For the presentation I contributed by either creating several slides and revising the work of my colleagues, organized the meetings with the UVA students and managed communication. Overall, communication wise I attended all meetings with my colleagues and organized many of them.
Reflecting on my role on the team, I feel like I balanced the group with both my coding expertise and the contribution to the written part of the project. My behavior was led by openness both on what I can do in a certain timeframe regarding the skills I have and on my availability. I showed respect and trust for the work of my colleagues who were better equipped or predisposed to handle a certain part of the project (like coding or creating videos). I wish I have done more on the coding part and communicated better with the students who handled most of that part, but overall, I am humbled to have worked with such a balanced group of people. From a student perspective, this is the first time where teamwork actually works. I think this was partly due to the different backgrounds each one of us has and to the dedication shown by each of them. I learned something from each of my colleagues and I wish we had more time to fine tune certain parts of the interaction with Nao and test it with real subjects.