Does a robot tutee increase children's engagement in a learning-by-teaching situation?

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Abstract. This paper presents initial attempts to combine a humanoid robot with the teachable agent approach. Several design choices are discussed, including the decision to use a robot instead of a virtual agent and which behaviours to implement in the robot. A pilot study explored how the interaction with a robot seemed to influence children's engagement as well as their attribution of mental states to a robot and to a virtual agent. Eight children participated and the interaction was measured via an observational protocol and a conversational interview. A main outcome was large individual differences between the children's interaction with the robot compared to the virtual agent.

Keywords: · Learning-by-teaching · Virtual agent · robot

1 Introduction/Background

The observation that teaching is a way of learning is at least 2000 years old [1]. About twenty years ago this approach – learning-by-teaching – was implemented in a digital form, where human students take on the teacher role and instruct a digital tutee or so called teachable agent, TA. There is rich evidence for the effectiveness of this pedagogical approach, both in terms of learning outcomes and motivational effects.

TA-based software seems to draw on socio-cognitive mechanisms that increase engagement in the task [2,3] Importantly, students seem to take responsibility for their TA's learning. In a study by [2] both 10-11- and 13-14-year-olds spent more time on learning activities when their task was to teach a TA compared to when learning for themselves. The study also provided evidence that the 10-11-year-olds treated their TAs as social entities by attributing mental states and responsibility to them.

In addition, results from several studies indicate that the central educational phenomenon of metacognition can be boosted by LBT-software. Students are encouraged to reflect on their TA's thinking and accuracy, and subsequently also apply metacognition to their own understanding [3,4].

In recent years learning-by-teaching with a robot, instead of a virtual agent, has attracted increasing interest. It has been theoretically discussed [5,6], and the pedagogical potentials of robot tutees have been highlighted. A robot is obviously more suitable than a virtual agent for learning fields with a physical or mechanical component such as table tennis or handwriting, but there are also other potential advantages to be gained from the physical embodiment of a robot. Both authors [5,6] discuss how robots have a greater possibility to use nonverbal channels for communication, such as posture, personal space, gaze, pointing and touch. Lemaignan et al. [7] carried out a study where children taught handwriting to a robot. A first study in a larger school-class indicated that the robotic system was accepted by the students and kept them focussed and engaged for short sessions. Later case studies showed that the system could be used as a tool for children with different attentional impairments, as they would accept the robot, could carry out longer learning sessions, and adapted themselves to the role as a teacher.

Our pilot study regards a comparison between a robot tutee and a virtual agent tutee with respect to effects on learners (in the role as teachers). Engagement and attribution of mental states were key areas of interest.

2 System and study design

The study made use of the play-and-learn-game Magical Garden [4,8] where young children learn early math by teaching a virtual agent in animal shape, for instance the panda Panders (Fig 1). In the robot version, Panders was replaced by Epi, a humanoid robot developed at Lund University Cognitive Science (Fig 2). The robot was designed to give the impression of being a child while still being decidedly robotic. Consequently, a simple geometric, almost rectangular, shape has been use as the basis for the head. The eyes are relatively large, suggesting child like proportions. The head has four degrees of freedom in the neck and eyes and it can also change eye-color and pupil size to identify different moods.

Fig 1. A virtual TA, thinking about a problem.

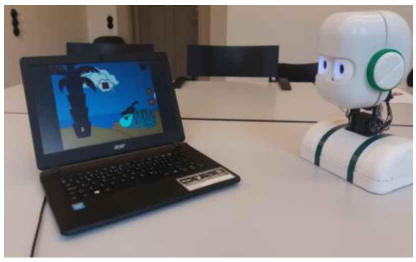

Fig 2. The robot, thinking about a problem.

In the robot version the virtual agent was blanked out, and the behaviours of the agent was sent as commands via http requests. This allowed for a simple solution to behavioural timing, as the robot only needed to receive all commands and synchronize each one with a predetermined behavioural pattern. The same was done with sounds, so that any command that should have triggered a sound made by the virtual agent instead triggered the activation of a sound file in the robot. The following seven behaviours were identified as relevant to re-implement in the robot:

Idle was designed to be the most basic mode in the robot, used whenever nothing else was displayed. This included pale blue eyes, random gaze shifts and changes in pupillary size, and movement of the eyes. *Speech* caused the robot to turn its head towards the participant and produce a synchronized blinking pattern with its mouth. *Acknowledgement* made the robot turn to the participant with yellow eyes. C*ontent*, *happy*, and *exhilarated* all built on the same base behaviour, which included yellow eyes and pupillary dilation. While *content* only used the baseline behaviour, *happy* added simple movements of the head, and e*xhilarated* used the baseline and even wider movements than *happy*. Finally, *sad* involved changing the eye-colour to a darker blue, moving the head down, and turning both eyes inwards.

The system architecture was primarily the same for both the robot and virtual agent designs. There were, however, dimensions that could not be kept the same. An example of this is the positioning of the agent. The virtual agent was always turned towards the student, but the robot had to be midway between both the participant and the game. This was necessary for allowing attention to be directed between both the game and the participant.

Eight children, age 5-9 (mean age 7), two girls and six boys, participated in the study. Each child taught both the robot and the virtual agent systems, with the order being randomized. They started playing the game and teaching their tutee – robot or agent – while the examiner filled out an observational protocol. After finishing two games, the game was closed and a conversational interview was carried out. Following the interview, the child started teaching the other tutee.

The interaction was measured using an observational protocol according to which the following was noted: Willingness to continue for another five minutes after an initial trial; displayed positive emotions during the interaction (e.g. happiness) and/or displayed negative emotions (e.g. irritation); overall attention and focus; displayed changes in teaching methodology; utterances regarding success and failure of the robot or agent as it tried on its own; utterances regarding success and failures in teaching the agent or robot; manner of talking about and addressing the agent/robot.

Another tool used in the study was a conversational interview. The questions used in the interview were based on a translated version of the godspeed questionnaire [9], with the goal to measure attitudes towards the tutee – robot and/or agent. The questionnaire is used to evaluate questions like: whether one finds the robot/agent to behave human-like versus machinelike (anthropomorphism); whether it seems lively versus lazy (animacy); whether it is nice versus not nice (likeability); if it is knowledgeable versus ignorant (perceived intelligence); whether it feels relaxing to be around the agent/robot versus tense (perceived safety).

3 Results and discussion

Some interesting differences were noted between children interacting with a robot TA and a virtual TA appear. Based on the observational data, the robot seems capable of attracting attention, something which should be useful for engagement. It does, however, also tend to lose it partway into the interaction. As for the ability to convey mental states, the robot at least seems to be comparable to that of the virtual agent, with certain children choosing to speak to it in a teaching manner. It is, however, possible that there is a dissonance between picturing the robot as a student and the idea that a robot is like a computer in that it has access to a multitude of information. Individuality appears to be central here, with children showing large variations in both engagement and ability to attribute mental states. Data from the conversational interview showed overall positive judgments for both the robot and the virtual agent. Individual differences were also observed here, especially in judgments of perceived intelligence. It was observed that the robot received lower score for anthropomorphism compared to the agent, but the high scores on animacy make these results harder to interpret. For more details on the study and its results, see [10].

Some improvements on the robotic systems as well as the study design are called for. Using motion capture technology, it should be possible to make more fitting and natural behaviors for the robot. Gaze behaviors such as gaze aversion could also be used to improve the interaction. Notably, the virtual agent displays a simple form of joint attention. A fuller study should also involve more children and longer player sessions, as well as children of a younger age-group.

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