CoWriting Kazakh: Efficacy of a Long-term Robotic Agent in a Physical vs Virtual Embodiment

A Preprint

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February 18, 2021

Abstract

The physical embodiment of the robots is one of its advantage in terms of engagement, motivation, and communication in human-robot interaction. At the same time, the use of virtual agents such as on-screen robots or avatars has been limited, yet they can offer similar and affordable experiences akin to physically-present robots. In this study, we compare the use of the embodied robot and virtual agent in learning the Latin-based Kazakh alphabet with children at the primary stage of education. According to our interaction design, children will be exposed to one of the three conditions: physical robot only, virtual robot only, and mixed reality in which the physical robot will be introduced in the first session, while the remaining sessions will occur with the virtual robot. To analyse overall effectiveness and social influence, we intend to use several measures, namely, a pre-test and initial/delayed post-test, engagement and satisfaction levels as well as mood change. This study has a great potential to address one of contradictory opinions about the effect of physical embodiment on learning outcomes in line with social impact.

***K*eywords** child-robot interaction · social robot · virtual robot · language learning · interdisciplinary

1 Background

As technology has advanced, we witness the development of artificial intelligence in various forms. Specifically, robots are being developed with their human-like appearance and capabilities. For many in the human-robot interaction field, using embodied robots has been a preferred medium to conduct research with people. Evidence shows a greater benefit in deploying physically present robots that are perceived as engaging, helpful, and interactive [1, 2]. However, there are alternative means of AI-driven communication that perform the similar function as the robot does. They include tablets, avatars, and virtual agents embedded with an intelligent system. Our previous research created a peer learning environment in which primary-school-age children and a social robot practice writing in a new Kazakh Latin alphabet based on the learning by teaching (LbT) strategy. That is, it enables the tutor to learn through the act of teaching, by promoting social learning built on an ability to teach another, and then reinforce knowledge as much as tutee [3, 4]. In the study, we introduced the peer robot that wants to learn Kazakh, whereas a child takes a role of its teacher who needs to use Latin script so that the robot can "read and write Kazakh". In comparison with the robot condition, children were exposed to the tablet condition in which they learned letters through navigating a pop-up window with guidance. The child learns the Kazakh Latin script through interaction and reflection on the correct spelling. As a result, we found no significant difference in the number of learned letters between the conditions.

We continue to seek out better learning aid for children to learn the Kazakh Latin alphabet in the framework of the CoWriting Kazakh project. For this reason, our main goal is to create an engaging environment that results in long-term and positive learning effects. In this study, we use virtual agents that can help individuals in their day-to-day life by creating a personalized social environment, having arguably less technical burden. There are contradictory findings in respect to the use of more affordable virtual agents in place of physical robots. Some favour virtual agents over robots, because they are easy to use and have no physical limitations. This, in turn, attracts researchers to use the virtual agents as a substitute for the physical robot due to its technical constraints and inability to sustain engagement over time. Other experts indicate that the physical embodiment increases social influence. In terms of the effect of physical presence, embodied robots are considered to have significant impact on user's engagement [5], task performance [6], and even learning gains [7]. For instance, Powers et al. [8] compared a computer agent projected either on a monitor or screen, tele-present robot on a screen, and collocated robot. In this context, participants engaged with the robot more than with the agent, meaning that they spent more time with the robot; but, they remembered less amount of information when interacting with the robot as opposed to the virtual agent. The latter suggests that knowledge retention is better achieved with the on-screen agent compared to physical robot. Interestingly, Fridin and Belokopytov [9] suggested that it is practical to use embodied robots for a limited amount of sessions and then continue using a virtual agent for the remainder of the intervention. This design is believed to create a buy-in for the reasonable use of robots in research. However, studies on language learning and teaching found no significant differences in terms of learning gains and embodiment [10]. In fact, the effects of physical embodiment were commonly explored in relation to individuals aged 18 and older. The advantage of one over another remains sparsely explored, therefore, it comes naturally to compare the overall effectiveness in the context of language learning with school-age children. This kind of novel intervention is likely to have a significant contribution for both child-robot interaction and language learning practices with technologies. We suggest that individuals respond to physical robots and virtual agents differently. To this end, the following research questions are posed:

1) Which robotic system (physical vs virtual) is more effective for learning a new alphabet? 2) What robotic system (physical vs virtual) best fits long-term learning? 2) Does physical embodiment increase child's engagement? 3) What robotic system does a child prefer for learning?

2 Experimental design

The design of the present study is based on our previous work [11] and adapted in coordination with the research question of the study. We aim to conduct a ten-session study that supports learning over longer periods. The mixed-subjects design will be applied.

2.1 Hypotheses and conditions

Based on our research questions, the main hypotheses are formulated as follows:

- H1: Children will learn more letters in the robot condition than in the virtual robot condition.
- H2: Children will retain more letters in the virtual robot and mixed condition than in the robot condition.
- H3: Children will be engaged interacting with the robot than with the virtual robot.
- H4: Children will find both physical and virtual robot helpful.

The following conditions are expected to test these hypotheses:

- In the **physical robot condition**, children interact with the robot across all sessions.
- In the **mixed condition**, children interact with the robot in the first session and then continues remotely with the virtual robot for the rest of the interaction.
- In the **virtual robot condition**, children interact with the virtual robot across all sessions.

2.2 Participants and setup

We will recruit children at primary level of education since they are among the first to acquire a new Latin-based Kazakh alphabet in schools. We plan to recruit 20 native Kazakh children speaking Kazakh as first language. In addition, we will document their writing experiences as most schoolchildren have to learn Kazakh, Russian, and English simultaneously from Grade 1 onwards. For this reason, we will collect their academic grades in language subjects as well as the length of time they had spent on using Cyrillic-based Kazakh and English. As the alphabet transition reform is still under preparation, it is expected that children have no training in Latin Kazakh. Before the experiments, we will ask an English teacher to distinguish low-attaining and high-attaining children in terms of the English language knowledge. In turn, we can evaluate the effectiveness of our system among children with different academic abilities. Children will be counterbalanced based on their English knowledge skills to various conditions. We will also counterbalance age and gender groups.

The study is expected to be conducted at one primary school in Nur-Sultan, Kazakhstan. Our experiments will be conducted on the school premises, which will be convenient in terms of mobility and participation rate. After obtaining an ethical approval for the study, we will approach potential gatekeepers in primary schools to agree for us to visit the school for a month or so on daily basis. We will reach out to classroom teachers for recruitment and further correspondence. To ensure voluntary participation, informed consent forms will be collected from parents or caregivers. We'll explain the study aims and procedure to children in the presence of their teachers. Parental consent forms will be distributed after the session. Children will be asked to return signed forms once their parents give their consent.

2.3 Robotic system

We will employ CoWriting Kazakh system detailed in Sandygulova et al. [12] which consists of a humanoid robot NAO, a tablet and its stylus. For a virtual robot condition, the NAO robot will be replaced by a speaking avatar of the NAO robot on the tablet's screen. Both robots (physical and virtual) are designed to use the same speech and gesture patterns. The system is autonomous for 20-30 minutes interaction (around ten words) while the experimenter controls the launch of the program.

2.4 Procedure

The procedure of the experiment will comprise a survey, pre-test, an intervention, an follow-up interview, an immediate and delayed post-test. The process will take around 30-40 minutes. Each child will attend the session with either a physical robot or virtual robot. One of the researchers will be in charge of arranging the participation of children and will guide each child for before and after the intervention. Children will complete a survey that consists of demographic questions and overall mood before the session. Then, a child will be asked to take a vocabulary pre-test that is necessary for documenting their prior knowledge of Latin Kazakh alphabet. Afterwards, a child will interact with one of the robots in a given condition. Then, follow-up interview will be conducted to record a child's overall satisfaction with the session through using a 5-point scale questionnaire (0-not at all helpful, 5-extremely helpful) and survey for mood change. Immediately, a post-test will be distributed to a child. Followed by immediate post-test, a delayed test will be conducted to within one month. Other participating children will follow the same protocol in all conditions.

Initial survey Children will respond to a short questionnaire that documents their demographic details. Children's self-reported mood will be assessed using emotion cards and a 5-point Likert scale.

Pre-test Prior to the intervention, a pre-test will be distributed to identify children's existing knowledge of Kazakh Latin alphabet. It will include open-ended questions on children's knowledge of the alphabet and multiple-choice questions according to children's age and vocabulary breadth. The chosen words will involve 9 unique Kazakh letters.

Intervention Following the pre-test, a child will be asked to sit in front of the robot. Each session will be based on the sequentional letter learning starting from simple to a more complex word spellings. For each session, we will choose 10 different themes. Praise and corrective feedback will be pronounced during the session. The procedure will be the same for other conditions. Activities may include:

The dialogue between a robot and a child might happen in the following way:

> Nao: -Hi. I'm a robot. My name is Nao. What's your name?
> Child: -...
> Nao: -I need your help. I'm learning Kazakh. Please, let's practice together.
> Child: -...
> Nao: How do you say "hello" in Kazakh?
> Child: Sálem
> Nao: Please write it in Latin, so that I can read it. Child: -...
> Nao: Great. Now let me write it too [writes using the correct spelling in Latin. The child learns from the corrective feedback].
> Child: ...
>
> ... continued until all letters in the name are written
>
> Nao: You're a great help. Thank you. I enjoy learning Kazakh with you. See you next time.

Follow-up survey The researcher will interview a child once the intervention ends. They will complete a satisfaction test using 5-point Likert scale that evaluates their overall satisfaction (0- "not at all helpful" to 5 - "extremely helpful"). They also will be asked to fill in the rapport questionnaire (What did you like about the robot?).

Immediate post-test After the intervention, children will be asked to complete the post-test that is necessary for calculating learning gains. They will be given another copy of the same list of letters and words as in the pre-test.

Delayed post-test To test our hypothesis regarding the letter retention, we will conduct a delayed post-test within a month once all sessions end. This allows us to identify what kind of the robot is effective for long-term learning.

Measures

1. Learned letters. The number of correct letters will be assessed before and after the intervention.
2. Satisfaction rate. The level of children's satisfaction will be recorded across the sessions.
3. Engagement. The time spent on the interaction with either a robot or virtual agent will be estimated.
4. Preference. Through interviews, children's preference of the robotic system will be identified.
5. Likeability. Users will be asked to choose between scales: nice/awful, friendly/unfriendly, human-like/machine-like.
6. Mood change. The mood of children before and after intervention will be documented using emotion cards.

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