Co-creation as a Facilitator for Co-regulation in Child-Robot Interaction

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ABSTRACT

While interacting with a social robot, children have a need to express themselves and have their expressions acknowledged by the robot. A need that is often unaddressed by the robot, due to its limitations in understanding the expressions of children. To keep the child-robot interaction manageable the robot takes control, undermining children's ability to co-regulate the interaction. Co-regulation is important for having a fulfilling social interaction. We developed a co-creation activity that aims to facilitate more co-regulation. Children are enabled to create sound effects, gestures, and light shows for the robot to use during their conversation. Results from a user study (N = 59 school children, 7-11 y.o.) showed that the co-creation activity successfully facilitated co-regulation by improving children's agency. Co-creation furthermore increases children's acceptance of the robot.

CCS CONCEPTS

• **Human-centered computing** → **Empirical studies in interaction design**; • **Computing methodologies** → *Cognitive robotics*; • **Applied computing** → *Consumer health.*

KEYWORDS

child-robot interaction, co-creation, co-regulation, user-study

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1 INTRODUCTION

The main aim of our research is to design and develop an autonomous social robot companion (a Nao robot) that can offer social support to children with cancer. We developed a narrative-based conversation that offers children an engaging distraction [17] and enables them to develop a supportive relationship with the robot [15, 16]. Throughout the conversation children learn more about the robot from the stories it shares about its adventures. Likewise, the robot learns more about the children from the information they disclose about themselves (e.g. their interests, and preferences). This is information the robot can use to personalize future interactions.

To keep the conversation engaging over time and to develop the child-robot relationship further, children reported that they want to co-regulate the interaction more [17]. Co-regulation in a dyadic social interaction means that both actors have to have agency during the interaction and are able to coordinate the flow of the interaction together [13]. Specifically, children indicated that they want to express themselves more creatively and they want the robot to acknowledge their expressions. Furthermore, they expressed a need to coordinate in what way, and how much, they express themselves during the conversation [17].

In the research discussed in this paper we aim to expand children's ability to co-regulate the narrative-based conversation with the robot. We designed robot behaviors that enable children to co-create expressive content for the robot to use during the conversation. Children can co-create sound effects, gestures, and light shows. By displaying the content made by the children, the robot explicitly shows it has heard and seen their creative expressions. Subsequently, the robot's behavioral design includes a behavior that enables children to coordinate their involvement in the co-creation process. In the remainder of the paper we discuss the rationale of our design (in sections 2 and 3) and we present the results of a user study (N = 59 school children; 7-11 y.o.) we ran to validate the design (in sections 4 - 7).

2 RELATED WORK

When a robot interacts autonomously there is a trade-off between how freely the children can express themselves during a conversation and how much the robot can appropriately respond to those expressions. Due to the limitations in natural language understanding [14], the robot needs to exert a lot of control over the conversation to safeguard the flow and work towards its supportive goals. This undermines the children's ability to co-regulate the interaction.

The need for co-regulation is not limited to a child-robot interaction. It is an important aspect of all social interactions [13]. Addressing the need for co-regulation, and all those identified needs related to it, poses a major design challenge. Who better to tackle this challenge than the children themselves? Co-creation has proven to be a powerful tool in the participatory design toolbox [20], that allows end-users to anchor their needs into the final design [19]. However, instead of using co-creation as a preparatory activity, we

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chose to embedded it as a part of the active child-robot conversation. In this section we will outline related work that informed the design process.

2.1 Co-regulation

The source of the identified needs lie in the desire to engage socially with the robot. According to De Jaegher, Di Paolo, and Gallagher a social interaction establishes a coupling between social actors that is engaging in nature "as it starts to 'takeover' and acquires a momentum of its own" [13]. It is this engaging aspect of a social interaction that is important for why many social robot applications have a tremendous potential [4].

Parties to a social interaction simultaneously pursue a joint goal and to achieve this goal jointly depend on each other [9, 10]. Co-regulation means that social actors coordinate their interdependence [13]. An example of such coordination is leaving pauses in a conversation to allow the conversational partner to take the turn [8]. Social actors continuously and reciprocally influence each other's actions during the social interaction [11] which requires agency on the part of each actor. It is important that during the interaction a sense of shared agency is maintained, without it the coupling between actors is lost [3, 10]. In a social interaction there cannot be one actor that fully dictates how the interaction evolves. Something that happens quite often in various degrees when interacting with a social robot.

2.2 Co-creation

Co-creation is a multi-faceted concept. Its most common use is that as part of a participatory design approach, where users are invited to contribute to the design phase [20]. There are powerful examples available where a wide range of aspects of a social robot were co-created. For example, Opsoro is a DIY robot platform that allows children to tailor the robot's appearance and animations to their liking [5]. By dressing children with diabetes up as a robot and letting them acting out what they want from a robot partner was one of the co-creation activities used to inform the design of a robotic partner for diabetes self-management [12, 18].

Co-creation can also be the act of creating together with a robot. The robot can act as a partner[2] or tool [1] in a creative process. The co-creative process can be the goal of a whole interaction [1] or serve a different (e.g. therapeutic) purpose [2]. In our design the robot acts as both a tool to create expressive content and a medium to display the created content.

Co-creation facilitates children's co-regulation ability in two ways. Firstly, the co-creation process is an integral part of the conversation and enables children to shape parts of it. Thus, supporting their agency. By explicitly using the creative input the robot further reinforces children's sense of that agency. Secondly, each co-creation moment provides an opportunity for children to coordinate their involvement.

3 THE CO-CREATION PROCESS

In our design co-creation is not a separate activity. Bits of co-creation are interwoven into the conversation. During those co-creative bits, the robot explicitly expresses a need for a particular piece of expressive content to enrich an anecdote its is telling. By allowing the robot to select which parts of the conversation are open for co-creation it remains able to keep the conversation on the rails. Children are invited to provide the requested expressive content for the robot. There are three types of expressive content children can create: a sound effect, a gesture, or a light show (see figure 1).

Children can use their own voice or physically make sounds (e.g. clapping hands) to create a sound effect. The robot will count down from three and starts recording the sounds the child is making. To create a gesture, the robot will invite the children to grab its arms. They can move it around and the robot records the motions. The robot will count down so the child knows when to let go. In both cases children can press a button on the robot's feet to indicate they are ready to start. Through dialog the children can create a light show. The robot asks them if they want to simply choose a color for the lights or if they also want to add an animation. They can choose to let the lights in the eyes and feet alternate or let all the lights blink with different colors. The robot can use the audio and motion recordings and the light show immediately, later on, and repeatedly to enhance the conversation. The created content is inherently personalized and adds to the expressive repertoire of the robot, exploiting all the expressive modalities the Nao robot has to offer.

The final aspect of our design addresses the different preferences children have about how much they want to be involved in the co-creation process. Sometimes children are in an observant mood and they just want to watch the robot do its funny thing, other times they are full of creative ideas they want to try out. To cater to these different needs and increase the opportunity for co-regulation even further, we have added three routes children can take during the co-creation process. Children can either create the expressive content as described above or they can choose to let the robot "download" two content candidates. In case of the latter, they can either choose their favorite candidate or let the robot pick its favorite. For example, after the robot plays two different samples of a roaring lion it asks "do you like the first or the second roar? Or do you want me to pick my favorite?".

4 METHOD

4.1 Hypotheses

We have developed a co-creation process that includes three modes for co-creation and an interaction design pattern that allows children to coordinate the co-creation process. The next step is to evaluate the design. We formulated three hypotheses we have tested with a user study. We need to start by validating whether the co-creation process actually contributes to supporting children's co-regulation. In this paper we focused on children's agency. We hypothesise that children experience more agency when they are enabled to co-create with the robot (H_1).

The main motivation for adding the co-creation process is to improve the child-robot interaction and children's relationship with the robot. In the current study we captured these aspects with the satisfaction of the interaction and the acceptance of the robot measures respectively. We expect the interaction to be more fun as a result of the co-creation process, improving children's satisfaction of the interaction (H_2). Furthermore, because the robot is the one

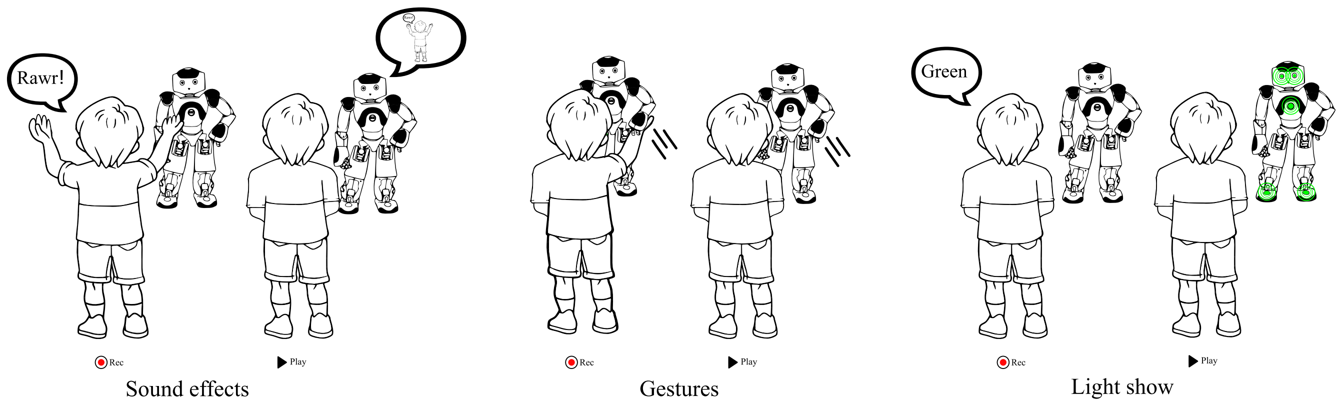

Figure 1: Illustration of the three different co-creation modes: sound effects (left), gestures (middle), and light shows (right). Each left child-robot pair shows the creation of content. The recording of a sound effect, moving the arms of the robot, and picking colors for a light show. Each right child-robot pair shows the robot using the created content.

who explicitly offers the children the opportunity to co-create we hypothesise that they will accept the robot more (H_3).

4.2 Experimental design

The focus of the user study is evaluating the effect of the robot's behaviors during the co-creation process. To properly evaluate these robot behaviors we need to compare it against a fair baseline. One where the interaction is as similar as possible apart from those specific behaviors. This brings us to the independent variable, the behavioral design, with two levels: full co-creation including coordination of involvement (co-creation condition) and limited co-creation without coordination of involvement (control condition). Because it is hard to assess one's attitude towards the robot for one condition independent of the other, the independent variable is a between-subject factor. Children's sense of agency, their satisfaction of the interaction, and acceptance of the robot are the three dependent variables.

4.3 Participants

59 participants (28 girls and 31 boys; 7-11 y.o.) completed the study. They were recruited via the after school care programs of four different primary schools with written consent from their parents. This study (ECIS-2020-07) was approved by the Ethical Committee for Information Sciences of our institution.

4.4 Set-up and procedure

The study was conducted in a separate room (e.g. councilors office) in the school. The robot was standing on the ground, the children were asked to sit in front of it. The researcher remained in the room, but was positioned behind the participant, at an appropriate distance, to avoid unnecessary contact between researcher and participant. Participants came in one-by-one.

When ready, participants were first introduced to the robot. This included a brief explanation on how to talk to the robot by the researcher and, in case of the co-creation condition, practicing with the different co-creation modes. Then a conversation started about the zoo. The robot and the child chatted about animals and the robot shared three anecdotes about its visit to the zoo. The robot expressed a need for additional expressive content (sound effects, gestures, light animations) to enhance the anecdotes. The conversation between both conditions was the same apart from the dialogs that are part of the co-creation process and the content elements that are created. In the co-creation condition participants have the option to coordinate their involvement by choosing which route they want to take (creation, own favorite, robot's favorite). In the control condition the robot always downloads two candidates of which the participant has to select their favorite.

After the conversation the participants filled in the questionnaires and were interviewed. When finished, the participant went back to their classroom and called the next participant. The complete interaction and the questioning took approximately 20 and 10 minutes respectively.

4.5 Measures and instruments

To measure the sense of agency, satisfaction of the interaction, and acceptance of the robot we composed a self-report questionnaire containing a likert-scale for each measure. *Robot acceptance* is the only of our outcome measures that has an instrument that was properly developed and validated for a child-robot interaction with the Nao robot [6]. The items for the remaining constructs were translated, made suitable for children, and were tailored to a child-robot interaction context[1]. For uniformity, the rating scale from the robot acceptance instrument was used for all constructs.

A lot of work has been done measuring people's sense of agency, mostly revolving people's movement or in low context tasks, in psychological and neuroscience research [21]. Inspired by Tapal et al. (2017) [21]'s general construct, we developed an explicit four-item scale for *children's sense of agency* that is tailored to our more localised and contextualized task.

[1]Final questionnaire and code can be found here: https://github.com/HeroProject/HeroGoalAgent/releases

No generic construct exist for the *satisfaction of the interaction*. Fitrianie et al. (2019) aggregated items for many constructs evaluating human-agent interaction [7]Attitude towards interaction is one of them, which aggregated items from 16 different papers. We selected the three most fitting items focused on satisfaction.

5 RESULTS

Because the scores of the measures were not normally distributed we used Mann-Whitney U tests to test our hypotheses. Reported data points are median [quartiles]. 32 participants were assigned to the co-creation condition and 27 participants to the control condition. A Bonferroni correction was applied to correct for the inflated chance of a type I error as a result of multiple testing ($\alpha_{bon} = 0.016$).

The median sense of agency scores were statistically significantly higher in the co-creation condition (4.7 [3.7, 5.0]) than in the control condition (3.7 [3.3, 4.3]), $U(59) = 639$, $p = .001$, $d_{cohen} = .89$.

No statistically significant difference was found in the satisfaction with the interaction scores between the co-creation condition (4.7 [4.7 5.0]) and the control condition (4.7 [4.3 5.0]), $U(59) = 445.5$, $p = .829$, $d_{cohen} = .053$.

The median robot acceptance scores were statistically significantly higher in the co-creation condition (4.6 [4.3 5.0]) than in the control condition (4.0 [3.5 4.5]), $U(59) = 661.5$, $p = .0004$, $d_{cohen} = 1.02$.

6 DISCUSSION

6.1 Hypotheses

The results show that the co-creation process improves participant's sense of agency. We can accept hypothesis H_1. It validates that the design of the co-creation modes and the interaction design pattern for coordinating involvement as a whole increases the opportunity for children to co-regulate the child-robot interaction.

The results showed no effect of the co-creation process on the satisfaction of the interaction. This leads to a rejection of hypothesis H_2. Participants rated their satisfaction as very high across conditions. This shows, once again, that interacting with a robot, regardless of behavior manipulation, is a fun activity for children. In hindsight, given the similarity of the overall experience in both conditions we, perhaps, should have used a more specific instrument to measure a more focused aspect of children's satisfaction of the interaction. Alternatively, we could evaluate the satisfaction of (different aspects of) the interaction entirely qualitatively. It allows for a more nuanced approach. We have included several questions about participant's satisfaction in our semi-structured interview. These results will be discussed in future work.

The results did show that participant accept a robot more when co-creation is part of the interaction. This allows us to accept hypothesis H_3. The robot is the one who explicitly gives children a choice how to co-create new expressive content with the robot. It is behavior that improves its ability to be social. Children, in the co-creation condition, indicated during the interview that they greatly appreciate this newfound social behavior of the robot. We reason that it is this explicit offering of a choice, and in particular the choice about how to coordinate the co-creation process, is responsible for the improved acceptance rating. In other words, the co-creation process improves the social ability of the robot, which has a positive effect on the child-robot relationship.

6.2 Limitations

There are two limitations to our study we would like to highlight. First of all, although we were quite happy with the sample in times of COVID-19, the size of and representation within our sample is limited. Due to the circumstances we had no access to children in the hospital. The participating schools were all located in the same moderate-high income neighborhood. A larger, and especially more diverse, sample is not only beneficial for statistical inference but greatly important for developing social robots that are inclusive for children with many backgrounds.

Secondly, the interaction was a single session, while the robot should ultimately engage children for multiple sessions. Although we feel confident that the positive effects of the co-creation will persist for more sessions, we need a multi-session user study to confirm that. We are currently preparing a multi-session user study.

6.3 Future work

We collected more data then we have discussed in this paper. For example, all the decisions made by the participants during the co-creation process were logged by the robot. In the interview we asked participants to motivate these decisions. In future work, we intent to explore and categorize these decisions and motivations. And address questions like, can we distill distinct profiles of children based on their interaction preferences and how can we accommodate those preferences to make future interactions more inclusive?

7 CONCLUSION

We have developed and validated a co-creation process that provides children with more opportunities to co-regulate their interaction with a social robot. Children can express themselves more creatively by co-creating sound effects, gestures, and light shows for the robot. It provides a novel way for the robot to acknowledge the children's expressions and for the children to see something of themselves in the robot. By enabling children to coordinate their involvement in the co-creation process, the robot gains a new social ability. One that is recognized and greatly appreciated by the children, reflected by their improved sense of agency and acceptance rating. We have taken steps to design a more inclusive robot, catering to children with different needs and preferences for the interaction. All with the hope to offer support to as many children in and outside the hospital as we can.

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