Designing Emotionally Expressive Social Commentary to Facilitate Child-Robot Interaction

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Figure 1: In this work, we explored children's experiences with and the design of *social commentaries* coupled with non-verbal emotional expressions for a reading companion robot. Children interacted with the robot in four phases: (a) the child read aloud to the robot; (b) the child showed the book to the robot; (c) the *robot* expressed emotion through facial expressions, gestures, LEDs, and speech, and the *child* shared their opinion after being prompted by the robot; and (d) the *robot* responded by sharing an opinionated commentary that would converge to or diverge from the child's opinion.

ABSTRACT

Emotion expression in human-robot interaction has been widely explored, however little is known about how such expressions should be coupled with feelings and opinions expressed by a social robot. We explored how 12 children experienced *emotionally expressive social commentaries* from a reading companion robot across five interaction styles that differed in their non-verbal emotional expressiveness and opinionated conversational styles (neutral, divergent, or convergent opinions). We found that, while the robot's opinions and non-verbal emotion expressions affected children's experiences with the robot, the *speech content* of the commentaries was the more prominent factor in their experience. Additionally, children differed in their perceptions of social commentary: while some expressed a sense of connection-making with the robot's self-disclosure commentaries, others felt distracted by them or felt like the robot was off-topic. We recommend designers pay particular attention to the robot's speech content and consider children's individual differences in designing emotional and opinionated speech.

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IDC '21, June 24–30, 2021, Athens, Greece

ACM ISBN 978-1-4503-8452-0/21/06…$15.00
https://doi.org/10.1145/3459990.3460714

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; • **Applied computing → Interactive learning environments**.

KEYWORDS

Reading Companion Robots; Emotion Expressions; Social Commentary; Robot Opinions

ACM Reference Format:
Nathan White, Bengisu Cagiltay, Joseph E Michaelis, and Bilge Mutlu. 2021. Designing Emotionally Expressive Social Commentary to Facilitate Child-Robot Interaction. In *Interaction Design and Children (IDC '21), June 24–30, 2021, Athens, Greece.* ACM, New York, NY, USA, 12 pages. https://doi.org/10.1145/3459990.3460714

1 INTRODUCTION

Social robots are expected to maintain conversational interactions with their users where they contribute to the conversation in meaningful ways and express thoughts, opinions, and emotion. Consider the following interaction scenario between a child and a reading companion robot, named *Maddie*:

Child: *[Reads a call-out titled "Mushroom Madness" and shows the section to Maddie]*
Maddie: Very interesting, isn't it? *[Expression of interest with open eyes, white light, slight head-tilt]* What do you think about mushrooms? *[Neutral expression with slight head-tilt]*
Child: Mom and I like to hunt for mushrooms—but I don't really know what to pick.
Maddie: You have to be careful with mushrooms, since a lot of them a really poisonous. *[Expression of fear with wide eyes, purple light, slight head-down, backing out]*

Here, the robot provides an affirmation: "Very interesting, isn't it?" It then responds to the child's comment with an opinion: "You have to be careful with mushrooms, since a lot of them a really poisonous." These statements illustrate what we call *social commentary*—speech acts that reveal the robot's feelings or opinions about the topic of the conversation.

As seen in the scenario above, social commentary integrates opinionated statements and emotional expressions. The human-robot interaction (HRI) literature includes a substantial body of work on designing emotion expressions and findings on the extent to which emotion expression facilitates the integration of social robots into human environments [8, 12, 20, 24, 36, 42]. Prior work has extensively explored how robots express emotion through body language, facial expressions, and speech [11, 17] or alternative modalities such as artificial expressions [37], non-linguistic utterances [41], LED lights in different shades and frequencies [45], or even texture [21]. When appropriately designed and effectively communicated [47], emotionally expressive robots can make interactions more enjoyable [6, 27] and support creativity, reading, memory, and learning skills among children [3, 4, 15, 26]. However, these expressions must be appropriately contextualized: both the *designed speech content* of the robot, i.e., new information being presented, and the *social context* of the interaction, e.g., the task of the robot and the environment in which it is operating, affect how emotion is perceived, particularly for children [14].

Despite the rich literature that exists on robot emotion, two key questions remain under-explored. How do we design emotionally expressive social commentary? How do children perceive and experience these behaviors? We believe that addressing these questions is critical toward realizing robots that can achieve the level of richness in conversations illustrated in the scenario presented earlier, to promote social connection over long-term interactions, and to better understand the social outcomes of children's interactions with robots with such capability. We believe that these experiences shape the viewpoints of children toward the robot and dictate how they continue to use it, especially in the long term, and highlight a knowledge gap in the literature on how social commentaries should be designed and how such behaviors affect child-robot interaction.

In the context of a long-term research effort to design socially adept learning companion robots for children, we designed expressive and opinionated social commentary for a social robot, where we associated non-verbal expressions of emotion with socially supportive and informative commentary. We tested five styles of social commentary that varied whether the robot displayed non-verbal emotional expressions and offered opinionated responses to children in its commentaries, including (1) no expression, (2) expression, (3) expression with *neutral* opinion, (4) expression with *convergent* opinion, and (5) expression with *divergent* opinion. In an exploratory study, we explored how children experienced these interaction styles when displayed by a reading companion robot. Our conceptualization of social commentary, design exploration that integrates expressions of emotion, feelings, and opinions, and the findings from our study can inform the design of social companion robots for a wide range of interaction scenarios, particularly with the goal of promoting social connection-making in long-term interactions.

The contributions of our work are as follows:

(1) *Conceptualization* of *social commentary* as part of the design space for social robots;
(2) A *design exploration* of social commentary that integrates expressions of emotion and opinion;
(3) Preliminary *understanding* of children's perceptions of and experiences of social commentary.

2 RELATED WORK

How people perceive a robot's social capabilities depends on how well the robot communicates its speech, emotion, and gestures [18]. HRI researchers explored the effects of emotion design across different modalities including movements [7, 19, 30, 35, 47], non-verbal [44, 45], and verbal [10] expressions. Nakata et al. [35] developed a framework for general *robot movement* inspired by dance psychology, and illustrated how robot motions affected user perceptions. For example, users perceived the robot's motion of moving backward as more surprised. Beck et al. [7] demonstrated that in addition to the robot's body language, a robot's *head orientation* can affect the user's ability to recognize expressed emotions accurately. Prior research has also explored *color* as being an effective way to convey emotional states in robots [44, 45]. Terada et al. [45] identified how people associated colors (hue values, frequencies, and waveform) with emotions in robots. The hue values determined basic emotion types, while frequencies and waveform suggested intensities. *Verbal emotion expressions* in social robots, including a robot's pitch, tempo, voice quality, articulation, and language was found to be effective in expressing primary emotions such as anger, calmness, disgust, and fear [10]. Overall, to facilitate relationships and personal connections, robots must send effective social signals to human partners.

Adaptive expressions are found to be particularly effective in facilitating relationships between *children and robots*. For example, Tielman et al. [46] designed non-verbal gestures, movements, and acoustic attributes for a social robot to represent emotional expressions and adapt to the emotional state of the child user. As a result, children felt a stronger relationship with the emotionally adaptive robot. However, children also perceived the non-affective robot to be more trustworthy and understandable. To investigate ways to maintain long term interactions with children, Ahmad et al. [1] tested game-based, emotion-based, and memory-based adaptations for a social robot. Emotion-based adaptations were found to be most effective in sustaining engagement with the robot, compared to memory-based and game-based adaptations. Cameron et al. [13] found gender differences in children's attitudes toward a social robot. While playing the game "Simon Says" with a social robot, boys were found to like the emotionally expressive robot more than a neutral robot, as no effect was found for girls. These findings suggest that enabling robots with emotionally expressive commentaries can facilitate social interaction and connection making in child-robot interactions.

Children can benefit from an *emotionally expressive* robot in social roles such as storyteller or reading companion. Prior work in this area shows that storytelling and reading activities with social robots can improve children's vocabulary, language development, memory, learning, and interest in reading and science [2, 25, 26, 33]. In addition to verbal emotion expressions, non-linguistic utterances such as "clicks, whirrs, and beeps" can also be effective means of communicating emotion to children [40]. However, benefits from verbal and non-verbal expressions may saturate over time. Expressing gestures extensively may distract children from reading [50], and an overly sociable tutoring robot may distract children from a learning task [22]. Similarly, sudden and unanticipated idle movements of an in-home social robot may be perceived as disruptive by its users [5]. Serholt and Barendregt [43] found that children engage with empathetic robots through communication channels such as gaze, facial expressions (smile or flush), verbal responses, non-verbal gestures, and suggest that designing responsive behaviors for robots that would detect signs from these communication channels would be valuable to promote social bonding and support learning with robotic tutors and children. In sum, the literature suggests that, when designing expressive robots for children, verbal and non-verbal expressions should be designed carefully to establish successful child-robot communication.

Prior work in robot emotion design has also focused on how children accurately detect the robot's emotions. Child-robot interaction studies (e.g., [13, 14, 23]) generally include a limited range of basic expressions for the robot (e.g., happy, sad, angry, fear, surprise). Cohen et al. [14] compared the use of five basic emotions for the Nao and iCat robots, finding no significant difference in children's emotion recognition accuracy. However, emotions were recognized with higher accuracy when expressed in the context of a storytelling robot, compared to without any context. Petisca et al. [38] found that, in some cases, a non-emotional robot may be perceived as more conscious, lifelike, and nice compared to an emotionally expressive robot. Kessens et al. [23] tested how children perceived the speech content and facial expression of an iCat robot in different roles, such as a companion, educator, and motivator. They found a robot that displayed verbal and non-verbal emotion expressions to motivate children to perform a task more, compared to a neutral robot. Their findings also suggest that the speech content of a social robot should be tailored for its role and task as children were able to recognize the emotions of an educational robot more, compared to a motivational robot.

Overall, prior work regarding the design of emotionally expressive social robots for children has primarily focused on how children recognize emotions expressed by the robot, and little is known about how children experience these conveyed emotions as a whole. Furthermore, the literature is limited in how to appropriately design *social commentary* for a robot that would incorporate non-verbal emotion expressions to reflect the emotional state of the social interaction. When designing sociable robots for children, there is a need to explore the multi-modal design approaches for *emotionally expressive social commentaries*, specifically for facilitating connection making and engaging children with the robot.

Our work aims to address the following research questions:

(1) How do we design *social commentary* that integrates expressions of emotion and opinion to facilitate child-robot interaction?
(2) How do children experience *emotionally expressive social commentaries* displayed by social robots?

3 DESIGN

We present our approach for designing *social commentary* and integrating *non-verbal emotion expressions* into their design. Resources used in this work including the user study materials, the robot's designed emotion expressions, speech content, and its source code for the interaction are available for open-access via OSF.[1]

Robot Platform. We used the Misty II[2] platform in our work which is a small semi-humanoid robot with a 4-inch LCD for its face, allowing for highly customizable facial expressions and displaying other cues. The robot has a multi-color LED chest-light that we utilized to support emotion expression. The robot has a three-degree-of-freedom head and two single-degree-of freedom arms and moves using a motor-driven tread system.

3.1 Multi-Modal Emotion Expression Design

The set of non-verbal emotions used in our work were designed by Zhao et al. [51] based on Plutchik's [39] model for emotion which includes *three intensity levels* for each of the *eight categories* of emotion, totaling 24 emotional states, as shown in Table 1. The robot's emotion expressions had multiple modalities including facial expressions, LED colors, and physical movements of the head, arms, and body (see Figure 2).

3.2 Speech and Verbal Expressions Design

We designed the robot's voice to have a natural and expressive tone that would reflect emotion in the best possible way. We generated the robot's voice using Google's Cloud Text-To-Speech API with Google's WaveNet voices[3]. We generated the robot's speech using the `en-US-WaveNet-H` voice with a pitch of +2.4 and a speed of 0.9 in order to achieve a speech that is more understandable, that appeared to fit with the character that is expressed by the robot's design, and that would remain consistent across interactions with different children. The resulting voice was a natural-sounding female voice, and we chose a set of female names that sounded similar to "Misty," such as "Maddie," "Melly," and "Maggie."

3.3 Design Guidelines for Robot Commentary

We created design guidelines for *knowledge support* and *social support* commentaries that a reading companion robot would express. Our knowledge-support guidelines aimed to *support the child's understanding of the readings* by summarizing the reading, offering predictions about what happens next, connecting ideas to prior

[1] https://osf.io/fjtuc/?view_only=b1e0127792634e10a21acb5406f8316e
[2] https://www.mistyrobotics.com/products/misty-ii/
[3] https://cloud.google.com/text-to-speech/docs/wavenet

Table 1: List of emotions presented by the Plutchik's "wheel of emotion" model, categorized by their intensity levels.

Low Intensity	Moderate	High Intensity
Serenity [Joy−]	Joy	Ecstasy [Joy+]
Acceptance [Trust−]	Trust	Admiration [Trust+]
Apprehension [Fear−]	Fear	Terror [Fear+]
Distraction [Surprise−]	Surprise	Amazement [Surprise+]
Pensiveness [Sadness−]	Sadness	Grief [Sadness+]
Boredom [Disgust−]	Disgust	Loathing [Disgust+]
Annoyance [Anger−]	Anger	Rage [Anger+]
Interest [Anticipation−]	Anticipation	Vigilance [Anticipation+]

knowledge, asking questions about the concepts, or reiterating vocabulary presented in the book. Our social support guidelines aimed to *support the social connection between the child and the robot* by disclosing information about itself and its experiences, making references to past interactions and shared experiences, personalizing the commentary by remembering and adapting to the child's likes and dislikes, and expressing its emotional state.

Using these guidelines, we designed two types of commentaries for the robot conditions in our study, *book-related summaries* and *self-disclosure*. Book-related summary commentaries were designed based on the knowledge support guideline with the goal of *supplementing what the child read about* by reiterating or providing additional information. Self-disclosure commentaries were built on the social support guidelines and were designed to *reveal the thoughts or experiences of the robot*, while still relating to the reading. In addition, we followed the knowledge support guidelines to design follow-up questions aiming to *ask the opinion of the child* related to a concept in the book. All designed commentaries included vocabulary from the book page.

Labelling the Robot's Commentaries with Emotion Expressions. We created a procedure to label the robot's commentaries with different categories and intensities of non-verbal emotions emotions, using Plutchik's emotion wheel model. The simple three-level approach of Plutchik's model allowed us to easily target the basic emotions and adjust (increase or decrease) the desired intensity levels of the expressions ranging from low, moderate, or high intensity (see Table 1). Below we describe an example procedure for labeling social commentaries with emotion.

Using the following example commentary: "Oh, I'm really afraid of the dark. I don't have any sensors that would work without any light", the commentary designer would first label the commentary with one of the *moderate* emotions that best suits the emotional state expressed in the commentary, in this case, *"fear"*. Next, the designer has the option of adding an amplifier *"fear+"* or *"fear–"* to

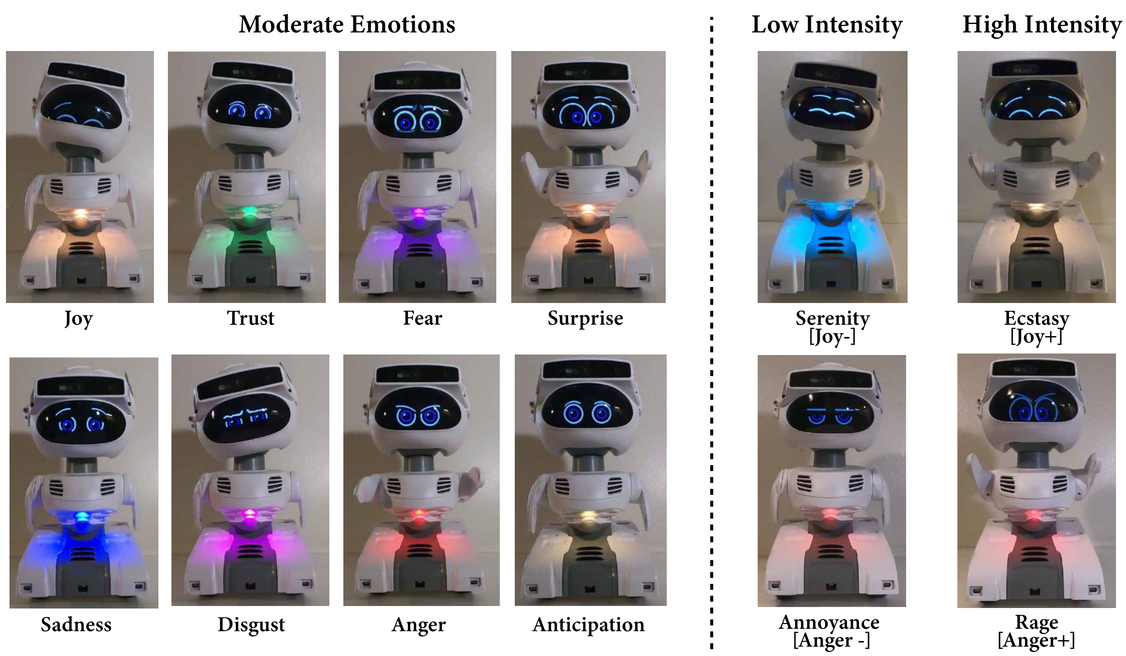

Figure 2: A set of all moderate emotions designed for Misty II (left). Examples of high and low intensity emotions for Joy and Anger are presented on the right. Some emotion expressions (e.g., disgust, fear, surprise, ecstasy, rage) are designed to have dynamic head, arm, or body movements in addition to static facial expressions.

express different intensity levels of the emotion. Based on Plutchik's emotion model, the amplified emotions *"fear+"* or *"fear–"* then correspond to the emotion expressions *"terror"* or *"apprehension"* respectively when expressed by the robot.

4 METHOD

We designed five robot personalities with varying emotional expressiveness and opinionated conversational styles and explored how children experienced these robots in a within-participants design.

4.1 Interaction & Social Commentary Design

All robots were identical in their voice, style of speech, neutral facial expressions, and eye-blinking rates. The robots differed based on their non-verbal emotion expressions (non-expressive or expressive), and while all robots included social commentaries, only three included an additional opinionated social commentary (neutral, convergent, or divergent opinions). The expressive commentaries were labelled with appropriate non-verbal emotions, while the non-expressive commentaries were neutral. For the opinionated conversational styles, the robot asked a question to the child for their opinion and responded with one of the following three styles: A *neutral* non-expressive opinion, an expressive *convergent* or *divergent* opinion designed to be closer to or farther from the child's opinion, respectively (see Figure 3).

4.1.1 Designed Robot Personalities. We designed five different robot personalities for children to interact with. Children interacted with the reading companion robots in the following order: Minnie, Micky, Maggie, Maddie, and Melly.

***Minnie:** Expressionless Robot.* The first condition, Minnie, had social commentary which lacked expressiveness. The robot had a neutral facial expression and did not have non-verbal expressions.

***Micky:** Expressive Robot.* The second condition, Micky, had social commentary with emotive gestures and facial expressions.

***Maggie:** Expressive Robot with Neutral Opinion.* The third condition, Maggie, had an emotionally expressive social comment, then transitioned to a neutral expression with a slight head-tilt, and followed-up with a question to elicit thoughts from the child. Finally, the robot responded by sharing a personal opinion, with a neutral expression.

***Maddie:** Expressive Robot with Convergent Opinion.* The fourth condition, Maddie, had an emotionally expressive social comment, then transitioned to a neutral expression with a slight head-tilt, and followed-up with a question to elicit thoughts from the child. Finally, Maddie shared an emotionally expressive opinion aimed to *converge* to, i.e., closely align with, the child's response.

***Melly:** Expressive Robot with Divergent Opinion.* The fifth condition, Melly, had an emotionally expressive social comment, then transitioned to a neutral expression with a slight head-tilt, and followed-up with a question to elicit thoughts from the child. Finally, Melly shared an emotionally expressive opinion aimed to *diverge* from, i.e., be further away from, the child's response.

4.1.2 Wizard of Oz Interaction Design. We used AprilTags[4] placed at different points of a book to serve as a stopping point in the reading and provide a reference for the robot to comment to the

[4] https://april.eecs.umich.edu/software/apriltag

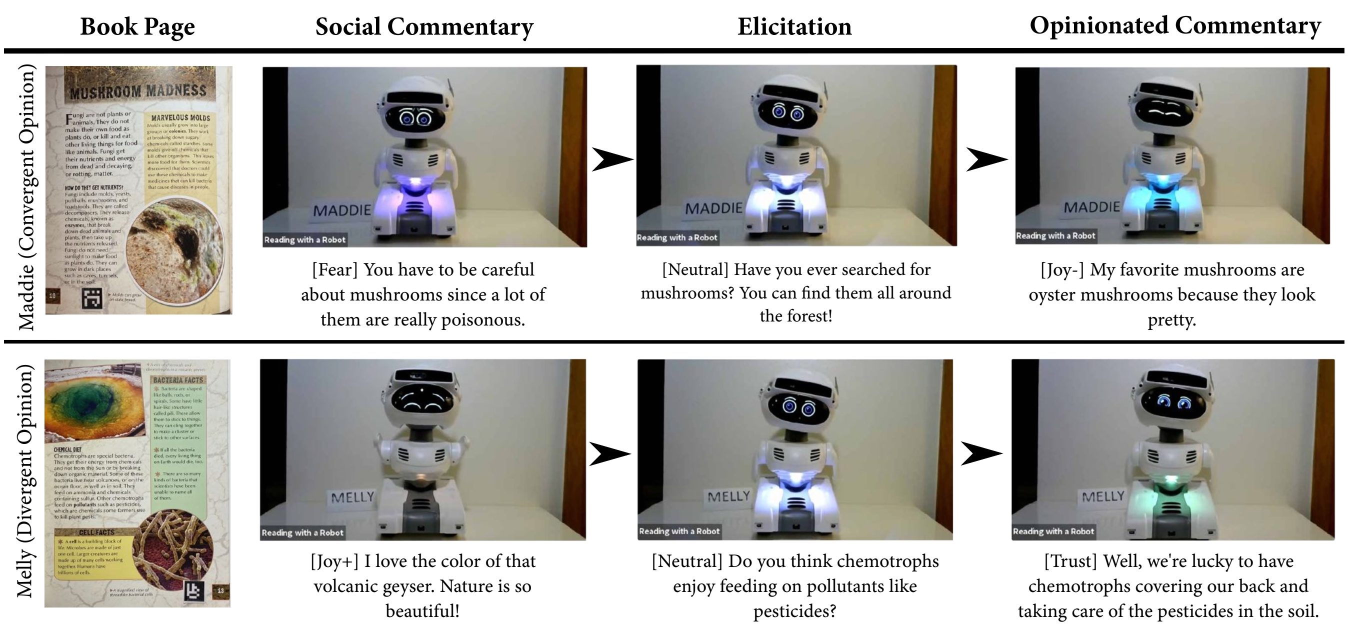

Figure 3: Example social commentaries designed for two of the robot personalities, Maddie (top) and Melly (bottom). In both conditions, after the child shows an AprilTag, the robots responds with a social support comment, asks a question to elicit thoughts from the child, and provides an opinionated response that either converges to or diverges from the child's answer. The convergent or divergent opinions of the robot was selected by the WoZ operator depending on the child's response.

child's reading. We conducted the study in a Wizard of Oz (WoZ) format which allowed us to adjust the *appropriate timing* of the robot's responses and determine which *type* of response to give (i.e., convergent or divergent) based on the child's answer. All commentaries expressed by the robot were *pre-defined* and the WoZ operator initiated the interaction only when a child showed an AprilTag to the robot and determined whether to have the robot express a convergent or divergent response.

4.2 Participants

We recruited 12 children (5 female, 7 male) between the age range of 10–12 ($M = 10.5$, $SD = 0.4$) through organizational mailing lists which included university faculty and staff. There were two families that had siblings that attended the study separately but in consecutive sessions (participants 4-5 and 6-7). We also measured children's science and reading interest based on validated questionnaires [32, 48]. Prior to the study, we asked parents the following questions about their child's reading ability and interest.

"To the best of your knowledge, your child's teachers would describe your child's reading ability as"— Parents 1, 10, and 12 reported "at grade level" and the remaining parents reported "above grade level" out of five options: Well below grade level, below grade level, at grade level, above grade level, well above grade level.

"How do you feel about how often your child currently reads books that are not required for school?"— Parents 1, 3, 4, 5, 6, 7, and 10 reported "I think my child should read more" and parents 2, 8, 9, 11, and 12 reported "I think my child reads a good amount" out of three options: I think my child reads too much, I think my child reads a good amount, I think my child should read more.

"How many minutes a week does your child typically spend reading for pleasure (e.g. not for school work) in a typical week?"— Parents reported an average of 121.25 min/week (SD = 152.8 min/week), with parents 1, 2, 8, and 11 reporting their child read more than 90-minutes per week for pleasure.

"How many minutes a week does your child typically spend reading for school work each week?"— Parents reported an average of 124.6 min/week (SD = 101.1 min/week), with parents 1, 2, 3, 6, 10, 11, and 12 reporting their child read more than 90-minutes per week for school work.

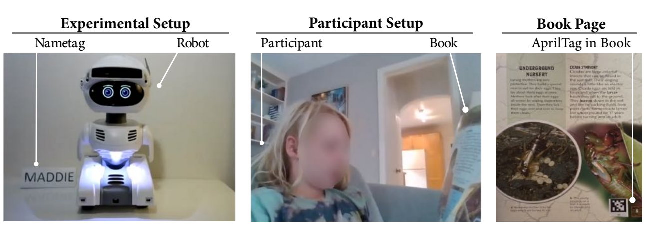

Figure 4: A facilitator, a Wizard of Oz (WoZ) operator, and the child participant were the attendees the study, conducted via video-conferencing. The experimental setup for the WoZ operator (left) included the social robot –Misty II– and a name tag of the robot. The participant setup (middle) included the child attendee and a book (right) with AprilTags placed on each page.

4.3 Procedure

The study was conducted remotely via the video conferencing software Zoom.[5] There were three user accounts present on the call: (1) the child and parent, (2) the facilitator, (3) the WoZ operator and the robot (see Figure 4). The study materials delivered to the participants included a copy of the book "Micro Life in Soil[6]" with AprilTags placed on every two pages and a tutorial booklet explaining how to use the AprilTags when interacting with the robot.

After explaining the study procedure and obtaining informed consent from the parents and the child, we started recording the session. We then introduced a tutorial robot and explained that it was a reading companion coach and its job was to evaluate the performance of five robot siblings (i.e., Minnie [Expressionless], Micky [Expressive], Maggie [Neutral Opinion], Maddie [Convergent Opinion], and Melly [Divergent Opinion]) who were training to become successful reading companions. We then explained to the child that the tutorial booklet contained information about how to use the AprilTags and would demonstrate how to interact with the robots. As the child read the tutorial booklet and showed the AprilTags to the camera, the tutorial robot re-iterated the study descriptions and guided the child through example interactions that included some non-verbal expressions. The WoZ operator controlled the timing for the robot's interaction. After the tutorial, we explained that the five robot siblings were ready for the reading activity. We also explained that each robot might have different personalities and highlighted that the child's feedback was important for us to evaluate the readiness of the robots. Our procedure for the reading activity started as the facilitator first introduced the robot's name, while the WoZ operator placed a name-tag next to the robot and sent a command for the robot to greet the child. After the introduction, the facilitator informed the child that they could start reading the assigned pages to the robot. The facilitator turned their camera off and disabled their microphone during the reading activity in order give a sense of privacy and not to distract the child.

During the study, children read two pages to each robot condition - a total of 10 pages. Each robot expressed two social commentaries —one for each page— including one *book-related summary* and one *self-disclosure* commentary and the order of these commentaries was balanced. Once the child finished reading a page they showed the AprilTag to the camera. Depending on the condition, the WoZ operator was responsible for selecting the appropriate pre-recorded speech of the robot as well as triggering the timing of when the robot gave a social commentary, followed-up with a question, waited for an answer from the child, and expressed an opinionated response. Children did not know the robot was controlled by an operator and the process aimed to replicate an autonomous interaction flow as closely as possible.

The facilitator conducted a semi-structured interview at the end of each robot condition (See Table 2, Part A) to learn about the child's experiences with the robot. During the interview, the WoZ operator removed the robot from view, but left the robot's name tag visible to remind the child of the robot they read with. After the interview, the WoZ operator placed a new name tag for the next robot condition and introduced the new robot.

[5]https://zoom.us/

[6]Natalie Hyde, Crabtree Publishing Company, 2010

Once the child completed reading the assigned pages and interviews for each robot condition, the facilitator conducted a final semi-structured interview (See Table 2, Part B) that focused on the child's overall experience, including all robot conditions. Following the interview, the child filled out two questionnaires to evaluate their science and reading interest.

The study lasted approximately one hour. Children read to the robot for about 25 minutes (five minutes for each condition), and the interviews in between took two minutes, while the final interview took approximately five minutes. The WoZ operator and the facilitator were the same people for each condition across all participants. Parents did not partake in the interaction nor the interviews; and received compensation of $15/hr at the end of the study. Children kept the book as a gift for their participation.

4.4 Data Analysis

We conducted a Thematic Analysis (TA) on the video recorded interviews with children. After the first two authors transcribed the interviews, they followed the TA guidelines presented by Braun et al. [9] and McDonald et al. [31]. The authors were familiarized with the data through conducting the study sessions, later coded the transcriptions from the video recordings, and re-iterated the codes until reaching an agreement. The qualitative analysis focused on identifying the themes related to children's experiences and preferences for the robot's emotion expressions and social commentary styles. When reporting our results, we used the notation (x/12) to denote that x of twelve children were categorized under a finding, e.g. (6/12) is used to denote six of the twelve children, and the notation Px when referring specifically to participant x, e.g. P4 is used to refer to participant four.

Table 2: Interview questions asked after children read to each robot condition (Part A) and after they completed reading to all robots (Part B). Depending on the study condition, <robot> was replaced with Minnie, Micky, Maddie, Maggie, or Melly.

Part A. Semi-Structured Interview Questions - After Each Robot Condition
How did you get along with <robot>?
What was <robot> like? How did you feel about <robot>
How did <robot> feel about the pages you just read?
Do you think <robot> was nice to read with?
Did you feel like <robot> was listening?
Did you feel like <robot> understood what you said?
How can <robot> be better?

Part B. Semi-Structured Interview Questions - Post Interaction Retrospection
Tell me about your experience today?
Can you share your favorite moment?
Which one did you like the most? Which one did you not like?
Would you prefer reading on your own or with a robot?
What can the robots improve? What would you keep?
If we had time to continue reading, which robot(s) would you like to read with more?

5 RESULTS

We identified three themes based on the interviews where children reflected on their experiences with the five different robot interaction styles. First, our exploration revealed that children enjoyed the emotional expressiveness of all robot conditions, even for the Minnie [Expressionless] robot condition which excluded non-verbal emotions. Second, the *speech content* of the robot's social commentaries was more influential on the children's experiences than its non-verbal emotional expressions. Third, we found that children enjoyed being asked about their opinion when interacting with the robots that had opinionated conversational styles (Maggie [Neutral Opinion], Maddie [Convergent Opinion], Melly [Divergent Opinion]), but the robot's neutral, convergent, or divergent opinion responses did not have a notable effect on children's experience.

5.1 Theme 1. Children Enjoyed Experiencing the Emotional States of the Robot — Regardless of the Expressions

Across all five robot conditions, children were mostly (10/12) attentive to the robot's emotional state and personality, and less attentive to the non-verbal emotion expressions including the facial expressions of the robot (5/12), its movement (2/12), or the LED color exhibited (1/12). When describing the robot's emotional state, some children described the robot to be "happy," "surprised," "excited," "sad," "scared," "disappointed," and "confused." Descriptions of its personality included "funny," "cute," "energetic," "calming," "talkative," and "positive." For example, P7 described Micky [Expressive] by saying that it "seems like a happy person, happy robot." P5 described Maddie [Convergent Opinion] as "talkative" saying it "had more questions and had a little bit more conversation about the pages." Two children (P10 and P11) mentioned how much they liked the robot's range of expressions. P11 stated "I guess I just liked how Melly [Divergent Opinion] could go from like happy to sort of just mad and then happy again." P10 echoed similar thoughts stating "I liked how they changed every time they went to say a different thing." However, P10 also felt the emotional expressions could be distracting in some conditions where the robot's emotions carried over "for too long."

When specifically discussing the Minnie [Expressionless] robot condition, several children (4/12) still discussed the robot's emotive state, despite the absence of non-verbal emotions expressed. For example, P3 described Minnie as "happy" and that it was "nice and calming." However, in the post-study interview, P3 later contradicted this by saying "[Minnie] had no feelings, no emotions" and that it "didn't move at all." P6 stated that when Minnie was commenting about the cicadas mentioned in the book, they thought the robot was "surprised to see some things." When Minnie commented on the amount creatures living in the soil, P12 said that "[Minnie] sounded excited about learning there was trillions of creatures." However, children in general did not express a difference between the expressionless robot and expressive robot conditions during the post-study interview, as one child (P11) noted that "[Micky] shows more emotion than Minnie." Overall, these findings indicate that children perceived emotional states from all five robot conditions, including the robot that does not display any non-verbal expressions, and these emotional states contribute to how children experience the interaction.

5.2 Theme 2. Children's Experiences were Shaped Mostly by the Speech Content

Most children gave insight about their experiences related to learning more about the robot through its *self-disclosure commentaries* (9/12) and learning more about the book with the robot's *book-related summary commentaries* (11/12). When the robot commented about the book or asked questions, some children (P10 and P12) perceived the robot as *"smart"* and *"knowledged"*. P12 said, "it made me feel like Maddie [Convergent Opinion] knows a lot about the mushrooms." Similarly, P10 stated, "Maggie [Neutral Opinion] gave a good scientific answer. So that made me think of her as one of the smart robots." When discussing the self-disclosure commentaries, P6 described how much they liked them by stating, "Micky [Expressive] wasn't afraid to tell me that she was a little grossed out from it." P9 said the robot's personal opinions made the robot "feel more lifelike." P10 noted that the robot's self-disclosure led them to *bond with the robot*, "I really liked the very end where we bonded over the pretty picture of the volcanic geyser" and elaborated "Melly [Divergent Opinion] asks questions and she lets you in her life. And she lets her into your life."

However, two children (P1 and P9) expressed a dislike for the robot's *self-disclosure* commentaries. P1 noted that the *self-disclosure* commentaries were *distracting* and took away from the reading, "it was kind of hard like I was focusing on reading and then Maddie [Convergent Opinion] would be like telling life stories." P1 further elaborated on this by stating, "usually when I do something I want to stay like with the reading and on topic, but when [the robots] kind of go off, it takes my brain away, and now I just start thinking about other stuff." P9 felt like the robot was not attending to the book when it responded with personal opinions "because Melly [Divergent Opinion] was just talking about like its own ideas ... it just didn't seem very attentive to the book." In particular, P9 described this as "if you are studying, you might want more about the text, not opinions."

In discussing the robot's *book-related summary* commentaries, children expressed that when the robot was "talking about the book" (P3), stating "facts about some of the things on the page" (P6), and elaborating "more on the pages" (P4), it helped them "understand and learn things" (P9). P6 summarized these thoughts as "I think it was nice to read with Maggie [Neutral Opinion] because she would elaborate on what I've already said, and she would tell me more about what she knows and what she learned." Further describing the contents of the commentaries, children (8/12) mentioned how much they liked it when they were asked *questions related to the book*, while others (4/12) noted it was helpful that the robot's commentaries included some difficult vocabulary presented in the reading. P4 noted that the robots had "a lot of questions," which made P4 feel like "[the robots] are really listening." P8 noted that Maggie [Neutral Opinion] "kind of asked like teacher questions" which helped their comprehension of the book. In contrast, P7 and P10 were disappointed that the first two robots (i.e., Minnie [Expressionless] and Micky [Expressive]) did not engage in asking for or stating their opinions and wished those robots "would have asked more questions."

Children (12/12) also discussed their experiences with what the robots said to them that made them feel like they were *listened* to, *understood*, or *payed attention* to. One child (P10) mentioned how much they liked that the robot acknowledged their thoughts, which promoted connection making. P10 elaborated on this by stating "I like that she Micky [Expressive] made her own comment because it let me into her thinking and what she was thinking about the passage that I read." and said "I thought that [Melly] was really paying attention to me and she was actually acknowledging me" due to Melly's [Divergent Opinion] response to the child's opinion. Following up, half of the children (6/12) expressed that they thought the *style of speech*, *commentaries*, and *emotions* impacted the *life-likeness* of the robots. For example, P2, P8, and P9 stated that their experience with all robot conditions felt like "reading with a normal person." P9 however, highlighted that the first two robots (Minnie [Expressionless] and Micky [Expressive]) were more "like a robot" because they did not have follow-up commentaries. While the lack of follow-up commentary was by design for these robot conditions, this indicates a desire to have further conversations with the robot.

For some robot conditions children had contrasting opinions about the robot's attention. For example, P3 described their experience with Melly [Divergent Opinion] positively as, "[Melly] talks about the idea, talks about what I read, and it really just seems like it's listening to every single word I say." In contrast, when Melly gave *self-disclosure* commentaries P9 felt they were unrelated and stated that "Melly just seemed like it was not listening." For Maddie's [Convergent Opinion] *book-related summaries*, P5 expressed that "I know that Maddie was listening to me because she was like asking questions about the book and making commentaries about the book." However, for the opinionated conversational styles, P10 felt misunderstood by Maddie and said, "I don't think [Maddie] really understood that I am not a big fan of mushrooms."

5.3 Theme 3. Children Appreciated, but Were Unable to Distinguish, Opinionated Commentaries Expressed by the Robot

Specifically for the robot conditions that were designed to express opinionated commentaries (Maggie [Neutral Opinion], Maddie [Convergent Opinion], Melly [Divergent Opinion]) children liked that the robot had an opinion but did not appear to recognize or prefer a difference between the neutral, convergent, or divergent styles of responses. P8 noted that Maddie [Convergent Opinion] asked "good questions" and said they were "like teacher questions," and P4 further expanded on this saying that Maddie's questions "made me feel like they're really listening." P12 gave similar input for Maggie, stating that they liked "how Maggie [Neutral Opinion] asked a question" and "how I had to answer that," indicating they liked being asked for their input.

During the post-study interviews, two children (P9 and P10) briefly mentioned a design suggestion, saying that they would like the robot to have its own opinions, even if it was *disagreeing* with the child's. P9 wanted both the child and the robot to be able to express opinions by using a statement in the interaction such as "I agree with that or I kind of disagree." P9 also elaborated that it would be fine if the robot disagreed or agreed with the child. Similarly, as a design suggestion, P10 stated "I do like that we bond over things, but I do want [the robot] to also have its own opinions and be able to speak for itself." When P10 was asked about how they would like the robot to speak for itself, they described the interaction with the following example: "If you showed us a picture like the picture right here [shows the book page], maybe the robot would say like, 'Oh, that looks like bones' and I'd be like, 'Oh, I thought that looked like breadsticks' and like [the robot] didn't have to really agree on everything. But that's the picture of the top of the pretty volcanic bionics, we could agree on that, like maybe not agree on everything. But some things you can agree on." In general, for the opinionated conversational styles, although we found that some children wanted the robot to express opinions and ask questions, they mentioned this as a future design suggestion and were not able to express a distinction between the different styles of opinionated commentaries that we tested in the study.

6 DISCUSSION

In this work, we explored *how emotionally expressive social commentaries should be designed* and *how robot's multi-modal emotion expressions and opinionated speech affects children's experiences.* We designed commentaries for a social robot that included a wide range of non-verbal emotional expressions with different intensity levels (high, moderate, low), different forms of social speech content (self-disclosure and book-related summaries), and different styles of opinionated commentaries (neutral, convergent, or divergent). We implemented our design into a *reading companion robot* and evaluated children's experiences with interacting with the robot.

Our exploratory findings, based on interviews with children, demonstrate the primacy of speech content over non-verbal expression, the nuances of how children interpret that speech content in relation to themselves and the shared activity, and how children experience sharing and receiving opinionated speech. In the paragraphs below, we highlight key takeaways from these findings and future directions to approach the exploration of designing emotionally expressive social commentaries in child-robot interaction.

Speech may be preferred over non-verbal expressions for conveying emotion to children. Our social commentaries were designed to make the robot appear life-like, friendly, and attentive to the users. Unexpectedly, we found that some children may perceive a robot *without* non-verbal emotional expressions as emotionally expressive when its speech content contains social components. This observation suggests that the *speech content of the robot* can be sufficient for displaying emotion. This finding complements prior work in understanding the importance of speech in determining how the robot will be viewed by its users [49], and prior findings that extensive non-verbal gestures might distract children from the activity [22, 50]. Non-verbal communication that is redundant to social expressions in speech content, may be crucial to human-human interaction, but less critical in child-robot interaction. Alternatively, amplified non-verbal expressions are not appropriate in reading interactions, and more nuanced expressions, such as those conveyed via speech, are perceived as being more appropriate, because they do not compete with task communication.

Key Takeaway. In child-robot interactions, the speech content of the robot can have more of an impact on how children experience the robot's emotions than what is expressed by the robot non-verbally. We suggest that when designing emotionally expressive social commentaries, emotional context can be infused into the speech content of the robot, and non-verbal expressions can be moderated in these scenarios.

The robot's self-disclosure commentaries may be distracting to the child and should be incorporated with information that closely relates to the shared activity. We designed emotionally expressive social commentaries for a reading companion robot that included *book-related summaries* or *self-disclosure* in its speech. We expected these commentary styles to facilitate shared communication, bonding, and social connection-making with the child. We found these commentary styles to be effective, particularly for the *book-related summaries*. However, we also found that some children had mixed feelings about the robot's *self-disclosure* commentaries. Prior work suggests that self-disclosure in child-robot interactions can promote trust and connection making [29]. Our findings enrich this understanding and indicate that children may feel that the self-disclosure commentaries were not relevant to the reading activity and were distracting. Children may be sensitive to how closely social comments are related to the shared activity and to the child personally. Self-disclosure, which would have been appropriate and expected in a conversation where the child and the robot are getting to know each other, might have been perceived as inappropriate or irrelevant in a reading scenario. Future work should further explore the use of robot self-disclosure as a mechanism for social connection-making and seek to explicate what scenarios and activities for which this type of interaction is best suited.

Key Takeaway. Designed commentaries should incorporate information that closely relates to the shared activity to avoid distracting children, and self-disclosure statements should be used minimally to maintain the benefits of connection-making, for example, at the beginning of the interaction.

Although the robot's opinionated social commentaries were appreciated by children, more work is needed to understand how children experience opinion styles. When presented with robot actions that incorporate *non-verbal emotional displays* and *opinionated speech content* designed to foster social connection, children responded positively and appreciated being able to share their opinions with the robot. Children enjoyed interacting with robots that used interaction methods more closely aligned with listening, understanding, and attending (Maggie [Neutral Opinion], Maddie [Convergent Opinion], and Melly [Divergent Opinion]) over robots that used didactic methods of interaction (Minnie [Expressionless] and Micky [Expressive]). In addition, although we designed the robots Maddie and Melly to express commentaries that would converge to or diverge from the child's responses—as a way to simulate an expression of shared personal opinions or disagreement—we did not observe any of the children realizing or distinguishing this convergence or divergence in the robot's speech.

Children in general treated all opinionated social commentary as being similar. The literature offers little insight into designing opinionated conversations that include such divergent or convergent opinions for a social robot's speech that would simulate discussions, conversations, personal opinions, and critical thinking with children. Future work is needed to explore the limits and design components that would contribute to designing *opinionated speech content* for robots.

Key Takeaway. Children appreciated the inclusion of *opinionated speech content*, which provided them with an opportunity to share their opinions with the robot as well as learn about the robot's opinions, although they were indifferent toward the different styles of opinionated speech. Opinionated social commentary designs for a social robot should include opportunities for the robot to ask the opinions of the child and respond to them in a manner that demonstrates that the robot also has its own opinions.

6.1 Limitations and Future Work

Our work is limited by a number of factors. First, our findings are preliminary, including a small sample of children. Second, our study consisted of a single hour-long interaction with the robot and was also limited by the styles of social commentary we implemented to the robot. We only tested five different combinations of social commentary, all of which were targeted for the context of reading with a reading companion robot. Third, all children interacted with the robots in the same order and were not asked to compare the robots in-between interactions. Fourth, our user study followed COVID-19 health guidelines, which affected our population sampling techniques and study design. Children experienced the interaction remotely through an online study via video conferencing. Given the important role of physical presence in how people perceive robots [16, 28, 34], further research is needed to understand how children experience social commentary in in-person interactions. Finally, our video conferencing style of our study limited the interactions. We designed the study in WoZ format to ensure the reliability of remote interactions. Since we were not able to deploy the reading companion robot in-person, the WoZ operator was responsible of managing the timing of the robot's speech, while the child had to interact with the robot remotely. The main limiting implication of this remote WoZ format was that children experienced issues with timing and conversational flow of the robot. Some children wished the robot would give them more time to think before answering with their opinion, while others desired clearer indications of when to converse further with the robot.

To address these limitations, our goal is to use the key takeaways to improve the design of emotionally expressive social commentaries, and deploy this robot in an *in-home long-term child-robot interaction study.* While our current work contextualized these social commentaries in a shared reading activity, the design implications can be applied to different social contexts. Specifically, future work should focus on conducting studies to understand how children's perceptions and experiences with the robot's emotionally expressive social commentary evolves in the long term. We believe despite the limitations of our work's exploratory nature, short time-span, limited styles of interaction design, and remote style of interaction, our findings will serve as a fundamental resource for future designs of emotionally expressive social companion robots for children. Finally, we believe that future research should explore adaptive methods for determining when the child feels that it is appropriate to transition to the next step of the interaction.

7 CONCLUSION

Our work explored how children experience emotionally expressive social commentaries from a reading companion robot and how different interaction styles affect their experiences. Our analysis yielded insight into how children experience the non-verbal emotions and socially supportive commentaries of a reading companion robot during interactions. We found that, while the robot's opinions on the topic at hand and its non-verbal expressions of emotion affected children's experiences with the robot, the *speech content* of the commentaries, i.e., the new information provided by the robot, was more influential on how children experienced the interactions. Book-related summary commentaries made the robot appear smarter and more invested in the reading activity, but some children found self-disclosure commentaries to be unrelated and to distract them from the reading activity. Children expressed a strong desire for sharing their opinions with the robot, but they were unable to distinguish the robot's different opinion styles. Our discussion highlights implications for designing more sociable robots for children.

8 SELECTION AND PARTICIPATION OF CHILDREN

Families were recruited through institutional mailing lists (including university staff and employee) targeting families that have a child aged between 10–12 that speaks fluent English. Children attended the study via video-conferencing from their own home. The consent process included describing the procedure to the parent and the child verbally, followed by verbal assent from the child and written consent from the parent. Parents were provided with options to opt-out from sharing any anonymized quotes and/or video recordings of their children and the consent form stated that confidentiality will only be broken by the researchers if abuse or neglect is observed. Children were informed that they could end the study anytime if they wish to do so. We started video recording only after obtaining consent.

ACKNOWLEDGMENTS

We would like to thank our colleagues Olivia Zhao and Emmanuel Senft for their valuable feedback throughout the design and execution of this study. We would also like to thank Gigi Mitchell for her help in providing the study resources to the participants. This work was supported by the National Science Foundation under award 1906854, "STEM-Mates: Designing Companion Robots with Socially Situated Interest Scaffolds for Informal, In-home STEM Learning."

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